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Journal for Technology of Plasticity, Vol.23 (1998), Number 1-2

MATERIAL PROCESSING BY DIFFERENTIAL HEATING AND SIMPLE PRESSING

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ABSTACT

An investigation of a new forming method for the production of complex geornetries is presented. The deformation is effected by the use of simple tools in a fleshless type operation where local heating is applied to the billet surface or volume thus allowing maximum deformation to occur where required. The technique is applied to cylindrical steel billets for the production of symmetrical flanges at the periphery of the workpiece and unsymmetrical local deformation on the surface of the billet. Also, compound flow problems are simulated using aluminium billets integrated with plasticine. The results show that the lateral profile is affected by the level of heating and that local deformation is greater at areas where the material flow stress is reduced. The process is potentially attractive for the production of near net shape complex parts and preforms for the forging industry.

1. INTRODUCTION

In Forging processes deformation takes place in three dimensions and in order to produce a particular shape, metal flow has to be constrained by the geometry of the tools as in closed die forging. In most cases excessive loading is applied in order to ensure complete filling of the die cavity. In the manufacture of complex parts by forging, and in order to reduce the loading requirements the process is carried out at elevated temperature. The production of flash, later removed by trimming or machining, and oxidisarion are inherent in these operations. Also, the heating and cooling cycles affect tool wear and the fatigue characteristics of the tooling arrangement thus reducing die life considerably. Open die forging [1], and wire and pipie dieless drawing [2] are among the processes which are employed to effect free flow and hence demand less loading. A combination of warm and cold processing sequence showed considerable improvement in process and energy utilisation when applied to extrusion of complex parts [3].

Forming of solid metal with a liquid phase core was studied in Japan [4] and it was found that the deformation behaviour is sensitive to the amount of liquid core. Thermal forming using laser heating was investigated in Germany [5] and applied to bending of plates made of two layers.

Differential heating is defined here as a process in which a small part of the workpiece is heated so that the flow stress at that particular zone is reduced. Material adjacent to the heating source will exhibit the lowest resistance to deformation as shown in Figure 1. Flow stress variation through the billet due to local heating will depend upon the billet hearing time, transfer time and heating tools. The relation between temperature and flow stress is non-linear and in addition most materials become strain-rate sensitive at elevated temperature [6]. Simultaneously forming the workpiece during heating reduces heat losses and gives more control over the deformation mechanism. However effective narrow local heating is achievable with a high-energy beam hearing source. The use of such beams is utilised in welding processes where deep welds with a depth to width ratio of 20:1 have been produced by exploiting an effect known as "keyholing" [7].

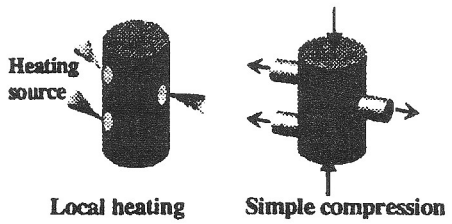


Fig.1 - Differential heating forming

This paper presents observations of an experimental study using differential heating to forming complex parts, and provides the basis for the application of differential hearing to produce a controlled "free" deformation mechanisms.

2. DIFFERENTIAL HEATING EXPERIMENTS

Experiments were conducted on a Rhodes 980kN press. Tool steel flat dies were used in all experiments and the load was measured using a load cell inserted in the top die. The displacement of the ram was measured using a height gauge potentiometer. The temperature in the through heating experiments was controlled by means of a thermocouple. ϕ 25.0 x 37.5mm 0.3% carbon steel (mild steel) billets were used in through heating and induction hearing experiments. The material flow stress was obtained for all testing temperatures and the average values are shown in Figure 2. The maximum strain achieved in the experiments was 1.4mm/mm. It is noticed that the flow stress at 690° C drops to approximately half of the value at ambient temperature. The flow stress for billets heated to quarter the steel melting point was greater than that at room temperature. This phenomena is well known for ferrous metals due to carbon migration in the temperature range of 100°C - 350°C.

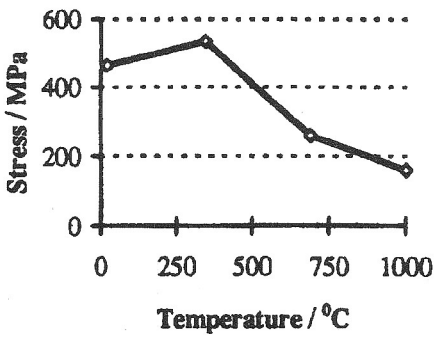


Fig.2 - Flow stress variation with temperature

2.1. Through heating experiments

In order to examine the effect of differential heating on deformation, steel billets were made out of three separate sections, each of a height of 12.7mm. The middle section was then heated in a muffle furnace. The three sections were re-assembled with the heated part in the middle then deformed to a height of 25.4mm. The process was carried out at four temperatures; 1000, 690, 345 °C and room temperature. Figure 3 shows the loading curves for split billets while Figure 4 shows the maximum diameter for each section at varying temperature.

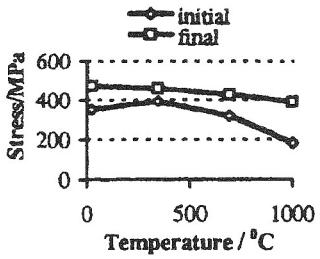


Fig.3 - Forming stresses

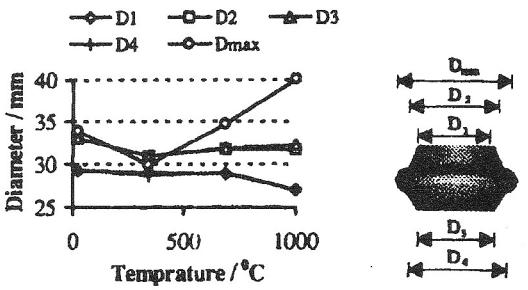


Fig.4 - Change in diameter with temperature

It is clear that the surfaces in contact with the dies exhibited similar deformation. The lowest deformation at the tool/material interface occurred at1000°C where the frictional resistance was higher than the shearing action between sections.

2.2 Induction heating experiments

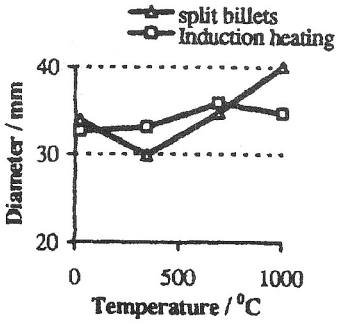
Similar experiments to those applied on through heated sectioned billets were carried out on full length billets with the middle section heated using a 3.2mm one-turn induction coil. Initial experiments were conducted to measure the time taken for the core of the billet to reach the required temperature. A hole was drilled to the centre of test billets and the temperature reading at three locations were recorded; top surface, lower surface and the centre of the billet. Figure 5 shows the comparison between the maximum diameter obtained in through heating and induction heating experiments.

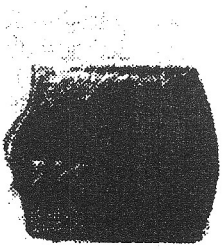
2.3 Local heating experiments

An Oxyacetylene burner set up was used to provide rapid heating to a small section, 5mm in height x10mm in length, through the billet. Flame heating penetrates through the billet faster than induction heating and thus the heat affected zone will be smaller. Varying heating time was applied to a total of 6 billets, which were subjected to strains similar to those of the previous experiments. The results demonstrated the effectiveness of the heating system and Figure 6 gives an example of a cam lobe type profile, which was formed by using flat tools. The maximum local deformation was found to increase with hearing time in this case.

2.4 Aluminium/plasticine experiments

Physical modeling of localised heating was carried out on aluminium billets ϕ 25.4 x 45 mm with 3.5mm diameter holes drilled through the cross section of the billet and filled with plasticine. The holes were positioned at 10,20 and 30mm from the top surface of the billet. With the application of small increments the flow of plasticine was predominent with negligible change in the outside diameter of the billet. Figure 7 shows an example of a complex profile produced by this method. The flow is local, anisotropy and directional due to the temperature gradient through the billet. Furnace and induction heating systems are slow and they require at least 15 seconds transfer tine. Rapid heating however can be achieved using beam heating, such as laser or electron beams where the heating tune is measured in μs and the heat affected zone is minimized.





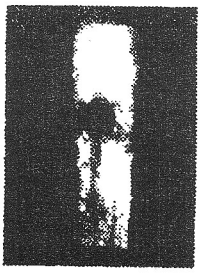


Fig.5 - Billet maximum diameter *Fig.6 - Local forming* *Fig.7 – Free flow simulation*

3. CONCLUSIONS

Differential heating forming has been investigated experimentally using different heating combined with simple compression. The process is capable of producing near net profiles with high material utilization factor. Split billet experiments demonstrated the effect of differential heating on metal flow, localised deformation has been produced by the use of fast flame heating, and aluminium/plasticine integrated billets.

4. REFERENCES

1. Osman, F. H., Aksakal, B., Bramley A.N.: "Computer aided flexible system for open die forging", Advances in Manufacturing Technology, Pub. University of Bath, UK, pp 216-221, 1993.

2. Kobatake, K., Miura, T., Kimura, S., Sekiguchi, H., and Luan, G.: "A new forming method of non-circular tapered pipes", Proc. of 4th ICTP conference, pp 67-72, 1993

3. Korner, E., and Knodler, R.: "Possibility of warm extrusion in combination with cold extrusion", l. of Material Processing Technology, vol. 35, pp. 451-465, 1992.

4. Mori, K Osakada, K., and Shiomi M.: "Finite element modeling of forming process of solid metal with liquid phase", J. of Material Processing Technology, vol. 27, pp. 111-118, 1991

5. Geiger, M. and Vollertsen, F.: "The mechanisms of laser forming", Annals of the CIRP, vol. 42, pp 301-304, 1993.

6. Hosford, W., and Caddell, R.: "Metal forming, mechanics and metallurgy", Pub. Englewood Cliffs, N.J.: Prentice-Hall,1983

7. Edwards, L, and Endean M.: " Manufacturing with Material", Pub. Butterrworths Scientific Ltd., London, 1990.

LOKALNO DEFORMISANJE UZ LOKALNO ZAGREVANJE

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REZIME

Prezentiran je novi metod obrade deformisanjem za izradu delova kompleksne geometrije. Deformisanj se izvodi uz pomoć jednostavnih alata i primenom lokalnog zagrevanja na mestima u okviru zapremine komada gde se zahteva maksimalna deformacija. Lokalnim zagrevanjem se smanjuje napon tečenja samo jednog dela pripremka i to onog na kome se zahteva najveći stepen deformacije. Ova tehnika je primenjena na cilindrično čeličnim uzorcima za izradu simetričnih delova sa obodom, kao i za izradu nesimetričnih delova. Takođe simuliran je proces tečenja kombinovanog materijala aluminijum- plastelin.
Rezultati pokazuju da lokalna veličina deformacije u velikoj meri zavisi od lokalnog zagrevanja. Ovaj proces može biti veoma uspešno primenjen za izradu net-shape obradaka kao i za dobijanje pripremaka za kovanje.
□

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ANALYSIS OF "INPUT" AND "STATE" COORDINATES OF THE EXTERNAL CYLINDRICAL SURFACE ROLLING BY METHOD OF COLD DEFORMATION

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ABSTRACT

This report, by shown methodology, tries to contribute to the effective solution of tasks in the field of studying and designing the processes and states. It also points to possible way of achieving high techno-economical effects. We studied the finishing process by method of cold deformation and then analysed possible effects compared to classical methods of the finishing process.

The basis of this methodology is the research of the internal structure of the process by applying the up-to-date experimental-analytic method based on the theories of multidimensional regression and dispersion analysis.

1. INTRODUCTION

The metal processing by method of cold deformation is based on the property of metal to deform when exposed to strains being higher than those on the elasticity boundary and less than maximal ones. By this kind of processing, elementary particles of metal generally deform and move (the flow of metal), but their mutual connection does not break off. These structural changes in plastic deformation are higher on the surface layers being farther away from the surface layer. As the result of such a state as well as of many other effects, plastic deformations are, by rule, followed by elastic deformations which are unwanted, because they effect the unstability of measures of the object being processed.

The application of this kind of processing, especially as the finishing processing is, judging by all, unjustifiably low, in spite of many known advantages over classical ways of finishing processes (planing, grinding, unscrewing honing, paste polishing, etc)

In relation to classical methods of finishing processing, this time, only some of the advantages of processing by method of deformation are being emphasized: high roughing quality of the processed surface, the increased hardness of the surface, the increase of resistance to wear out, the increase of material fatigue boundary the increase of work productivity, the decrease of the total production costs, the increase of the exploitation of product characteristics, etc.

The advantages mentioned show clearly that, in the future, special attention should be paid to processing by method of cold deformation with the aim of constant growth of total techno-economical effects of working systems. Generally, to accomplish such effects, is neither easy nor simple, in the first place because of the high structural complexity of such processes. The processes in general, especially those by method of cold deformation, belong to a group of very complicated processes with a very high number of state coordinates. The surface and time flow of these processes beside high complexity are characterized by constant effect of disturbances, both external from the environment and the internal ones from the mere system, which may cause the uncontrolled changes of the optimum of the process and make its controlling difficult both in space and time. These facts show that it is necessary to find such a method which would effectively solve many problems in this field and, at the same time, be available to a larger circle of process and system designers.

This paper shows one of the possible ways of effective solution of the problems already mentioned by applying the up-to-date experimental analytic method, based on the theories of regression and dispersion analysis. It deals with a powerful device for multidimensional studying processes and systems /1/ applied in this particular case in analyzing the process by deformation.

By using this method, the main role being played by the conducted experiments in real production conditions, vital informations were obtained about interactions in the process, and made the basis for reliable analyses and conclusions which would be practically impossible or difficult by using classical-analytic methods.

2. THE CONCEPT OF METHOD

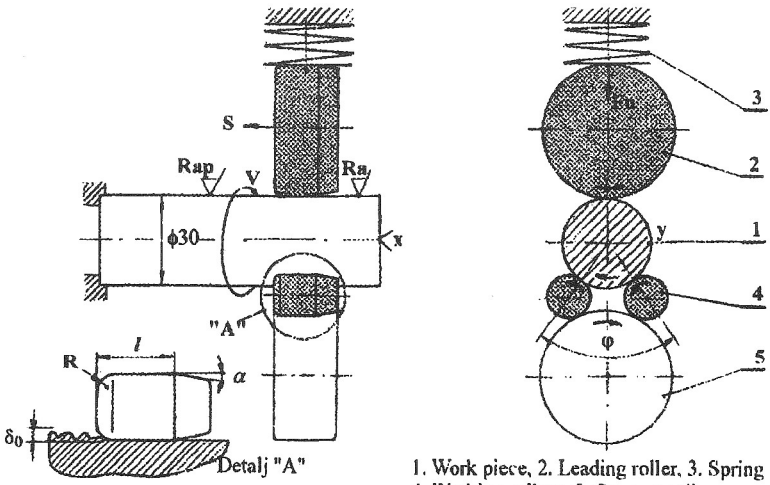
The process analysis is the first stage in the complete procedure of the application of experimental-analytic method of description, modeling, and leading the process. At this stage, the first task consists of the choice of the state function of the process, the choice of "input" coordinates of the process, the determination of the significance of the "input" coordinates and the determination of strength and rank of the effect of the "input" coordinates on the chosen "state" function of the process. The procedure stages of the analysis of the process by this method is done by dispersion analysis where the chosen set of "input" coordinates / x_i, i=1-n/ is selected in two groups: the one affecting the process significantly and the other one the effects of which are not essential for the process. Then, the group of the significant "input" coordinates are ranked according to the degree of their effect on the process, thus making conditions for the effective application of the next stages of studying the processes /modeling, optimization, controlling /. The selection and ranking the "input" coordinates is of exceptional importance for the following given stages because they provide high efficiency of studying the process and getting certain results. It is necessary to include all the important "input" coordinates, because leaving out even a single significant coordinate may cause an error in identifying or interpreting the state of the process behaviour. On the other hand, including all the "input" coordinates in studying the process, in spite of their significance, leads to long and expensive researches, having no justification of any kind. The process of selection of "input" coordinates is necessary and, at the very beginning, elements

those "input" coordinates which are not significant for the processes, and the next stages of studying them continues with only significant coordinates.

3. EXPERIMENTAL VERIFICATION METHOD

3.1 Processing system

- **machine:** Universal lathe PA-25 "Potisje", Ada
- **tool:** Special tool for processing by method of cold deformation (cinematic scheme given in Figure 1)
- **workpiece:** Piston machine of pneumatic working cylinder ϕ30h7x800 (mm), material: Č 1730. (C60)
- **measuring instruments :** TALYSURF -5M Device for precise measuring of roughness "Taylor Hobson"
  AEROPAN -C , Pneumatic device for precise measuring of dimensions. "Massy".
- **technical process data:**
  - The force of the leading roller: Carried out by combination of plate springs
  - Tool regulation: On the carriage with a knot joint, turnable in the plane z-y because of selfcentering towards the workpiece
  - Working rollers: Drive through turning movement of the workpiece, material Č 4146. (100 Cr 6), hardened at 65 HRC and with processing quality of working surface N4.
  - Addition for processing: δ_0= 0.01 mm/pw
  - SHP means : Cutting oil R- EP20 (***FAM Kruševac***)



1. Work piece, 2. Leading roller, 3. Spring
4. Working rollers, 5. Carryng roller

Fig.1 Kinematics processing scheme

3.2 The choice of "state" functions and "input' coordinates of the process

In this case it is decided to analyze and study the process through two state functions which are of the exceptional interest for the process:

-The roughness quality function of the processed surface (Ra) and

-The precision quality function of processing (Tit).

The set of "input" coordinates (variables) of processing has been chosen with a considerably larger number of variables in regard to the existing practice. Namely, the aim is to investigate a larger effect of possible "input" coordinates on the state of processing e.i. to do a multidimensional analysis of the process which gives a higher level of precision of the obtained results compared to a one dimensional analysis which often present inadmissible level of approximates in solution of complicated problems. In this particular case, a set of variables of the process, in this case, has been taken for both chosen functions of the state.

$$\begin{aligned} Ra &= Ra(V, S, \varphi, \alpha, l, R, HB, Fu, Ra(p), Tit(p)) \\ Tit &= Tit(V, S, \varphi, \alpha, l, R, HB, Fu, Ra(p), Tit(p)) \end{aligned} \qquad (1)$$

where are :

V/m/min/-the main movements speed
S/mm/o /-the auxiliary movement speed
φ /°/-the position angle of the working roller
α /°/-the cone angle of the working rollers
R/mm /- the working rollers radius
l/mm/-the cylinder length of the working roller
HB-workpiece hardness
Fu/kN /- the pressure force of the leading roller
Ra(p)/μ m/- the previous processing roughness
Tit(p)/μ m/- the previous processing precision

3.3. Coding the variables of the process

The process analyzing in natural coordinate (1) is, by rule, very difficult and often impossible especially when analyzing the process with a larger number of variables as the case is in this example. That's why all the variables of the process code on three levels (lower (-1), middle (o), upper (+1). The variables of the middle level of the process are mostly chosen as the literature recommends (prospects, catalogs and the like) or according to the facts of the experience of the process, the lower and upper levels are formed by varying the middle one in a corresponding degree adopted by experience. The results of the procedure carried out are given in table (T-1).

3.4. Forming the plan matrix of the process

In the case of studying the process with a larger number of variables, as in this one, the application of the procedure of forming the plan matrix by means of saturated plans of an accidental balance is effective /1/. A set of (k) variables (in this case k=10) divides into a definite number of groups (mostly from 4 - 6 variables in a group). Then for each group a corresponding complete or partial plan is defined. In this case variables of the process divides into two groups (x_1, x_2, x_3, x_4, x_5) and ($x_6, x_7, x_8, x_9, x_{10}$). For each of the groups a partial plan of a quartereplics $(1/4)\cdot 2^k$) was chosen and formed a plan matrix with a number of experiments.

$$N = (1/4)\cdot 2^k + n_0 = 12$$

where is : n_0=4 -a number of experiments of mutual replicas mixing, k=5 -a number of variables in one group. The obtained plan matrix of the process was given in table (T-1).

T-1

No	HYPER SPACE OF "INPUT"												HYPER SPACE OF "STATE"	
	Level variables / Natural variables		V m/min	S mm/o	φ °	α °	l mm	R mm	HB	F_d dN	R_{ap} μm	T_{ip} μm		
	Upper (+)		140	0,60	110	3,5	35	3,5	230	340	12	24		
	Middle (0)		120	0,40	90	2,5	30	2,5	19	280	7	14	FUNCTION "STATE"	
	Lower (-)		100	0,20	70	1,5	25	1,5	150	220	3	4		
	Order of experiments / Coding variables		X_0	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	$Y_{(Ra)}$ μm	$Y_{(Tit)}$ μm
1	7	1	+1	+1	-1	-1	+1	+1	+1	+1	+1	+1	+1	0,29	13
2	10	18	+1	-1	+1	+1	-1	+1	-1	+1	+1	+1	-1	0,33	9
3	3	15	+1	+1	-1	+1	+1	+1	+1	-1	-1	-1	+1	0,13	18
4	13	20	+1	+1	+1	-1	-1	+1	-1	-1	+1	+1	-1	0,28	13
5	22	29	+1	-1	+1	-1	+1	-1	+1	+1	-1	-1	-1	0,14	3
6	24	16	+1	-1	-1	-1	+1	-1	-1	-1	-1	-1	+1	0,07	18
7	28	6	+1	-1	-1	+1	-1	-1	-1	+1	-1	+1	+1	0,21	14
8	25	27	+1	+1	+1	+1	-1	-1	+1	-1	+1	-1	-1	0,15	8
9	12	31	+1	-1	-1	+1	-1	+1	+1	-1	-1	-1	-1	0,09	10
10	21	2	+1	+1	+1	-1	+1	-1	-1	+1	+1	+1	+1	0,31	15
11	16	6	+1	-1	-1	-1	-1	+1	-1	-1	+1	+1	+1	0,23	22
12	17	29	+1	+1	+1	+1	+1	-1	+1	+1	-1	-1	-1	0,17	2

3.5 Performance of the experiment

On the basis of the formed plan matrix of the process each of N=12 experiments is performed. The values of the chosen functions (Ra) and (Tit) were measured, and registered in a corresponding column of table (T-1). The order of experiments is randomized in time.

3.6 The evaluation of dispersion results of measuring the values of the state functions

The evaluation of dispersion results of measuring the values of the state functions is done by dispersion analysis, according to quantities of median (Me) as a parameter which best represents the center of dispersion of the measuring points of the process. The difference of medians (ΔMe) for both levels of each variables of the process (x_i) i =1-1o (T-2) are established by this procedure.

T-2

State functions / Variables of the process			x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
Ra(μm)	Median M_e	+	0,225	0,225	0,160	0,155	0,255	0,145	0,250	0,285	0,285	0,220
		-	0,175	0,170	0,255	0,180	0,160	0,225	0,140	0,135	0,160	0,160
	Diff. med. ΔM_e		+0,050	+0,055	-0,095	-0,025	+0,095	-0,110	+0,110	+0,150	+0,125	+0,060
Tit(μm)	Median M_e	+	13,0	8,5	9,5	14,0	13,0	9,0	6,0	13,0	13,5	16,5
		-	12,0	16,0	14,0	11,0	11,0	14,5	15,5	7,0	9,0	8,5
	Diff. med. ΔM_e		+1,0	-7,5	-4,5	+3,0	+2,0	-5,5	-9,5	+6,0	+4,5	+8,0

3.7. The action of the strength variables upon the process

This procedure is done by dispersion analysis in several consequent cycles, but because of the space limit only two of them are being shown

-For the function (Ra):

-The first cycle:

The Table (T-2), according to the quantities of (ΔMe), shows the domination of the action of variables (x_8,x_9,x_7,x_6) and the strength of the action of (Bi) on the process in this cycle is determined for them. A table with a number of spaces (n_j) corresponding to chosen variables (x_i) for both levels (+) and (-) is formed.

T-3

Variables x_i	$+(x_9)$	$-(x_9)$	$+(x_7)$	$-(x_7)$	$+(x_6)$	$-(x_6)$
$+(x_8)$	0.29 0.33 0.28 [1] 0.31 0.23 Σy_j=1.44 $\bar{y}_1$=0.288	[3] 0.15 Σy_j=0.15 $\bar{y}_3$=0.15	0.29 [5] 0.33 0.31 Σy_j=0.93 $\bar{y}_5$=0.31	0.28 [7] 0.15 0.23 Σy_j=0.66 $\bar{y}_7$=0.22	[9] 0.29 0.15 Σy_j=0.44 $\bar{y}_9$=0.22	0.33 0.28 [11] 0.31 0.23 Σy_j=1.15 $\bar{y}_{11}$=0.29
$-(x_8)$	[2] 0.21 Σy_j=0.21 $\bar{y}_2$=0.21	0.13 0.14 0.07 [4] 0.09 0.17 Σy_j=0.60 $\bar{y}_4$=0.12	0.14 [6] 0.21 0.17 Σy_j=0.52 $\bar{y}_6$=0.17	[8] 0.13 0.09 Σy_j=0.22 $\bar{y}_8$=0.11	0.13 0.14 [10] 0.09 0.17 Σy_j=0.53 $\bar{y}_{10}$=0.13	[12] 0.07 0.21 Σy_j=0.28 $\bar{y}_{12}$=0.14

The strength of the action of variables on the process is determined according to:

$$B_i = \frac{\sum \bar{y}_{j(+)}}{n} - \frac{\sum \bar{y}_{j(-)}}{n},\quad i= 8,9,7,6\quad j=1\text{-}12,\ B_8 = 0{,}100,\ B_9 = 0{,}114,\ B_7 = 0{,}075,\ B_6 = -0{,}040$$

-The second cycle

The determination of the strength of the action of the other variables on the process continues in this cycle. Corrections of the measured values of the state functions for the values of the obtained values B_i /1/ are previously done. Then testing the strength of the action of variables (x_1,x_2,x_5) the procedure as they dominate according to the values of (ΔMe).

It is obtained in this cycle:

B_{10}=-0,044, B_3= 0,036, B_4 = 0,048

The determination of the strength of the action of other variables (x_1, x_2, x_5) is done in the last cycle by an identical procedure after which it is obtained: B_1= 0,023, B_2= -0,043, B_5=-0,003. Finally, the rank and strength of all the variables on the process, that is, the chosen state function (Ra) is obtained, Fig. 2.

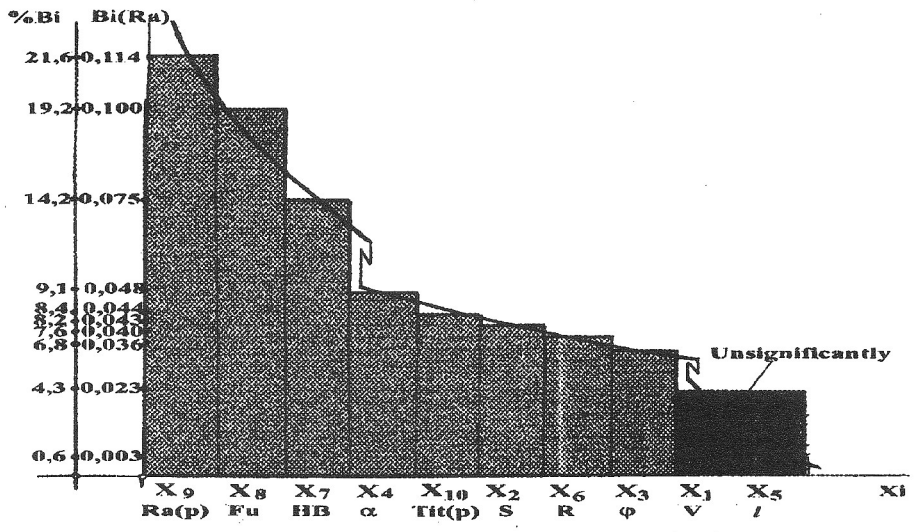


Fig.2 The rank and strength of the action of variables on the function (Ra)

Analysis of the obtained results:

- The obtained dependence Ra=Ra (x_i), Figure 2 shows that, according to the strength of the action on the process, that is, the function of the quality of roughness of the processed surface (Ra), all variables come into three groups: The first one where the action of variables (x_9,x_8,x_7) is expressed, the second where the action of variables (x_4, x_{10}, x_2, x_6, x_3,) is mild and the third one in which the action of variables (x_1, x_5) is very weak.
- It is seen that a considerably stronger effect on the process in this example has a group of variables connected with the previous processing, load and material of the workpiece than the group of variables connected with the geometry and regime of work.
- The necessity of the application of multidimensional method of space analysis is confirmed, for none of the chosen input variables has a specially expressed dominant effect on the process to be taken as special and the only one, but it must be done with a bigger number of variables rather balanced effect, especially of group (x_9, x_8, x_7)
- The marked effect of impression rank and strength of the action of all the "input" variables on the process, that is, the state function of the quality of roughness of the processed surface (Ra) gives a possibility for the choice of the effect of the process, for the corresponding change of variables leads to desired effect and directs the course of the process towards the maximum quality of roughness of the processed surface. It means, in this case, that the variables of the process tend to values: Ra(p)=3, Fu=220, HB=150, α=3,5, Ti(p)=24, S=0,2, R=1.5, φ =70, V=100, l=25.
- Interpretation of more correct reasons for such obtained results of the rank and strength of the effect of the chosen variables of the process, because of the mere interpretation complexity, is possible by means of a considerably deeper analysis and by an analysis of a mutual action of the first and upper row of all the variables of the process, and it will be the topic of further investigations.

For the function (Tit):

The determination of the rank and strength of the action of "input" variables (x_i, i=1,10) on the state function of the quality of processing precision (Tit) is identical to the procedure carried out for the function (Ra), so there is no need to repeat it.
The results of this procedure are shown in Figure 3.

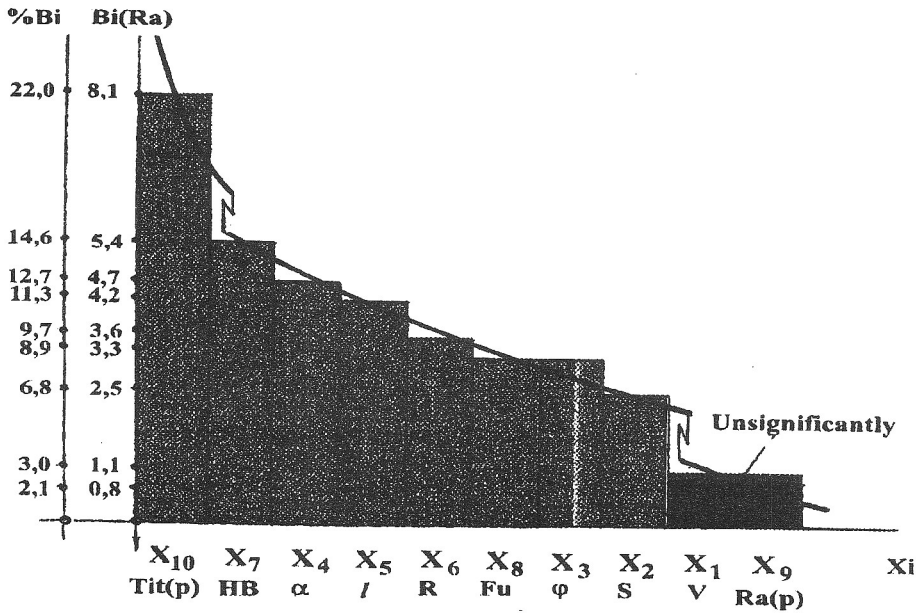


Fig.3 The rank and strength of the action of variables on function (Tit)

Analysis of the obtained results

- The obtained dependence Tit =Tit (x_i), i=1–10, shows that, according to the strength of the action on the process, that is, on the function of the quality of the process precision (Tit) variable (x_{10}) distinguishes itself, that is, precision of the previous processing (Tip) with the strongest action, which is analog with the previous analysis for the function (Ra) which suffered the strongest effect of the roughness of the previous processing (Rap).
- The balanced effect of the other chosen variables in this case points to the necessity for a multidimensional analysis of the process, for each one-dimensional analysis would certainly lead, to rough and inadmissible approximations with unwanted consequences.
- These researches show that in finishing processing by plastic deformation a considerable quality improvement of the precision of the previous processing can be achieved (about 20% for this example of processing) which allows a possibility of a lower precision quality of the previous processing and the decrease of the total expenses as well.
- The determined rank and strength of the action of all "input" variables on the process, that is, on the state function of the processing precision (Tit) gives a possibility for the choice of wanted effects of the process, that is, a possibility to direct the process to a maximal quality processing precision. It means that, in this case, the variables of the process lead to values: Tit(p)=4, HB=230, α =3,5, l=25, R=3,5, Fu=220, φ =70, S=0,6,V=100, Ra(p)=3.

4. CONCLUSIONS

On the basis of the obtained results by analyzing the finishing processing by method of cold deformation the following results of greater significance can be established:

- The previous statement that such processes belong to a group of very complicated ones, which in their internal structure manifest numerous and complex interactions, are still not studied enough, and which, generally, may condition a large number of state coordinates of the process.
- Such circumstances demand a multidimensional analysis, that is, the study of the effect of a larger number of variables on the process, in order to avoid frequent mistakes because of inadmissible unprecise approximations of one-dimensional analysis, so as to obtain more exact and reliable conclusions and identification of the state parameters of the process, that is, to analyze and study the process in a domain of practical reality.
- To achieve these aims and solve complex problems effectively and reliably judging by all, is only possible by applying the experimental-analytic methods, the methodology and procedure of which is shown in this paper.
- The determined rank and strength of all the chosen variables on the process, which is being observed especially such a large number of them, is very significant for possible effects of the process, for it enables the location of the work regime of the process in the domain of wanted effects, including multicriteria approaches to work regulation as well.
- In case a higher level of obtained results precision is wanted and to determine a more exact location of desired effects of the process within the identified domain it is necessary to do the next steps of the applied method (mathematical modeling the upper hyperspace of the observed state parameters, the observation of the topography of these surfaces the discovery of possible extremes and modeling their environment which will be further investigation of the authors of this paper.
- The analysis in this particular case points out that beside the advantages of processing by method of deformation in cold compared to classical methods of finishing processing previously mentioned it is possible to achieve considerable techno-economic effects. In this case the rise in production (p) by 280%, the improvement of the roughness quality level of the processed surface (Ra) by 45%, the improvement of the processing precision level (Tit) by 20% compared to the previous processing, the decrease of the total process costs (Top) by 190% with the obvious improvement of exploatation of the product characteristics.
- The multidimensional analysis done in the example of this process makes a basis for its application on any other process or system in the largest possible scope, practically without limitation.

5. REFERENCES

/1/ Stanić J.: Engineering measuring method, Faculty of Mechanical engineering, Beograd,1990.
/2/ Ivanovič P.: Method of analysis and mathematical modeling of processes and systems, Project, Faculty of Mechanical engineering, Kragujevac, 1985.
/3/ Ivković B.: Theory of cutting, Faculty of Mechanical engineering., Kragujevac 1991.
/4/ Ivanović P.: Analysis and designing numeric control the processes and states, as aspect the rise of productivity, Project, Faculty of Mechanical engineering, Kragujevac, 1985.
/5/ Stanić J.: Introduction into theory of tehno-economic optimization, Faculty of Mechanical engineering, Beograd, 1988.

ANALIZA KOORDINATA "ULAZA" I "STANJA" PROCESA ZAVRŠNE OBRADE SPOLJAŠNJIH CILINDRIČNIH POVRŠINA METODOM HLADNOG POVRŠINSKOG VALJANJA

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REZIME

Neprekidno je nastojanje istraživača i projektanata proizvodnih sistema, procesa i proizvoda u njima, da se ostvari najviši mogući nivo tehno-ekonomskih efekata.

Poseban je interes, da se takvi efekti ostvaruju u proizvodnim sistemima i procesima u metalopreradjivačkoj delatnosti, kao baznoj za sve ostale privredne delatnosti.

U radu se čini pokušaj davanja doprinosa takvim nastojanjima na primeru obradnog procesa završne obrade spoljašnjih cilindričnih površina metodom deformacije na hladno. Pri tome dodatni razlog za ovo proučavanje je sadržan i u injenici da je ova vrsta završne obrade neopravdano nisko zastupljena, posebno u domaćim proizvodnim procesima.

Za analizu ovog tipa obradnog procesa korišćen je savremeni analitičko-eksperimentalni metod zasnovan na teorijama višedimenzionalne regresione i disperzione analize, pri čemu su eksperimentni izvedenu u realnim proizvodnim uslovima, a u analizi uključeno čak deset koordinata "ulaza" u proces.

Analize dobijenih rezultata pokazuju da ova vrsta obradnih procesa, u poredjenju sa klasičnim vrstama završne obrade, mo`e dati značajno veće tehno-ekonomske efekte, što daje dovoljno razloga da se u budućnosti istima posveti znatno veća pažnja.

Osim istaknutog, dobijeni rezultati analize, iskazani kroz jako veliku razliku u rangu i jačini dejstva svih odabranih koordinata "ulaza" na proces pokazuju da je, za ovu vrstu obradnih procesa, a verovatno i šire, nužna višedimenzionalna anliza, čime se osiguravaju egzaktniji i pouzdaniji zaključci u odnosu na moguče i često korišćene jednodimenzionalne analize. Ovo upućuje na potrebu nužne primene pokazanog metoda i za druge vrste procesa i sistema u širem opsegu.

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CHECKING OF SELECTED LUBRICANTS FOR METAL SHEETS DRAWING IN A SPECIAL DEVICE

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ABSTRACT

The knowledge of the coefficient of friction between a metal sheet and a forming tool is necessary for the computerized constructional solution of tools for the deep drawing as well as for the optimum selection of a suitable lubricant for the sheet drawing. There exist various methods for the lubricant testing, the one of which is the drawing of the strip of sheet in a special device in which the strip is lubricated on both its sides.

1. INTRODUCTION

When drawing a metal sheet, the plastic deformation processes inside the material are connected with the internal friction influencing the stress and energetic conditions of deformation, the wear of a forming tool and the surface quality of a part. Kragelsky's adhesive deformation theory of friction and wear as well as Fleischer's energetic theory are considered to be sufficiently worked out and perspective [1, 2].

2. CONTEMPORARY METHODS OF LUBRICANTS PROPERTIES CHECKING

For the checking of a lubricant properties various testing devices are used in the laboratories. For the given conditions they must approach the real conditions of the industrial practice as much as possible. The application of the testing devices for the mentioned aims of testing is limited by particular testing conditions [4, 5].

3. A DEVICE WITH CYLINDRICAL GRIPS AND A MODEL FRICTION TEST

One of the methods of the properties testing of a lubricant for the shaping of steel deep-drawing sheets is the drawing of a metal sheet strip of prescribed dimensions with a layer of a tested lubricant through a special device (Fig. 1).

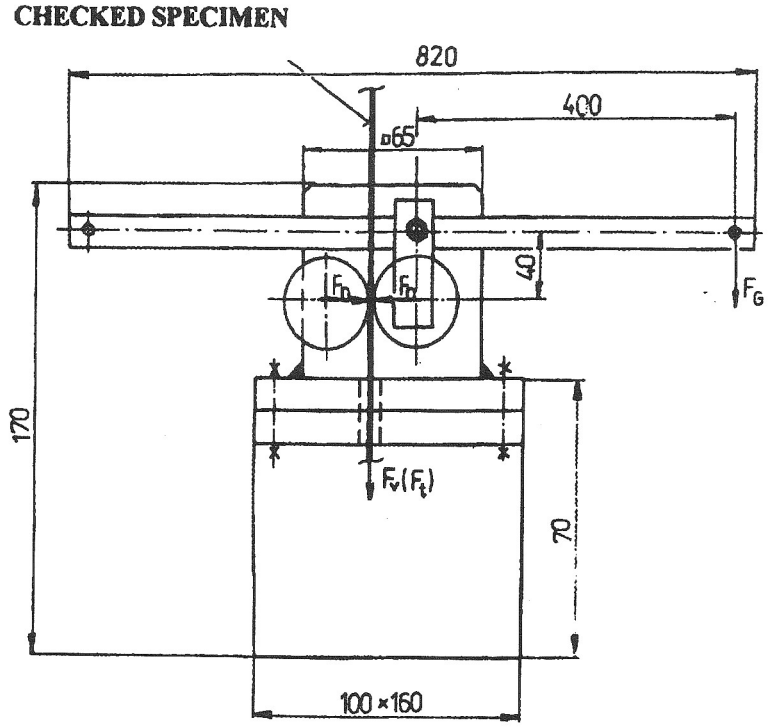


Fig.1 - The special device for the checking of a lubricant.

The principle of testing consists in the determination of a drawing force (friction force) when a sheet strip 2 x 20 x 200 [mm] is repeatedly drawn through the divice at quite specific conditions (see the List of conditions 1 - 7). The thrust F_n in the range 92,7N to 981 N is possible to be adjusted in the device by means of a calibrated weight. The coefficient of friction f can be determined from Coulomb's law.

The experiments were done with 10 selected kinds of lubricants:

UNIMET 81N, AQUANET LS, QUANET SUPER 2, DRAWSOL 3750 DB, DRAWSOL WDC 9, DAG DELTA 144S, DAG DELTA 5119, DAG 5480, DAG 5520 and DAG 5535.

The comparison of lubricants and the determined average values of the coefficient of friction see Fig. 2.

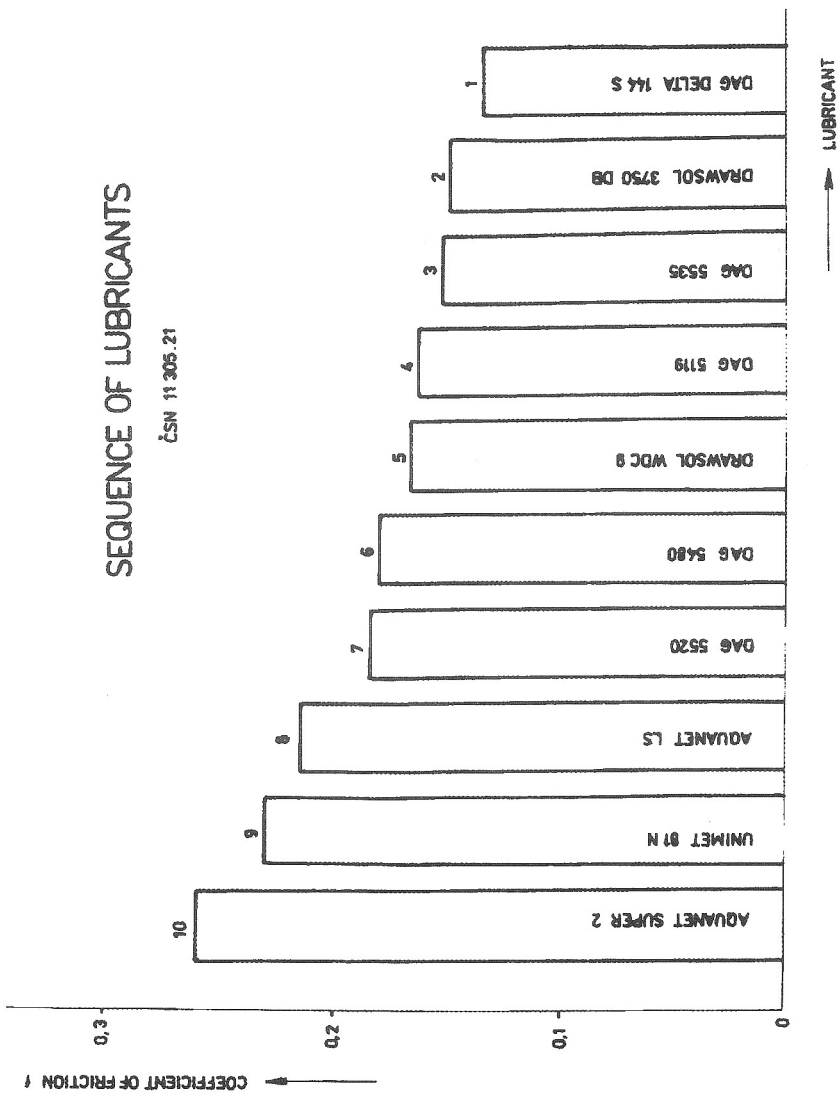


Fig.2 - The coefficient of friction determined by a model test, using the drawing of a sheet strip with the mentioned lubricants.

Example of a record of the F_t from the ZD 10/90 device
Conditions:

- ZD 10/90 - adjusted scale 0 - 2 kN
- The special device for the checking of lubricants (see Fig. 1)
- Specimen: P2-20x200 mm, ČSN 11 305.21, Ra = 1.02 to 1.06 μm, R_{max} = 10.1 μm - for longitudinal direction, R_{max} = 7.3 μm - for transversal direction. (MITUTOYO SURFTEST 201) hardness 110 HV 10 (ZWICK 3212 Hardness Testor, load 100 N, 15 s)
- The kind of a lubricant: DRAWSOL WDC 9
- Drawing velocity: 40 mm/min
- Temperature: 20° C
- Thrust F_n: a = 92.7 N, b = 185.4 N, c = 303 N, d = 421 N, e = 538.6 N, f = 981 N.

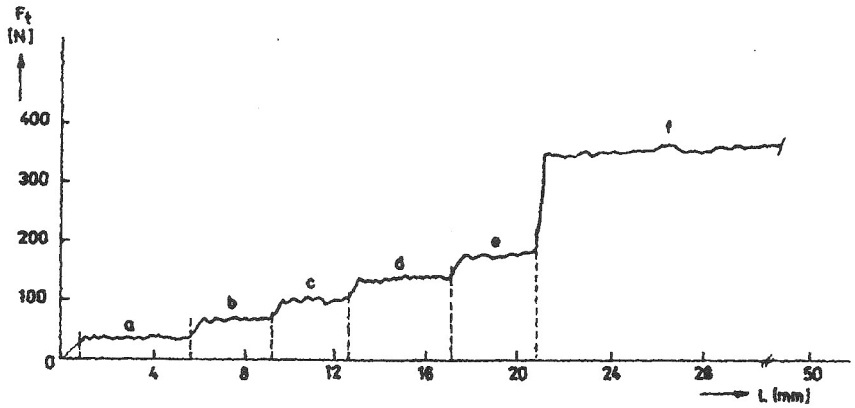


Fig. 3

Fig.3 - The change of size and the course of the friction force F_t at the loading F_n in the range 92.7N to 981 N, the DRAWSOL WDC 9 lubricant.

4. CONCLUSION

The problematic reproducibility of the complicated real condiditions of a sheet drawing is to be taken into consideration when evaluating the quality of the lubricants. A laboratory test with a checking device gives an information for the specific conditions of drawing. The suitability of a lubricant in the industrial practice is to be checked by a performance test in the real conditions of a particular shaping operation.

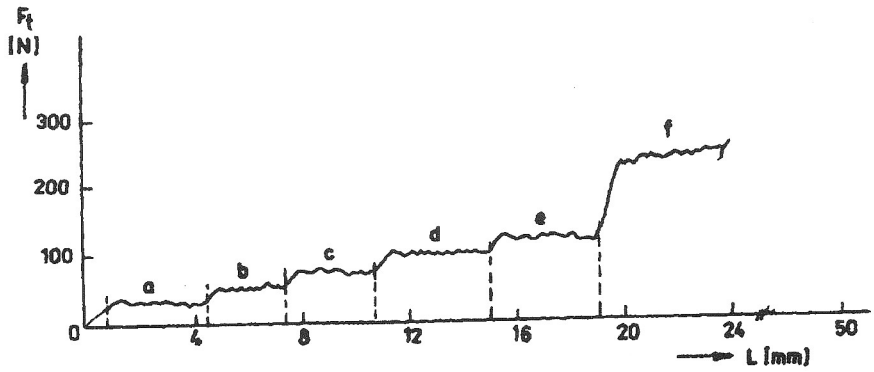


Fig. 4

Fig 4 - The change of size and the course of the friction force F_t in the range 92.7 N to 981 N, DAG DELTA 144 S lubricant (the best one).

5. REFERENCES

1. ZONGOR, J.: Tribology in Constructional Practice. Strojárska ročenka 1990, Bratislava, ALFA 1990, p. 74-79 (in Slovak).
2. BLAŠKOVIČ, P. - BALLA, J.: Tribology. ALFA, Bratislava 1990 (in Slovak).
3. BENZING, R. at al.: Friction and Wear Devices, 2nd Edition, Park Ridge, ASLE 1976.
4. DVOŘÁK, M.- ŠANOVEC, J. - KÁBRT, P.: Lubricants and Their Experimental Checking in Sheet Drawing. Strojírenská výroba, 1996, No. 5-6, p. 32-34 (in Czech).
5. SMRČKA, J. - FALTÝN, P.: Coefficient of Friction of Deep-Drawing Steel Sheets. Strojírenská výroba, 1989, No. 12, p. 42-45 (in Czech).
6. DVOŘÁK, M.: Possibility to Apply New Lubricants for Production of Parts of Special Technics. Materiály a technologie ve výrobě speciální techniky - Proceedings of IV. Odborný seminář v rámci Mezinárodního veletrhu obranné a bezpečnostní techniky a speciálních informačních systémů, DT Brno, 1977, p. 76-82, (in Czech).

ISPITIVANJE MAZIVNOG SREDSTVA ZA DUBOKO IZVLAČENJE LIMA POMOĆU SPECIJALNOG UREĐAJA

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REZIME

Za komjuterizovanu analizu procesa deformisanja kao i njegovu optimizaciju neophodno je poznavanje koeficijenta trenja. Postoje različite metode za testiranje maziva. Jedna od njih je i postupak dubokog izvlačenja trake u specijalnom uređaju gde se traka podmazuje sa obe strane.

Princip merenja je baziran na određivanju sile vučenja (sile trenja) kada se traka dimenzija 2x20x200mm nekoliko puta provlači kroz uređaj pod specifičnim uslovima.

Istraživanja koja su opisana u ovom radu vršena su na 10 različitih sredstava za podmazivanje. To su:

UNIMET 81N, AQUANET LS, QUANET SUPER 2, DRAWSOL 3750 DB, DRAWSOL WDC 9, DAG DELTA 144S, DAG DELTA 5119, DAG 5480, DAG 5520 and DAG 5535.

Dato je upoređenje pojedinih mazivnih sredstava (sl.2) kao i odgovarajućih koeficijenata trenja.

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VIBRATION OF ROLLING EQUIPMENT AND ITS INFLUENCE ON FORMATION OF SURFACE MACROTOPOGRAPHY

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ABSTRACT

The influence of vibrations of skin-rolling mill and grinding machine tools on the macrotopography of sheet surface is described in the article. The research has been carried out using of the System for Measurement and Spectral Analysis of Vibrations of industrial equipment (VIBRA) and Automated Complex for Surface Macrotopography Research (ACSMR).

1. INTRODUCTION

Furieu's analysis of the surface macroprofile allows to detect periodic components of the profile. These methods have proved to be effective while analyzing the surface obtained from machine processing [1,2]. No scientific research of the same type for the surfaces obtained from rolling is known to us.

The vibration of rolling equipment influences the formation of sheet surface macrotopography. The example of it the so-called defect of "ribbing" that is observed on the sheet surface as alternation of light and dark strips perpendicular to the direction of rolling. It can be visually observed on the sheet rolls surface by diffusive illumination. It is less distinct on smaller patterns. The defect is often observed on one stand of skin-rolling mill 2500 of SRS № 5 of MMK, where the sheet is rolled with thickness of 0.8÷1.5 mm under reduction of 0.5÷1 %.

A number of hypotheses of "ribbing" defect origin has been suggested: either it is the consequence of periodic component vibrations of some elements of the rolling mill, or it is the consequence of periodic component vibrations of some elements of grinding machine tools under working rollers' grinding.

2. EQUIPMENT

The system for measurement and spectral analysis of rolling equipment vibrations (VIBRA) has been worked out. [3]. The system in question consists of sensors, blocks of recording information and the block of interface with computer. This self-contained block is able to record information simultaneously from three channels of wavegrams of vibrations (vertical and two horizontal components of vibration). At any time it is possible to read and process the information in the computer using special programs.

Specification:

1.	Frequency range of the vibrations measured , Hz	1-1000;
2.	Time of recording, ms	125, 250, 500,1000;
3.	Number of the sensors connected	3;
4.	Number of memory blocks	4;
5.	Number of discretization steps	2040;
6.	Overall dimensions, mm	100×195×280;
7.	Voltage of power supply , V,Hz	220; 50;
8.	Type of computer necessary for processing the wavegrams not lower in class than IBM 486 AT.	

VIBRA has allowed to research the vibrations of some units of rolling mill and test the suggested hypotheses experimentally.

In our earlier work [4-7] it has been reported about the Automated Complex for Research of Surface Macrotopography (ACSMR) worked out in the Scientific Research Center (SRC) "Macrotopography" of Southern Ural Branch of Russian Engineering Academy. The profile has-been taken with high and low frequency filters disconnected with the help of this system.

It is necessary to use high frequency filter for research of sheet macrotopography. Measuring is carried out with the help of a special post with rectilinear bearing and the spherical bearing of the sensor glides along the surface of the bearing. To adjust the system is a difficult task for it requires achieving parallelism of the surface of the bearing to the surface of the pattern and the slightest deflection under a large evaluation route may result in the readings exceeding the possible maximum vertical deflections.

3. EXPERIMENTAL RESEARCH

We have researched the surface of the sheet patterns with the defect of "ribbing". The cut off of profilograph step was accepted as 0.8 mm. The evaluation area has been very large - 45x20 mm which is the maximum limit for profilograph. We shall remind for comparison that usually evaluation areas of roughness are selected about 3x3 mm. Such large evaluation route 45x20 mm was selected because the observed ribbing period is 20x35 mm.

In Fig.1 you can see two charters of the surface: "a" the charter of the surface made without presence of any filter; "b" the charter of the surface made under the influence of a high frequency filter.

The charter of the surface "b" has shown that the spatial period of harmonic component of the profile is 25÷30 sm. The visual measurement of this quantity (the distance between dark strips in one) gives approximately the same meaning. Thus the physical origin of "ribbing" defect is sheet surface ripple.

The sheet ripple can be caused both by vibration of the rolling equipment and by vibration of the grinding machine tools.

From Fig.1 it is clear that the spatial period of periodic component of the profile T_d is 25÷30 mm. The speed of rolling $V_{rol.}$ is 18 mps. Hence it presents no difficulty to calculate the frequency of the periodic component of the vibration that affects the sheet surface in the process of rolling $F_v = V_{rol.}/T_d$. In this instance the frequency of «dangerous» vibration of the rolling mill will be within the range of 602÷724 Hz.

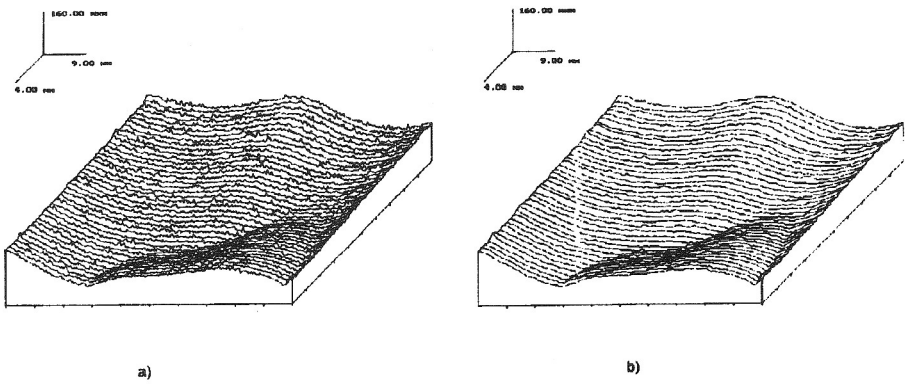


Figure 1. - General topography of the surface (a) and macrotopography (b)

In the process of rolling the metal of marks 0,8Ю with the reduction 0.5÷0.9 per cent and the speed of rolling ~ 18 mps the vibrations of the following units of the rolling mill were measured:

- of the unreeler (engine, reducer (reduction gear));
- of working rollers driver (engine, reducer);
- of the chuck of the lower bearing roller (on the side of the operator, on the side of the mill drivers).

One of the examples is given on fig.2.

From the given wavegrams and spectral functions of unit's vibrations of the rolling mill. It follows that there are no harmonic components of vibrations within the so-called «dangerous» range, whereas. The most powerful harmonics of the mill are within the frequency range of 5÷340 Hz - Table 1. Consequently the vibration of the above-mentioned rolling mill units cannot be the cause "ribbing" defect.

So as the vibration of the rolling mill units cannot be the cause of "ribbing", another hypothesis has been suggested and namely that the sheet defect of "ribbing" is the consequence of working rollers. Vibrations of the following units of grinding machine tools were examined: "ribbing" of the lunettes and of the grinding circle driver.

We calculate the frequency range of "dangerous" vibration for a grinding machine tool $F_t = \pi * D * w / (60 * T_d)$ at the speed of the rotation of the roller 20,30,40,50 rpm.

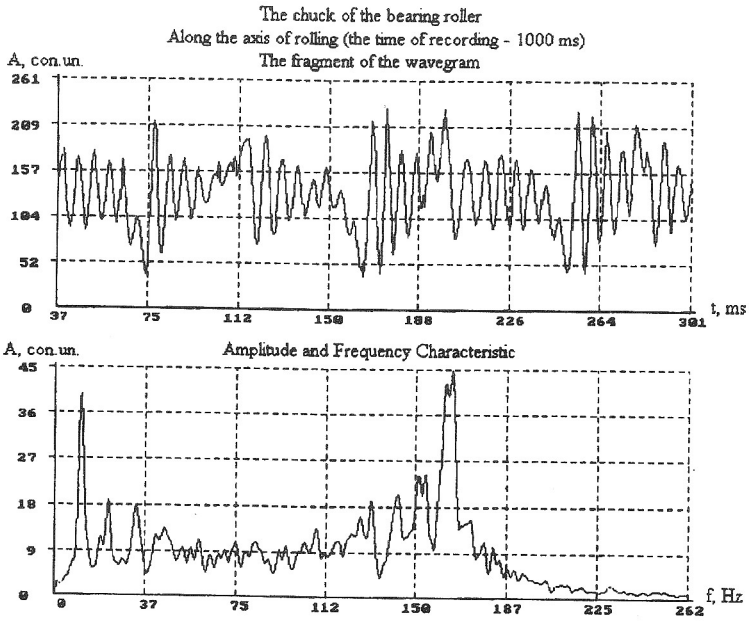


Figure.2 – The wavegram and spectral fragment of the vibration of the bearing roller chuck

Table 1

The most powerful harmonics frequency of the rolling mill units.

The rolling mill units	The engine of the unreeler	The reducer (reduction gear) of the unreeler	The engine of the working roller driver	The reducer of the working roller driver	The chuck of the lower bearing roller	Unreelerin
The frequency range of vertical and horizontal components of the vibrations, Hz	20÷210	15÷200	80÷215	20÷340	10÷240	5÷290

Table 2

The frequency range of the "dangerous" vibration

The frequency of roller rotation, rpm	20	30	40	50
The frequency range of the "dangerous " vibration, Hz	17.4÷20.9	26.1÷31.4	34.9÷42.0	43.6÷52.3

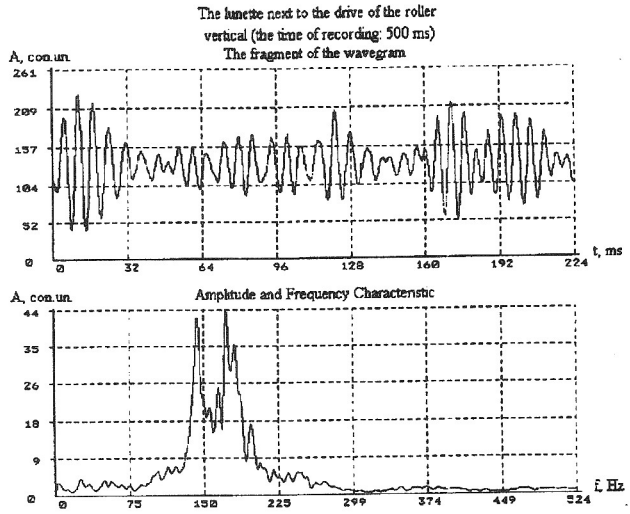


Figure 3. - The fragment of the wavegram and the spectral function of the lunette vibration next to the roller driver.

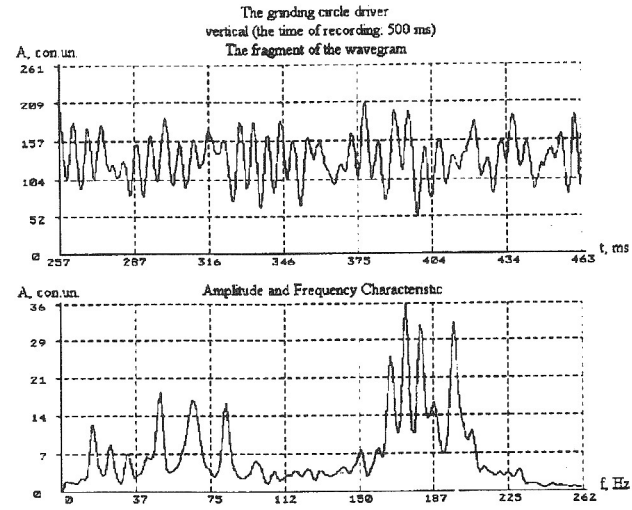


Figure 4. - The fragment of the wavegram and the spectral function of the circle driver vibration.

The lunettes vibrations are measured in the process of the roller work when the load I = 80 A, the speed of the rotation of the grinding circle W_c=750 rpm, the speed of moving of the carriage $V_{car.}$= 1 mpm and the frequency of the rotation of the roller varies from 20 to 50 rpm. One of the examples is shown on fig. 3.

The vibrations of the grinding circle driver were measured at different grinding parameters; the rotation frequency varied within the range of 500÷1000 rpm and the speed of the roller rotation within the of 20÷50 rpm. One of the examples is given on fig.4.

From the given wavegrams and spectral functions of grinding machine tool vibrations it appears that the harmonic components of lunettes vibrations are not observed in the "dangerous" ranges at the frequency of the roller rotation 20÷50 rpm, but they are present in the drive of the grinding circle at any combinations of the parameter meanings of grinding. And so these components of the vibration result in the "ribbing " of the working rollers processed by grinding machine tools that thereupon affects the sheet.

4. CONCLUSION

The equipment and methods for detecting and explaining "ribbing" defect origin of "ribbing" in the process of rolling have been considered in the article.

The given equipment and methods may also be used for the following:

- rolling equipment diagnostics;
- rolling equipment research;
- rolling equipment adjustment;
- adjustment of grinding machine tools in the grinding process of skin-rolling mill rollers.

5. REFERENCES

1. Konczakowski, Andrzej. Research on the influence of Turning Process on Geometrical Structure of Machines Surfaces Based on Spectral Analysis of the Surface Profiles. // Of the Polish Society of Mechanical Production Engineering, journal, № 10, Poland, 1979

2. Brock M. Furieu's analysis of the surface roughness. // Notiziario tecnico, journal, № 3, 1986, p 19-33.

3. V.K. Belov, A.A. Shponko. Usage of portable equipment for vibration determination in building construction in ecological research. // Ecological problems in industrial areas of the Urals Extracts of international research conference, Magnitogorck, Mining Metallurgical Academy, 1997.

4. V.K. Belov, A.Yu. Lednov. Problems of surface microtopography measurement and their solving. // Solid and laminated materials processing: interuniversity research materials, Magnitogorck, Mining Metallurgical Academy, 1995, p. 102-107.

5. V.K. Belov, A.Yu. Lednov. Automated Complex for Surface Macrotopography Research. // interuniversity research material, Magnitogorck, Mining Metallurgical Academy, 1996, p. 79-85.

6. V.K. Belov, A.Yu. Lednov, A.V. Revin. Research of alteration in sheet skin-rolling of profile ordinate distribution. // Solid and laminated materials processing: interuniversity research materials, Magnitogorck, Mining Metallurgical Academy. 1996, p. 71-75.

7. V.K. Belov, A.Yu. Lednov. Alteration research of distribution function, correlative function, spectral density function of sheet surface ordinate profile under skin-dressing. // Problems of metallurgical development in the Urals at the 21st century boundary: Research materials, Vol.1., Magnitogorck, Mining Metallurgical Academy, 1996, p. 192-198.

VIBRACIJA VALJAONIČKOG POSTROJENJA I NJEN UTICAJ NA MAKROTOPOGRAFIJU POVRŠINE VALJANOG PROIZVODA

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REZIME

Vibracija valjaoničkog postrojenja utiče na stvaranje makrotopografije površine lima. Vizuelni efekat ove pojave se ispoljava u pojavi svetlih i tamnih traka na limu, u pravcu normalnom na pravac valjanja. Difuzionom iluminacijom ovaj efekat se može uočiti i na valjaoničkim valjcima. Nekoliko hipoteza za objašnjenje ovog fenomena je do sada predloženo. Najčešće se objašnjenje traži u periodičnoj vibraciji nekih elemanata valjaoničkog stana ili u periodičnoj vibraciji nekih elemenata mašina na kojima se finalno obrađuju valjaonički valjci.

U ovom radu dat je detaljan opis uređaja za merenje i spektralnu analizu valjaoničkog uređaja (VIBRA) koji je kreiran od strane autora rada. Takođe je razrađena metodologija merenja i analize rezultata. Ovaj uređaj može se takođe koristiti i za:

- *dijagnostiku postrojenja za valjanje*
- *istraživanje postrojenja za valjanje*
- *podešavanje postrojenja za valjanje*
- *podešavanje mašine za obradu valjaka*

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INFLUENCE OF VARIABLE CONTACT CONDITIONS ON THIN SHEETS METALS FORMABILITY BY DEEP DRAWING

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ABSTRACT

Presented in the article is comparative view of experimental results of pure deep drawing (deep drawing of cylindrical cup with flat bottom) in conditions of constant blank holding force with different contact conditions (dry, oil, polyethylene foil) on one side and the results of deep drawing with variable blank-holding force and different contact conditions on the other side. Variable blank-holding force implies the possibility of programme control of any kind of force dependence on travel. Classical autobody steel sheet metal is used, and strain distributions j_1, j_2 and j_3 (in dependence on location on work piece and in forming limit diagram –FLD), drawing force, work piece depth and the appearance of defects (wrinkles and fracture) are being observed. Three program controlled variable blank-holding force models are used: decreasing, increasing and combined. First results, presented here, show that variable blank-holding force has significant influence on conditions of friction on work piece flange, and thus on deep drawing process and work piece characteristics. That influence may result in significant improvement in technology of deep drawing of thin sheet metals.

1. INTRODUCTION

In structure of total tribological scheme of deep drawing process duration, the sheet metal blank-holder zone has special significance (fig. 1). On one side the friction on blank-holder significantly influences the course and result of plastic forming process, and on the other side blank holding force is a very convenient parameter for monitoring and control. That is the most important reason for many current researches of blank holding force influence in many research and industrial world centres /1, 2/.

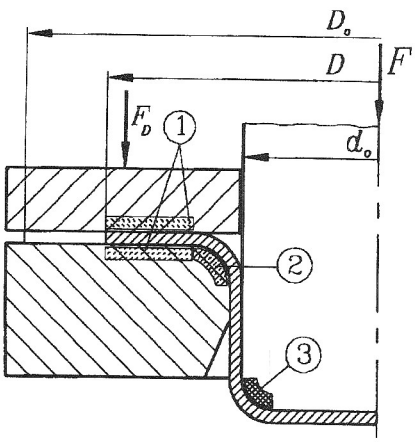


Fig. 1 - Friction zones

Two types of defects may appear in course of drawing: wrinkles at sheet metal surface and fracture. These appearances, so to speak, form the framework for successful continuance of the process. Besides material characteristics and tool and machine condition, the process and finished work piece can be influenced by drawing ratio, condition of tool-sheet metal contact surfaces and blank-holding force. The other group of influential factors is much more convenient for change, if necessary. This mostly applies to the lubricant application and blank-holding force control. For example, it is relatively easy to replace the lubricant, but it is much more difficult to replace the tool or press. In general, deep drawing realization so far implied constant blank-holding force and it was considered generally accepted. Not until the development of new sheet metals generation and increased demands, in the last few years, did the intensive work start on researching the influence of variable blank-holding force (VBF) by application of modern computer systems for acquisition and control.

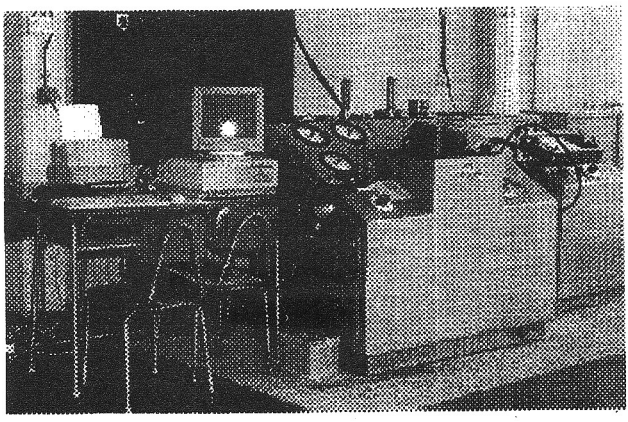
At faculty of Mechanical Engineering in Kragujevac the modification of laboratory press for investigation of sheet metal – ERICHSEN 142/12 was carried out, by computer system which, besides acquisition, makes possible the obtaining of programme defined blank-holding force (phot. 1).

2. EXPERIMENTAL RESEARCHES

In the context of planned comprehensive researches of the variable blank-holding force influence, preliminary results of experiments realized so far are given here. The machine on which experimental researches are performed is already mentioned hydraulic triple action laboratory press-ERICHSEN 142/12. Maximal measuring force range is 0-130 kN, forming speed is 0-200 mm/min and blank holding force is 0-32 kN. Maximal punch diameter is 50 mm and maximal drawing ratio is 2.4. On the whole, in machine there are inductive transducers of force and travel with standard manometers with Bourdon`s tubes for all working actions. Blank-holding force is controlled by hand regulated hydro-valve.

For the purposes of these researches, the modification in part for blank-holding force realization was carried out. Modification includes built-in electromotor drive with DC motor and two connected reduction worm gears, applied on hydraulic valve for blank-holding force regulation. Control of electromotor drive is performed in closed loop based on hydro-valve axle angle position, which is measured by multirotating potentiometer. Control of electromotor drive is integrated in data acquisition and control computer system because process speed is relatively small (phot. 1). Data acquisition and control system contain PC computer with built-in 12-bit AD-DA card and accessory moduls: driver for control of DC electromotor, signal amplifier with filter and switch elements. In that system, based on previously recorded blank-holding force dependence

on angle position of valve axle (i.e. potentiometer voltage) would make possible the obtaining of valve axle position dependence on time during drawing process, and in that way variable blank-holding force.



Phot. 1 View of complete equipment

Table 1: Material properties

Č0148P5 s_o=0,8 mm				
R_M, MPa	R_P, MPa	A_{80}, %	n	r
385,5	234	34,0	0,23	1,242

By switching DC electromotor drive in desired moments with the use of specialy developed electronic unit change of blank-holding force to programme defined value measured indirectly by axle angle position potentiometer, may be obtained. The choice of any kind of force dependence was provided through software, developed for service of the experiment. Because of limited space, it is impossible to give all details about design, making and application of this system, so, for all further information, the authors must be consulted.

Material used for investigation was steel sheet metal from class Č0148P5 (foreign manufacturing) with characteristics given in the tab. 1 which gives medium values considering the plane anisotropy of sheet metal. Fig. 2 shows the strengthening curve and fig. 3 shows the forming limit diagram (FLD).

In course of experiment planning, the model of pure deep-drawing (cylindrical part with flat bottom) was chosen, with punch diameter 50 mm, bottom radius 6.5 mm and die radius 3.5 mm. Forming speed was fixed to 20 mm/min. Drawing ratio had to be chosen in a way to be close to the limit value, so that the differences caused by the influence of VBF could be noted. With ratio 2 and techicaly dry contact surfaces with constant blank-holding force F_D=15 kN the process had its course towards the end without any defects. With ratio 2.2 and dry surfaces (degreased by acetone) and with the application of oil (of a domestic producer) for deep drawing (F_D=6-10 kN) the fracture appeared. With the application of polyethylene foil and oil and F_D=10 kN at the end of travel wrinkles appeared, while with force F_D=12 kN, the process ran successfully to the end,

which meant that blank diameter 110 mm is adequate for such investigation. Knowing that conditions at contact surfaces very significantly influence the drawing /3/, one out of previously three mentioned types had to be chosen. Lubrication by oil was chosen from two reasons: it doesn't belong to the extreme conditions and it satisfies the commonest operating conditions in industry. The general approach in the realization of experiment is to put the work piece of chosen geometry (with mentioned contact conditions) under investigation by constant blank-holding force of appropriate intensity on one hand, and on the other hand with the application of VBF of appropriate intensity range and law of change as well, in dependence on travel, i. e. time.

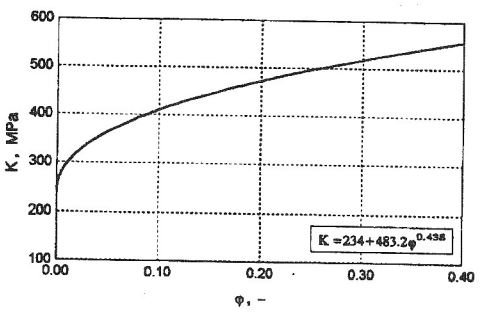


Fig.2 - Strengthening curve

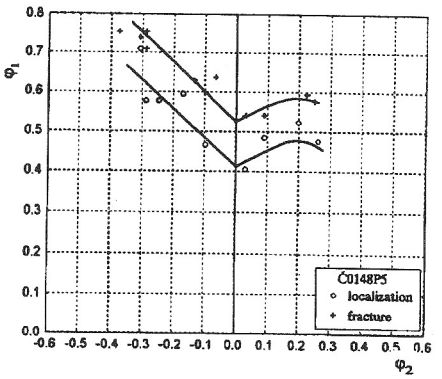


Fig.3 - Forming limit diagram (FLD)

2.1 The choice of constant blank holding force (CBF) and variable blank holding force (VBF)

In choosing CBF generally accepted principle was adopted: $F_D=q\cdot A$, q being the specific holder pressure and A being the maximal contact surface (at the beginning of drawing) of holder and sheet metal. In this particular case:

$$A=\frac{D_o^2-(d_1+2s+2r_M)^2}{4}\pi=\frac{110^2-(50+2\cdot 0.8+2\cdot 3.5)^2}{4}\pi=6806.3\ mm^2$$

Concerning the values of q, eight following approaches given in the tab. 2 were considered. Examining the values in the tab. 2 and taking into consideration our own experimental data from previous researches /2, 4/ and this one, CBF was adopted as medium value from sections 3 and 4, F_D=12.2 kN. In choosing the decreasing dependence of VBF, the principle of constant specific holder pressure realization was set, with regard to decrease of contact surface from the start value to zero. During that, the flange diameter takes values from D_0=110 mm to 58.6 mm on die radius. After that, at the very end of process, when full work piece depth is realized, there is no sheet metal holding. The surface of flange is $A=0.7854\cdot D^2$ - 2697 mm^2. Because of the control of valve requirements for VBF it is necessary to ascertain F_D dependence on time. At adopted forming speed for total work piece depth (54 mm) the process lasts 165 s. For the purposes of simplification, it is considered that the flange maintains circular shape and that there is linear connection between flange diameter and time. Finally, for decreasing regime, VBF has the folowing form:

$F_D=qA=12200-96.9\,t+0.137\,t^2$, N,

where is q=1.8 MPa=const. considering CBF being 12.2 kN and $A_{max}=6806.3$ mm^2.

This dependence is represented in fig. 4 by dashed line. Three steplike lines correspond to truly realized change. By the application of VBF according to scheme 1, which is the closest to the given curve, 23.3 mm depth is obtained. For line 2, depth 25.6 mm is obtained and 26.7 mm for line 3, so that the work piece obtained by that dependence is chosen for comparison with other types of VBF.

Table 2

Ord. num.	Manner of determining q, author and year	q, MPa	F_D, kN
1	$q=\frac{1}{200}(R_M+R_P)$, G. Sachs, 1931. /4/	3.1	21.08
2	$q=0.002\div0.0025(\beta-1)^2R_M$, E. Siebel, 1954. /4/ β=2.2 drawing ratio	1.11-1.388	7.55-9.45
3	E. Siebel, H. Beisswanger, 1955., /4/ $q=0.002\div0.0025\left[(\beta-1)^3+0.5\frac{d}{100\cdot s}\right]R_M$	1.351-1.689	9.2-11.5 F_{Dsr}=10.35
4	B. Zunkler, 1985. /4/ $q=0.0757\frac{\beta^{\frac{2}{n+1}}-1}{\beta^2-1}R_M\cdot n\cdot e^n\left(\frac{ln\,\beta}{n+1}\right)^{n+2}$, n-strain hard. exp.	2.125	14.05
5	L. A. Schofman, 1964., /5/ Empiricaly dependent on the material (steel with <0,5% C)	2-2.5	13.6-17
6	L. A. Schofman, 1964., /5/ $q=0.0056\cdot R_M(\beta-1.1)\frac{D_o}{100\cdot s}$	3.265	22.22
7	L. A. Schofman, 1964., /5/ $F_{D\,min}=0.0045\cdot R_M(\beta-1.1)\left(1-\frac{1}{\beta^2}\right)\frac{D_o^3}{100\cdot s}$	/	25.08
8	E. A. Popov, 1968., /6/ $F_D=0.1\left(1-\frac{18\beta}{\beta-1}\frac{s}{D_o}\right)\beta^2\cdot F_{max}$ $F_{max}=\pi ds(\beta-1)R_M$	/	21.38

For increasing dependence, the shape of VBF according to detailed research conducted in /7/ was applied. Empiric equation is as follows: $F_D = (1.1 \div 1.25) F_{D\,max} \cdot sin\left(\frac{\pi}{2}\frac{h}{h_{max}}\right)$, h being the punch travel (argument) and h_{max} being the maximal work piece depth. For this particular case (according to the medium coefficient value) the following equation is obtained:

F_D=14340 sin(1.667h), N or in function on time

F_D=14340 sin (0.546 t), N

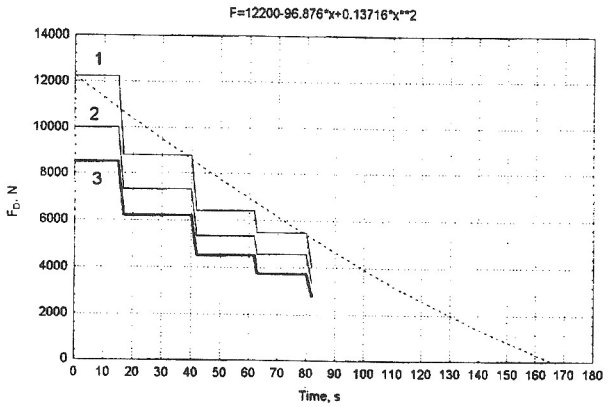


Fig.4 - Decreasing dependence of VBF

Fig. 5 gives the shape of this curve with experimentally realized gradual dependence. The argument of sinus function in the previous equation is obtained in degrees and in fig. 5 in radians.

In determining combined dependence, analytical expression for drawing force obtained by analysis and modifications of classic approach was used as basis /3, 5, 6/. Because of limited space the finished formula will be given:

$$F = \pi d_1 s\left[\left(1.15\frac{K_M}{1-\varphi_M} ln\frac{\sqrt{1+m^2-\rho^2}}{m\cdot\rho} ln\frac{\rho}{m} + \frac{2\mu F_D}{\pi d_1 s}\right) e^{\mu\frac{\pi}{2}} + \frac{R_M}{2\frac{r_M}{s}+1}\right]$$

In the previous formula $d_1=d_o+s$ is medium work piece diameter, $\varphi_M=n$ is maximal value of uniform natural strain, K_M is equivalent stress for φ_M, $m=d_o/D_o=r_o/R_o$ is drawing coefficient, $\rho=D/D_o=R/R_o$ is flange deformation (argument) and r_M is die radius. The obtained shape of curve corresponds to experimental results relatively well. Analytical shape of VBF is obtained in order to perform certain unloading of drawing force F with help of F_D. Horizontal axis of symmetry was set (empirically determined as F_C=28.8 kN) and mentioned curve was copied so that (for this example) equation in function on time (t, s) was obtained:

$$F_D = 2F_C - F = 57600 - 127.67\left[\left(724.65 ln\frac{\sqrt{1.206-z^2}}{0.454\cdot z} ln\frac{z}{0.454} + 19.1\right)1.17 + 39.5\right],\ N$$

$$z = \frac{t}{302.198} + 0.534$$

In fig. 6 the curve is represented by dashed line according to previous dependence, and steplike line shows experimentaly realized VBF.

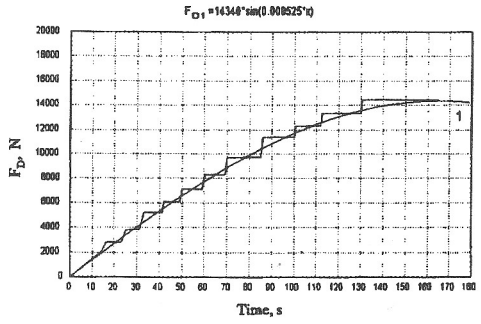


Fig.5 - Increasing dependence of VBF

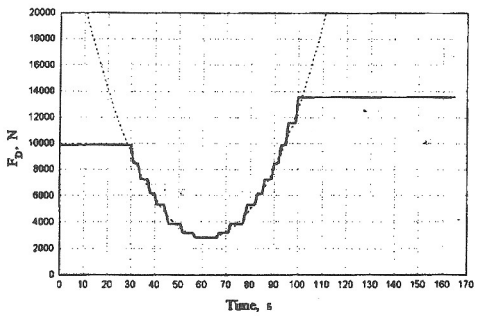


Fig.6 - Combined dependence of VBF

2.2 Results

Figure 7 shows strain distributions (strain paths in FLD) for case of CBF and for all of the three used conditions of contact surfaces. In fig. 8 drawing forces dependence on travel is noted. Curve 1 is at CBF and curves 2, 3 and 4 are at VBF. Curves shapes are ordinary, but the period of the process duration is changed. For case 2 the increase of depth is 27.8 %, in case 3 it is 15.3% and for case 4 it is 10.05% (in relation to case 1) which is one of the indicators of significant positive impact of VBF.

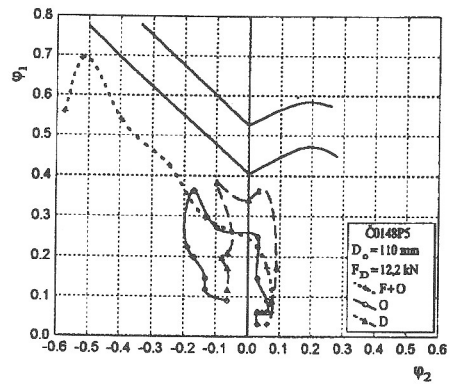


Fig.7 - Strain distributions in FLD

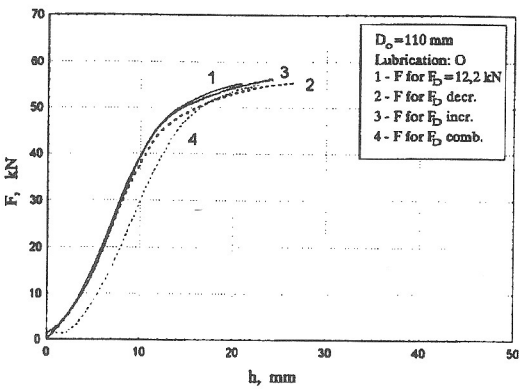


Fig.8 - Drawing forces dependence on travel

Fig. 9 gives comparative survey of strain distributions in coordinate system of main strains in sheet metal plane (FLD). The shape and uniformity of realized knot is the best in case of increasing and combined VBF. It is more obvious in the third main strain distribution diagram (thickness strain, that is thinning) in dependence on the location at the work piece. The most uniform curve, with no particular thinning, was obtained for combined VBF.

Previous results were accompanied with drawing depth and blank-holding force dependence diagram in limit cases of appearance of wrinkles or fracture (fig. 11). This diagram was obtained afterwards, although the knowledge of position of twisted limit wrinkles and fracture before choosing the type of dependence and intensity range of VBF is very usefull.

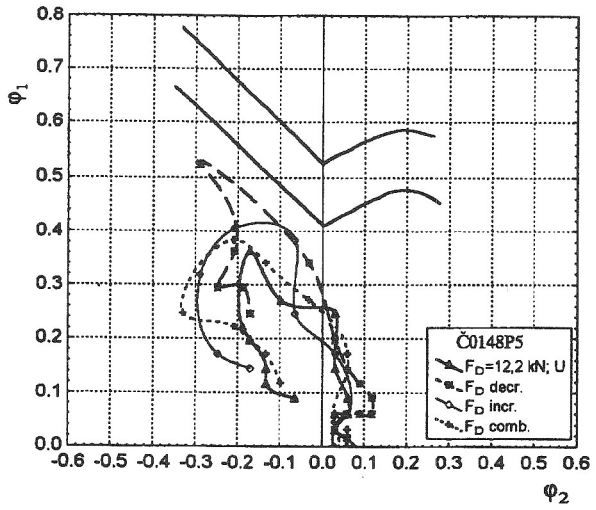


Fig.9 - Strain distributions in FLD

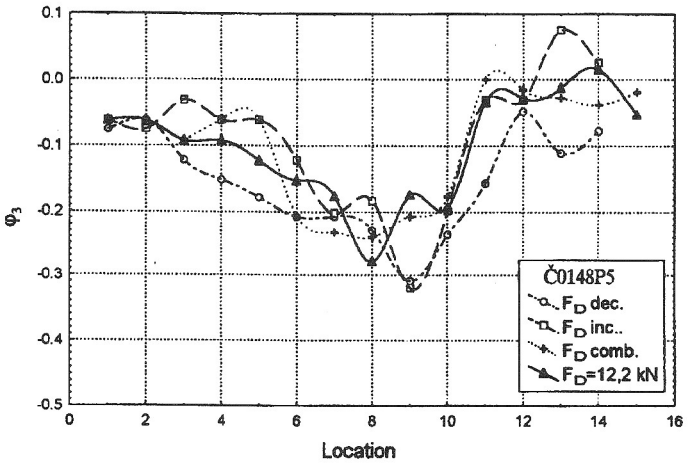


Fig.10 - Distribution of thinning strain

Diagram is determined by series of drawing depth measurements at varying CBF, and in appropriate contact conditions. For each work piece (one point of curve) the measurement ends with finding the location of wrinkles or fracture. The moment of the appearance of wrinkle is determined by instrument with comparator with reading precision 0.01 mm. Criterion for the

appearance of wrinkles adopted in this paper is sheet metal holder displacement in the direction oposite to blank-holding force for 0.05 mm. In different researches (/7/ for example), similar indicator is used. In the mentioned paper the displacement value was 0.1 mm. Here, much more rigorous condition was adopted for the purposes of more effective distinction between the appearance of wrinkles and fractures in the zone where limit lines of these defects are joining.

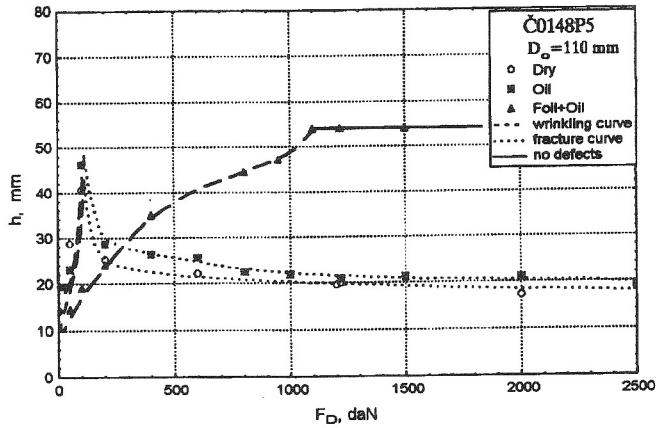


Fig.11 - Limit curves of wrinkling and fracture

3. CONCLUSION

The area of VBF influence in deep drawing of thin sheet metals can be significant for the improvement of technological results of forming and more thorough knowledge of the process itself. Researches are in progres in many world centres as well, but there are no results which would bring to unequivocal conclusions. Besides experiments, which are of main importance, process simulations in big software packages were also included (PAM-STAMP, LS-DYNA 3D, ABAQUS etc /8/).

Results presented in this paper (in reduced form) obtained at Faculty of Mechanical Engineering in Kragujevac, suggest the positive influence of the decreasing blank-holding force on the drawing depth (increase is about 27%) and influence of applied combined dependence of VBF on the strain distribution with depth increase about 10%. Results are preliminary and in the following period different materials, work piece geometries, contact conditions and types of VBF dependence will be considered.

4. REFERENCES

1. Saedy S.A., Maylessi S.A.: An improved manufacturing process in sheet metal forming, 19th IDDRG Biennial Congress, Eger, Hungary, 1996. Proc., 119-130.
2. Aleksandrović S., Stefanović M.: The influence of the blank holding force in deep drawing, Tribology in industry, 20, 2, Faculty of Mech. Eng. Kragujevac, june 1998, 47-52, (in

3. Stefanović M.: Tribology of deep drawing, Faculty of Mech. Eng. Krag., 1994, (in serbian).

4. Zunkler B.: Zur Problematik des Blechhaltedruckes beim Tiefziehen, Blech Rohre Profile 32, 7, 1985., 323-326, (in german).

5. Schofman L.A.: Theory of cold forming processes, Maschinostroenie, Moscow, 1964.

6. Popov E.A.: Fundamentals of theory of sheet metal forming, Maschinostroenie, Moscow, 1968.

7. Katkov N.P., Reschetov V.F. : Determination of optimal conditions of flange holding, Kuzn. Scht. Proizvodstvo, N°9, 1971, 16-18. (/5/, /6/ and /7/ are in russian).

8. Traversin M., Kergen R.: Closed loop control of the blank-holder force in deep drawing: finite element modeling of its effects and advantages, Journal of Mat. Proc. Techn., 50, 1995, 306-317.

9. Stojic M.: Digital systems control, Naucna knjiga, Belgrade, 1989. (in serbian).

UTICAJ PROMENLJIVIH KONTAKTNIH USLOVA NA OBRADIVOST TANKIH LIMOVA DUBOKIM IZVLAČENJEM

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REZIME

Rad daje uporedni prikaz eksperimentalnih rezultata za duboko izvlačenje cilindričnog komada u uslovima konstantne sile držanja sa različitim kontaktnim uslovima (suvo, ulje, polietilenska folija sa uljem) s jedne strane i za izvlačenje sa promenljivom silom držanja i različitim kontaknim uslovima, s druge strane.Promenljiva sila držanja podrazumeva mogućnost programskog zadavanja bilo koje zavisnosti sile od hoda uz pomoć specijalnog uređaja sa DA sistemom. Koristi se klasičan karoserijski čelični lim, a prate se distribucije deformacija j_1, j_2 i j_3 zavisno od lokacije na komadu i u dijagramu granične deformabilnosti, sila izvlačenja, dubina komada i pojava defekata (nabori i razaranje). Primenjuju se tri modela programski zadate sile držanja:opadajući, rastući i kombinovani. Prvi rezultati ukazuju da je promenom sile držanja moguće značajno uticati na uslove trenja na obodu komada, a samim tim i na proces dubokog izvlačenja i karakteristike gotovog komada. Taj uticaj može rezultirati značajnim poboljšanjem tehnologije dubokog izvlačenja tankih limova.

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MODELS OF DEFORMATION IN CONTROLLED FORMING PROCESSES

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ABSTRACT

Differential heating and open die forming processes can be incorporated easily in flexible manufacturing where energy is minimised and material utilisation is maximised. Profiling of a work piece in an open die environment requires tools, which are simple in shape and much smaller than the overall size of the final product. Large plastic deformation is effected by an incremental procedure which is implemented progressively over the entire length of the workpiece. Differential heating is another form of open die processing where the material is heated locally and deformation is effected by free flow. It is shown that the local deformation is greater at areas where the material flow stress was reduced .The investigation explores the use of both techniques in computer integrated manufacture environment. A new computer control open die set up system has been designed and manufactured.

1. INTRODUCTION

Computerisation and flexibility are the essential features for a modern competitive production system. At the present time where forging plants are being obliged to work increasingly smaller batches and to improve the precision of the forging process. Like many other manufacturers, they have to make significant adjustment to achieve shorter production runs, greater flexibility and improved cost effectiveness. Empirical rules, based on intensive experiments on swaging of a long bar exist, and only special purpose machines that employ incremental deformation have been developed [1, 2]. The introduction of robots in forging has been limited to handling the workpiece from the furnace to the press, from one cavity to another or

applied to extrusion [5] and the results showed greater saving in energy. Thermal forming using high energy beam heating has recently been of interest, it provides focused and accurate application of heat [6]. Very recently, it was demonstrated that local heating could be used to produce complex profiles by simple processing [7]. This paper presents a new on-line computer controlled set-up for the manipulation of the workpiece material and to provide accurate interaction between workpiece orientation and the action provided by the tools. Also, it introduces the application of local heating in order to control metal deformation.

2. OPEN DIE FORMING

Open die forging is traditionally associated with large size parts due to the limited size and capacity of forging machines and the high cost of tooling. The characteristics of the process is that only small section of the workpiece is being worked at any one time. The level of deformation is controlled by axial and rotational manipulation of the workpiece between every consecutive compression step. The economic benefits of small batch production, in particular to the forging industry, suggest that a promising line of development could be to couple an automated open die forging process with a flexible on-line process design system as shown in Fig. 1 .

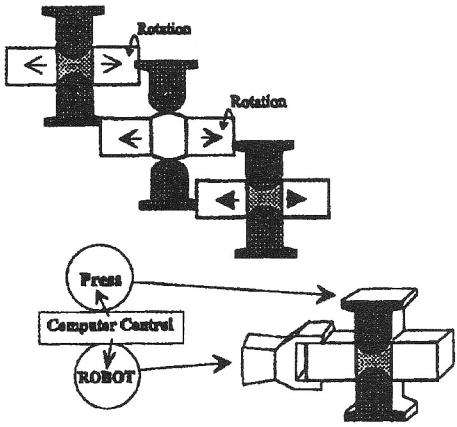


Fig.1 - Incremental deformation system

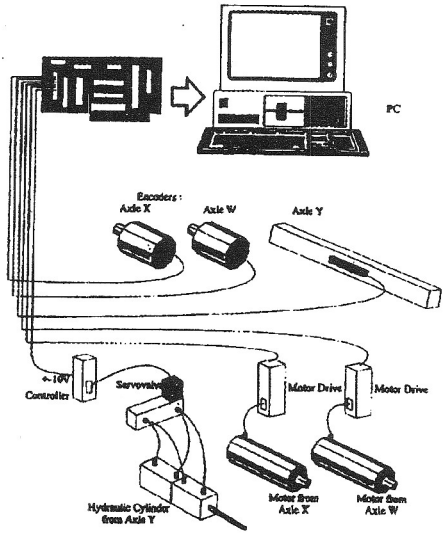


Fig.2 - Workpiece control system

A new hydraulic press has been designed with full computer interface to control press stroke and speed. The hydraulic circuit consists of a double acting cylinder, a servo control mechanism and a directional control valve, which sustains a constant ram speed irrespective of the press load.

The stroke of the ram is measured using a linear encoder. A schematic diagram of the control system is shown in Fig.2 and the workpiece control axes are given in Fig.3. The

positioning tolerance is 10 microns for the axial displacement and 0.15 degrees for rotation. The design includes also a zero weight system to ensure that the workpiece is free from any loading during the positioning process, i.e. rotation or axial displacement.

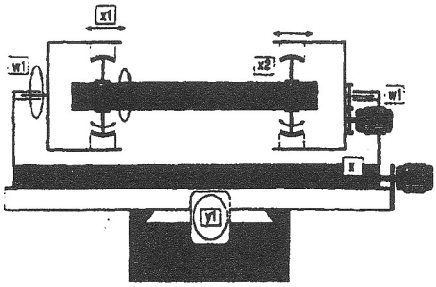


Fig.3 - Workpiece manipulation

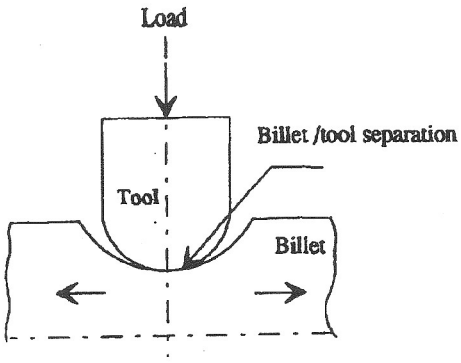


Fig.4 - Semi-cylindical tool

However, when open die forging processes are used there are some fundamental difficulties in planning the sequence of operations, which are necessary to achieve the required shape transformations in a systematic way. Adaptation of the Upper Bound technique was investigated by Osman *et al* [8] and a solution for flat tools was proposed which provides a systematic approach to predict the optimum operating sequence for achieving a desired geometry. The new press design has been used to investigate the deformation mechanism in open die forging when using semi-cylindrical tools as shown in Fig.4. The deformation mode in these processes is characterised by an extension which increases the length of the workpiece and lateral spread in the direction of the width. An example of the spread profile from a semi-cylindrical tool and at different levels of penetration is shown in Fig.5.

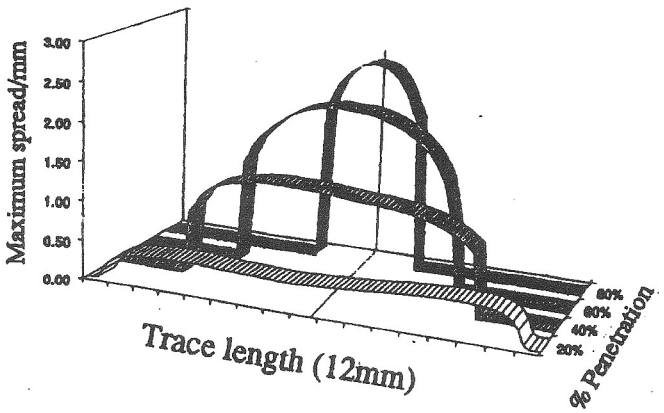


Fig 5. - Billet lateral profile at different penetration

3. DIFFERENTIAL HEATING

Fig.6 shows a schematic diagram of differential heating where a small volume of the workpiece is subjected to intense heat, hence its flow stress will reduce considerably. On the application of load a complex mechanism of deformation will take place forcing lower flow stress material to deform.

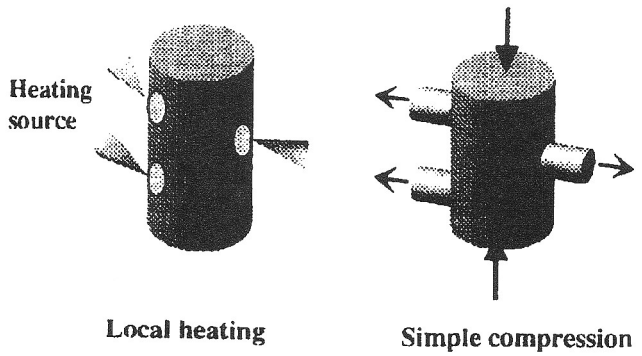


Fig.6 – Idealised local deformation

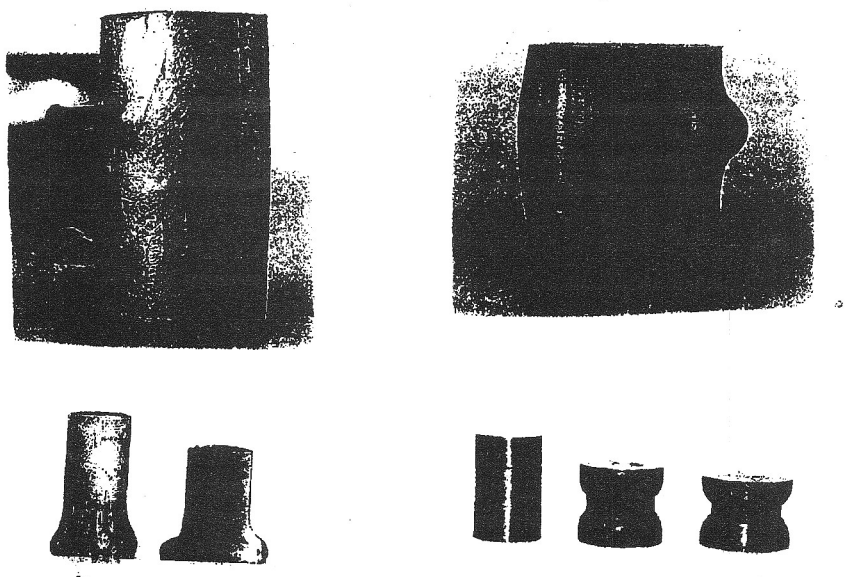


Fig. 7 - Examples of deformation by the differential heating

Several experiments were carried out to demonstrate the effectiveness of differential heating and to study the local mechanism of deformation. Induction heating and flame heating were used in these experiments. Also, compound billets, e.g. steel/aluminium, aluminium/plasticine .... etc. were used to simulate the variation of flow stress within the deforming material. It is important to note that effective processing will depend on achieving the correct temperature gradient through the billet. Fig.7 shows examples of the deformation pattern.

4. CONCLUSIONS

Two processes, open die forging and processing of metals under differential heating were investigated for their potential for the production of complex geometries. Both operations are capable of producing near net shape parts and adaptable to computer integrated manufacture. A new machine, incorporating linear and rotational manipulators, was designed and manufactured for open die processing. It employs simple flat and semi-cylindrical shaped tools. Experiments using differential heating showed the effect of local heating on the mechanism of deformation and demonstrated its use for the production of asymmetrical flow pattern.

5. REFERENCES

1. K. Lange: NC Radial forging - a new concept in flexible automated manufacturing of precision forging in small quantities. Proc. 25th MTDR Conf, 63-72, (1985).
2. M. Wehrheim and R. Kopp: Automated process to produce a near-net-shape workpiece by open die forging. Proc. 4th Int. Conf. Tech. Plasticity, 2, 1102- 1107, (1993).
3. B. W. Rooks, K.0. Okpere and R.M.H Cheng: Asynchronous sequential control of billet handling system for feeding a hot forging machine. The Industrial Robot, 1, 66-71, (1973).
4. E. Appleton, W.B. Heginbotham and M. Kohono: Design study and feasibility trial for a robot blacksmith. Proc. 8th ISIR, Stutgart, (1978).
5. E. Korner, and R. Knodler: Possibility of warm extrusion in combination with cold extrusion. J. of Material Processing Technology, 35, 451 -465, (1992).
6. M. Geiger, and F. Vollertsen: The mechanisms of laser forming. Annals of the CIRP, 42, 301-304, (1993).
7. F. H. Osman and E. Menygold: Use of differential heating in metal forming processes. Proc. 5th ICTP, Ohio, USA, 1, 295-298, (1996).
8. F. H. Osman, B. Aksakal, A. N. Bramley: Computer aided design system for open die forging. Advances in Manufacturing Tech. VII, Bath Univ. Press, UK, 216-221, (1993).

OBLICI DEFORMACIJE KOD KONTROLISANIH PROCESA DEFORMISANJA

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REZIME

Kompjuterizacija i fleksibilnost su među najvažnijim karakteristikama modernih proizvodnih sistema. U novije vreme, proizvodni pogoni su prinuđeni da se prilagođavaju uslovima proizvodnje u malim serijama, što uslovljava suštinsku promenu osnovnih postulata u proizvodnji.

U procesima kovanja zagrevanje se izvodi u cilju snižavanja napona tečenja i poboljšava tečenje materijala. Topla i polutopla obrada primenjuje se i u istiskivanju. Ovaj rad ilustruje novi "on-line" kompjuterizovani sistem za manipulaciju materijala uz obezbeđivanje visokok nivoa tačnosti. Pored toga analiza se i obrada u uslovima lokalnog zagrevanja koje se izvodi u cilju mogućnosti upravljanja deformacijom materijala.

Dva procesa, slobodno kovanje i deformisanje u uslovima diferencijalnog zagrevanja istraživana su sa ciljem da se odredi njihova aplikativnost pri proizvodnji delova kompleksne konfiguracije. Pokazalo se da su oba navedena procesapogodna za tu svrhu.

Konstruisana je i izrađena nova mašina za slobodno kovanje koja je snabdevena ravnim i cilindričnim alatima.

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WORKING SYSTEM CREATION AND MATERIAL FORMABILITY OCCURRENCE

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ABSTRACT

There are many possibilities for working system creation in Technology of Plasticity. The numbers of different working system are given variety chances of using potential possibility of the material to occur formability. In general, formability of the material is depended on state of stresses in the plastic zone. Different working systems offer different realisation of state of stresses. It means that the states of stresses in plastic zone are potential possibilities of the working system. Which one of these will be used is depended on working system creation. The main effected factors on the state of stresses in the plastic zone are: shape and dimension of plastic zone, that is, workpiece geometry, die geometry and tribological factors in the contact surfaces. The changeability of state of stresses during the process of plastic deformation in the plastic zone further complicate the finding of optimal conditions for occurrence of formability. Therefore, the strain history should be taken in consideration. Forming limit curve (FLC), given as a function of effective strain on stress formability index, that is, state of stresses, gives possibility in looking for optimal condition for occurrence of material formability. Relate to these a problem is the definition of number of stage in multistage forming. The scientific bases for design of multy stage forming are the optimal conditions for material formability occurrence. Indicated questions and problems is the subject of consideration in this paper based on the theoretical and experimental investigation for years in Laboratory for Technology of Plasticity, University of Novi Sad.

1. INTRODUCTION

Material formability occurrence is depended on two fundamental groups of influential factors: the material of workpiece and the working conditions (Fig. 1). Workpiece material with its chemical composition and microstructure state makes the part of whole formability only. This part of formability is usually called as plasticity. The consideration of this part of formability belongs to

the material consideration. It is not the subject of study in this paper. The second part of formability is depended on working conditions. The working conditions are determined by the working system. This part of formability is depended on three basic influential factors: shape and dimensions of plastic zone, that is, workpiece geometry, die geometry and tribological factors in the contact surfaces. The working system creation should be based on the optimal creation of state of stresses. However, the problem is that the state of stresses in the plastic zone is changeable during the process of deformation. This problem is solved by strain history consideration and by adequate interpretation in the forming limit diagram. Why the state of stresses in the plastic zone is changeable, Main reason for that is changeable workpiece geometry during the process and constant die geometry. The tribological conditions in the contact surfaces are changeable during process of deformation as well and they effect on the state of stresses. The state of stress in changed as a rule for the worse related to the possibility of material formability occurrence. Besides that, the hardening of the material during cold forming processes is effected on the material formability. The solution of these problems is often found in multy stage forming. By the optimisation of material formability occurrence, the problems of multy stage forming could be solved on the scientific base.

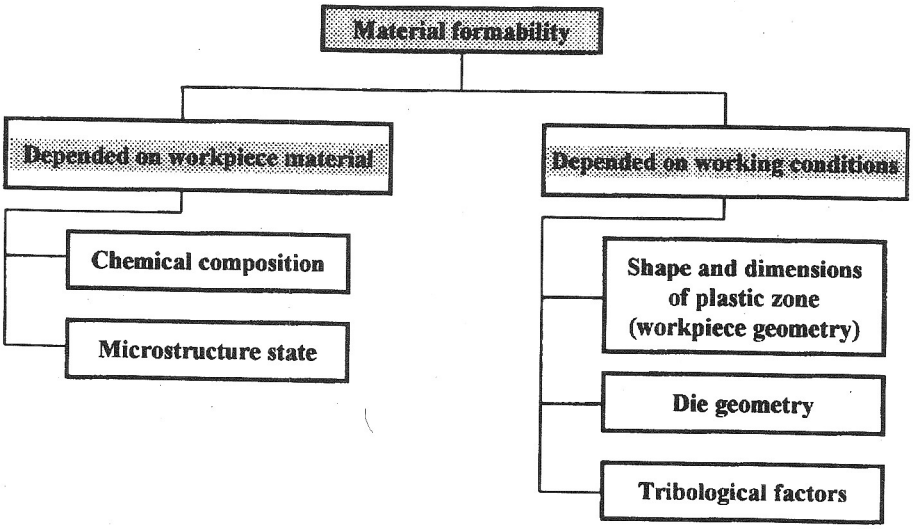


Fig.1 - Material formability and influential factors

2. POTENTIAL POSSIBILITIES OF STRESS SYSTEM

The state of stress in the plastic zone is possible to realise in a number of different ways. Each state of stress is characterised with its possibilities related to the material formability occurrence. If we taken in consideration the number and direction of main normal stress components than according to [4,6] the nine different combination is possible to formulate

(Fig.2). There are two uniaxial- three biaxial- and four triaxial states of stresses. The increase of limiting strain, that is, increase of potential possibilities to occur formability is indicated by arrows in this fig. The given schemes in Fig.2. present qualitative description the possible combination of stress components.

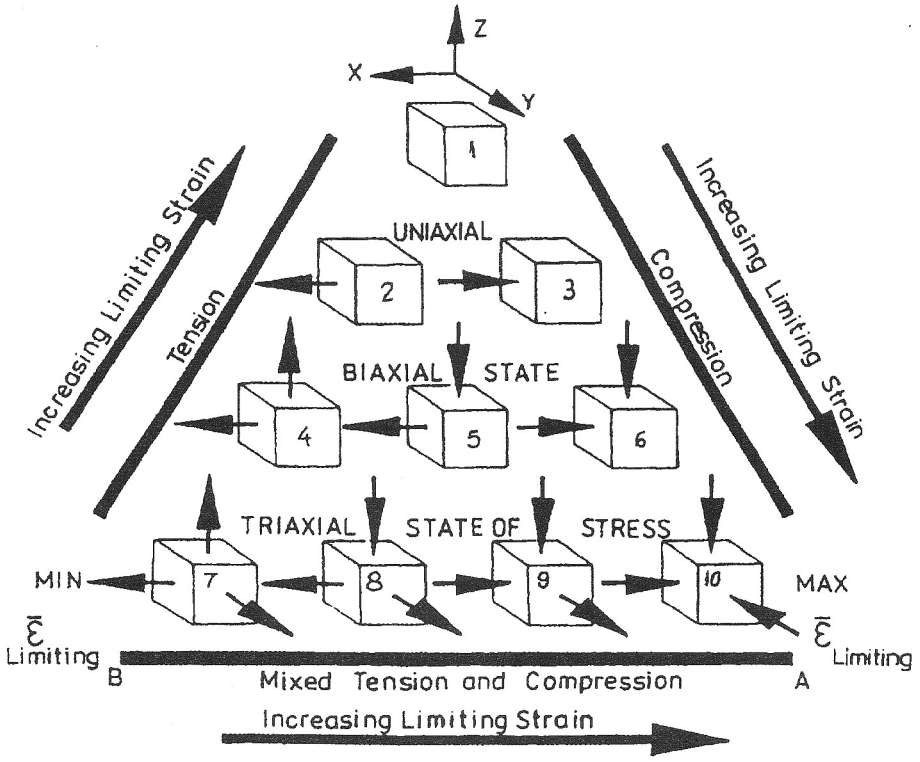


Fig. 2. - The state of stresses formulated on the base of number and direction of normal stress components

But the real possibilities of stress system related to occurrence of material formability is possible to show if we taken in consideration not only the numbers and directions of stress components, but the change of its quantity as well, that is, the change of spherical tensor of state of stresses related to the scheme of strains. So the study of change of stress components should be connected with possible realisation of strain schemes. Such a description is given in the Fig.3. Normal stress components are systematised according to change of spherical stress tensor and in keeping with possible strain schemes. The 31 possible schemes the states of stresses with different potential of material formability occurrence are shown in the Fig.3.

The maximum quantity of positive spherical tensor of stresses is in the first line, that is, in the cases of bulk tensions. This value is decreased up to zero-value in the cases of pure deviator's state of stresses (schemes 4.3., 5.1. and 5.2.) and than spherical stress tensor is got in the negative region in order to obtain the maximum negative values in the cases of bulk compression's. The possibility of certain stress schemes in occurrence of material formability is in the opposite with the increase of spherical stress tensor. The increase of these possibilities is started form the scheme 1.1. (where the possibilities are in the minimum) up to the scheme 7.5 (where the possibilities are in the maximum). In order to create the working system in optimum way, at first should be selected possible optimal stress-strain scheme. In other words, the optimal method of deformation should be selected.

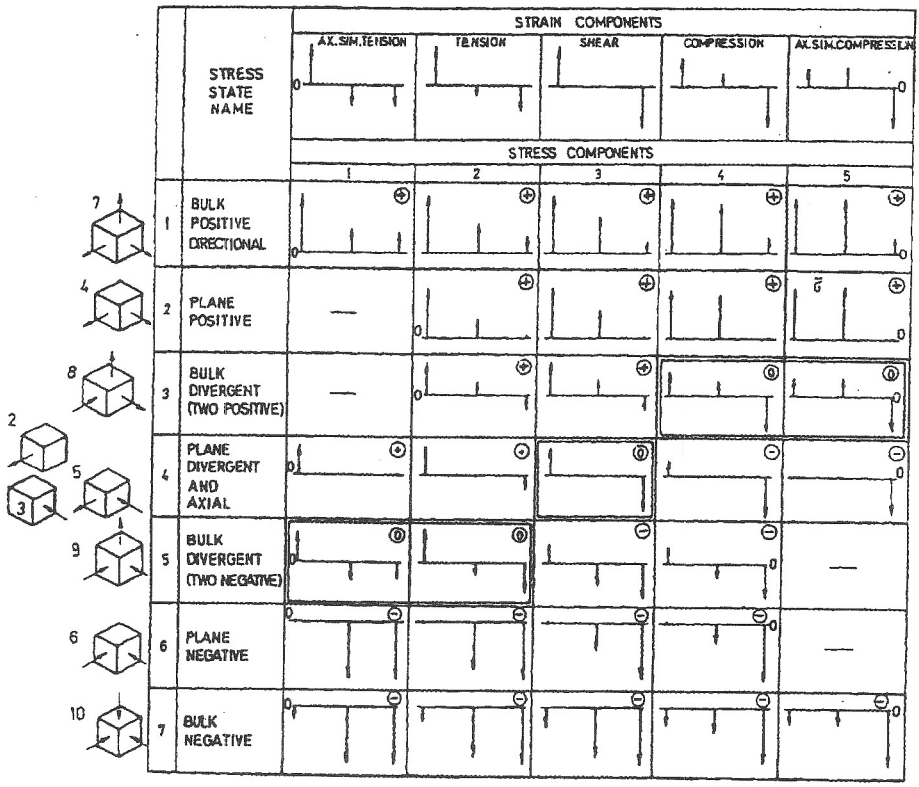


Fig.3. - Stress-strain schemes connected with the changes of spherical tensor of stresses

3. STRESS FORMABILITY INDEX AND FORMING LIMIT CURVE

The search of optimal stress-strain scheme by means of schemes given in fig. 2 and 3 is not possible due to qualitative character of these data and they do not include explicit connection stress components with possible strains in a quantitative form. Hence, the authors [1,4] have been formulated stress formability index as

$$\beta = \frac{\sigma_1 + \sigma_2 + \sigma_3}{\bar{\sigma}} \tag{1}$$

which the spherical tensor of stresses is, but reduced on the unit of effective stress ($\bar{\sigma}$). As it is known the spherical stress tensor is responsible for occurrence of material formability and effective stress is responsible for the beginning of plastic flow. Than, the link stress formability index with effective strain is made possible to formulate limit curve (FCL) in the forming diagram (FLD) in the form

$$\overline{\varepsilon_{limiting}} = f(\beta) = f\left(\frac{\sigma_1 + \sigma_2 + \sigma_3}{\bar{\sigma}}\right) \tag{2}$$

Every point of FLC, that is, every ordinate of this curve, has to be determined by experimental investigation. Therefore, we are developed different deformation models [2,3,4,6], which are shown in the Fig.4. These models of deformation that is different methods of deformation are made possible to obtain different quantity of stress formability index and systematised on the axis of abscissa (Fig. 4.). The deformation models shown in the Fig.4. was the subject of theoretical and experimental investigation for years in the Laboratory for Technology of Plasticity University of Novi Sad. The maximum possible effective strain was calculated for every model on the base of measurement the strains components in different directions. The effective strains for every model are the ordinate of forming limit curve. These ordinates are decreased with the increase of stress formability index.

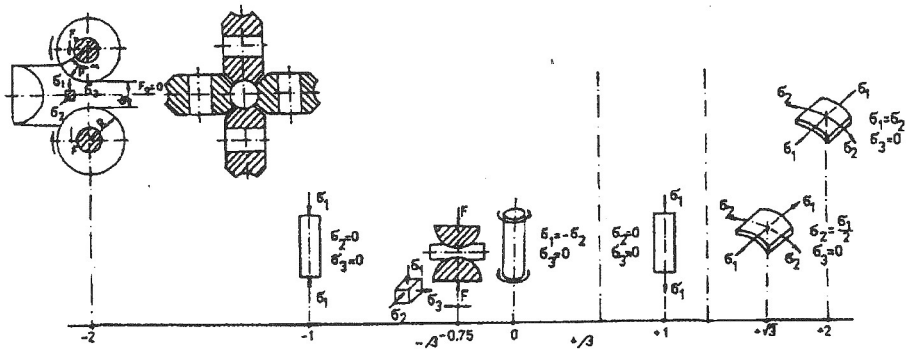


Fig. 4. - Stress formability index and models of deformation

4. FORMING LIMIT CURVE AS A BASE FOR WORKING SYSTEM CREATION

Forming limit curve defined by relation (2) makes possible optimal creation of the working system related to the occurrence of material formability under the condition that the state of stress is kept constant during the process of deformation. Such an opportunity is not often met in the praxis. As a rule, the state of stress is changeable during deformation. In all these cases, the effects of strain history have to be taken in consideration by the formulas:

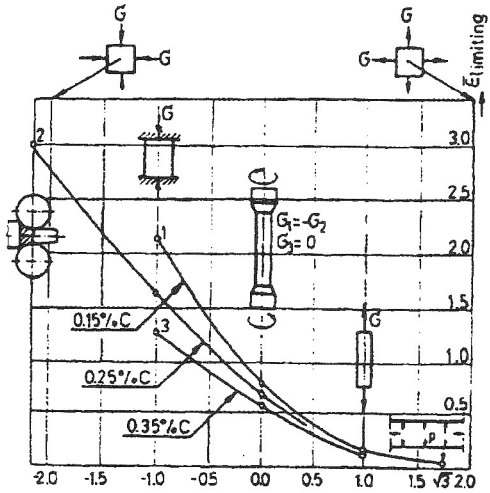
$$\varepsilon = f_1(\beta); \qquad 0 \le \varepsilon \le \varepsilon_{limiting} \tag{3}$$

using

$$\beta_m = \frac{1}{\varepsilon_{limiting}} \int_0^{\varepsilon_{limiting}} \beta(\varepsilon) d\varepsilon \tag{4}$$

The relation $\beta_m = f_2(\varepsilon)$ should be determined by experimental investigation.

Each material (for each chemical composition and for each microstructure state) has own forming limit curve. As an illustration, some forming limit curves are shown in the Fig.5.



β	$\bar{\varepsilon}_{limiting}$		
	0.15%C Steel 1	0.25%C Steel 2	0.35%C Steel 3
- 2.15	-	2.98	-
- 1.00	2.10	1.65	1.28
0.00	0.82	0.72	0.65
1.00	0.16	0.15	0.14
1.73	0.07	-	-

Fig. 5. - Forming limit curves (FLC)

The range of β is: $-2 \le \beta \le 2$. The optimal creation of working system is possible if the influential factors (Fig.1.) are taken in consideration. The ordinates in the FLD are quantitative expression of material formability. Different abscissa points offer different occurrence of

formability. Therefore, the optimal creation of the working system includes two important questions. The selection the optimal abscissa point in the FLD is the first and the keeping constant the state of stress during the process of deformation is the second important question. To give the positive answer on the second question is very difficult due to changeable work piece geometry and constant die geometry. The surface conditions are changeable during the process as well. For the time being the solution is found in intuitive decision about the number of stage in multy stage forming. In this way for the next step the die geometry is changed according to changed shape of workpiece in order to keep the same abscissa point in FLD. Multy stage forming caused the increase of production costs so the solution of the problem is in the better using of material formability by means of optimal creation of the working system. Better use of Material formability means decrease of production costs. If the use of multy stage forming is a necessity than the optimum number of the steps is possible to define by means of FLC, again using the material formability in optimum way. The change of influential factors according to the scheme in Fig.1. helps to find optimal solution.

5. CONCLUSIONS

- Potential possibilities of the stress system is very large in metal forming processes and its influence on the occurrence of material formability is predominance
- The stress system in the plastic zone is created by the working system
- The optimal use of material formability is possible to realised by means of FLC and adequate creation of the working system
- In the creation of the working system the influential factors on the state of stresses are extremely important
- By multy stage forming the optimal number of stage is possible to defined by means of FLC

6. REFERENCES

1. Vujović V., Shabaik A.H.:
A new workability criterion for ductile metals. Journal of Engineering Materials and Technology. ASME, July 1986, Vol.108, pp 245-249.

2. Vilotić D., Shabaik A.H.:
Analysis of upsetting with profiling dies. Transactions of the ASME Journal of Engineering Materials and Technology, October 1985, Vol.105, pp 261-264.

3. Vujović V., Plančak M., Vilotić D., Shabaik A.H.:
The use of cold workability test results to predict FLC as the function of stress state. Proceedings of the 2nd ICTP, Stuttgart 1987, pp 453-459.

4. Vujović V., Plančak M., Vilotić D., Shabaik A.H.:
Forming limit investigation by means of stress formability index. Advanced Technology of Plasticity 1990, Kyoto, Japan, 1990, pp 1305 – 1310.

5. Vujović V., Plančak M., Vilotić D., D., Trbojević I., Francuski P.:
Formability potential of the material in metalforming. Proceedings of the 5th International Conference on Metalforming ICMF 1991, Gyor, Jun 1991, pp M48-M60

6. Vujović V., Vilotić D., Plančak M.:
Die geometry, stress components and material behaviour in cold forging. Proceedings of the 9th International Cold Forging Congress, Solihull UK, May 1995, pp 95 – 101.

KREIRANJE OBRADNOG SISTEMA I OBRADIVOST MATERIJALA

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REZIME

Postoji mnogo različitih mogućnosti za kreiranje obradnih sistema u tehnologiji plastičnosti. Različiti obradni sistemi poseduju različite potencijale obradivosti. Generalno, obradivost matrijala zavisi od naponskog stanja u plastičnoj zoni. Glavni faktori koji utiču na naponsko stanje su: oblik i veličina plastične zone, geometrija obratka, geometrija alata, triboloski faktori u kontaktnom sloju alat-materijal.

Činjenica da se naponsko stanje u toku procesa menja, još više usložnjava ovu problematiku. Istorija deformisanja svakako treba biti uzeta u obzir pri svakom projektovanju redosleda operacija u tehnologiji plastičnosti.

Kriva granične obradivosti, kao grafički izraz zavisnosti efektivne deformacije i naponskog stanja predstavlja polazni podatak za svaki materijal u traženju optimalnih rešenja procesa deformisanja.

Istraživanja ove problematike se već duži niz godina vrše u Laboratoriji za tehnologiju plastičnosti na Fakultetu Tehničkih Nauka Univerziteta u Novom Sadu.

U ovom radu razmatraju se problemi vezani za međuzavisnost između obradnog sistema, obradivosti, krive granične obradivosti i istorije deformisanja.

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ON MUTUAL ROUGHNESS EFFECT OF WORK AND BACK UP ROLLS UNDER SHEET ROLLING

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ABSTRACT

Forms of roughness transfer have been determined in the system roll-roll and roll-stripe under stripe rolling on 4-h and multirolling mills. Experimental results confirming the model are given.

1. INTRODUCTION

Describing the formation of microtopographical strip surface under rolling only surface effect of the work role and strip is usually considered. However, experimental data show that microtopographical surface formation is a more complicated process including both the effect of work roll and rolling metal and the effect work and back roll surfaces. This effect becomes especially obvious when back up roll hardness is commensurable with work roll hardness.

We offer the following of microtopographical surface formation under sheet rolling on 4-h and multi-h rolling mills:

1. microtopographical surface formation in the system work roll – back up roll in the process of resilient-plastic and plastic surface deformation of these rolls;
2. transfer of the microtopography on the metal surface in the process of plastic deformation of sheet surface under rolling.

Theoretical grounds of the model and experimental data confirming the model are being discussed in the paper.

2. WORK ROLL - BACK UP ROLL CONTACT

Changes in microtopographical surface of work roll and sheet under rolling on 4-h and multi-h rolling mills occur both due to the work roll – strip contact and to work and back up roll contact; the roughness of backup rolls primarily influences the roughness changing of work rolls when using back up rolls of increased hardness.

Let's analyze the problem of microtopographical surface transfer of one roll on the surface of the other under different values of interaction forces between them. According to classification in [1], a pair of work roll – back up roll is considered highest kinematics pairs cylinder-cylinder with parallel axis. Rolling load and stress p determine type rolls interaction and the character of microtopographical surface transfer of one roll on the other. It is possible to single out 3 stages work and back up roll surface interaction with the growth of stress.

Phase I is characterized by microscopic deformation when hard microroughness penetrates into milder metal (fig. 1), y-axis transfer is done, however, microroughness deformation take place independently and macrotransfer of metal along x-axis does not take place.

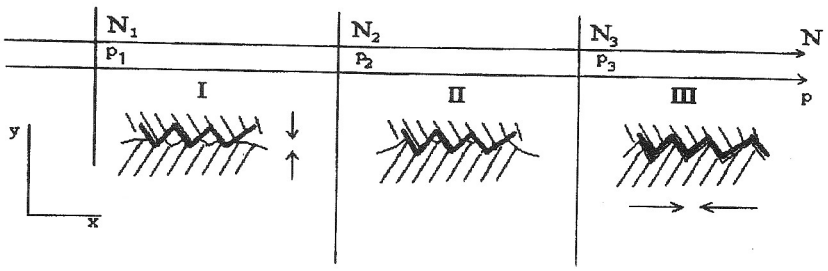


Fig. 1. - Phases of work and back up rolls interaction with p-stress growth in contact zone.

Partial transfer of surface microtopography of one roll on the surface of the other takes place at this phase. Plastic deformation in contact zone takes place if values of p satisfy inequality $p>p_1=2,12(HV)^5(1-\mu^2)^4(tg\theta*E)^{-4}$ or under load on 1 mm roll length

$$N > N_1 = \frac{22,9(HV)^{10}(1-\mu^2)^8 R_1 R_2}{tg^8\theta * E^9 (R_1 + R_2)} \qquad (1)$$

where is:

HV - Vicker's hardness of a milder roll;

tgθ - Tangent of medium angle of microroughness slope towards basic line;

R_1, R_2 – radius of work and back up rolls;

μ - Poisson ratio;

E - elasticity module.

Phase II is also characterized by microscopic deformation, however practically there is no transfer along y-axis, but deformation takes place without interaction of neighboring microroughness. Metal macrotransfer along x-axis is not done. Imprint ratio of microtopography of one surface on the other is close to unity.

Transfer from phase I to phase II takes place under stress of $p>p_2=0,066m^2HV$ or under load on 1 mm roll length

$$N > N_2 = \frac{0,52m^2HV^2 R_1 R_2 (1-\mu^2)}{E(R_1 + R_2)} \qquad (2)$$

where is m - ratio, depending on type of surface treatment ($1.2<m<1,5$).

Stage III is characterized by completing microscopic deformation, metal transfer along x-axis is done under full imprint of surface microtopography of one roll on the other and its "smearing" along direction of metal transfer. This phase takes place under stress of $p>p_3=0.433HV$ or under load on 1 mm roll length

$$N > N_3 = \frac{3{,}14m^2HV^2R_1R_2(1-\mu^2)}{E(R_1+R_2)} \qquad (3)$$

This phase is intolerable.

Formula (1) – (3) are received supposing that ordinates of roughness surface profile correspond to normal distribution and tangent of angle microedges slope is connected with height parameter R_a and step parameter S_m by correlation $tg\theta=4r_a/S_m$.

In the process of rolling hardness of surface roll layer is increased, which moved borders of p_1, p_2 and p_3 to the right (fig. 1) to the area of large values of p. If running of surface layer of work and back up rolls is accompanied by reduction (increase) of medium angle of microedges slope and $tg\theta$, then this process moves the border p_1 to the right (to the left). So, with changes of hardness and surface roughness of rolls in the process of rolling the character of roll interaction will charge. Having differentiated (1) on the length of rolled metal l we get

$$\frac{dN_1}{dl} = N_1\left[\frac{10}{HV}\frac{d}{dl}(HV) - \frac{8}{tg\theta}\frac{d}{dl}(tg\theta)\right] \qquad (4)$$

Value dN_1/dl is determined mainly by relation HV^{10} to $tg^8\theta$; the sign depends on relative of hardness changes of HV and $tg\theta$. Surface layer hardness of rolls in the process of running in may either reduce or increase, i.e. $HV=HV(l)$ and $tg\theta=tg\,\theta(l)$. If $d(HV)/d(tg\theta) > HV(l)/tg\theta(l)$, then contact of rolls' surface in the process of rolling moves to the area of elastic plastic deformation, under which there is no transfer of surface roughness from one roll to the other. If $d(HV)/d(tg\theta) < HV(l)/tg\theta(l)$, then imprint of surface roughness of one roll on the other improves.

3. WORK ROLL – STRIP CONTACT

If is also possible to single out 3 phases at the work roll – strip contact. Phase I, at which plastic deformation of strip microroughness begins, is done under loads in width strip unit

$$N > N_1 = \frac{22{,}9HB^{10}(1-\mu^2)^8R_1}{tg^8\theta * E^9} \qquad (5)$$

where is HB – strip Brinell hardness.

Plastically saturated contact (phase II) is reached under loads

$$N > N_2'' = \frac{0{,}52m^2HB^2R_1(1-\mu^2)}{E} \qquad (6)$$

Metal macrotransfer along x-axis (slip zones in the center of deformation) start at phase III under loads

$$N > N_3'' = \frac{3{,}14m^2HB^2R_1(1-\mu^2)}{E}. \qquad (7)$$

Taking into consideration, that rolled metal hardness is less than rolls' hardness, and also that not only surface layer deformation takes place under rolling but of strip volume, it is probable that phase III is implemented under strip rolling, and possibly phase II is implemented under small pressing.

4. EXPERIMENTAL DATA, CONFIRMING THE MODEL OF SURFACE STRIP MICROTOPOGRAPHICAL FORMATION UNDER ROLLING

Let's make calculation for rolling mill, which was work roll radius R_1=250 mm and back up roll radius R_2=650 mm with hardness HV=600. According formula (1) and (2) and (3) we get N_1 up to 1 kN/mm, N_2=3,3kN/mm, N_3=20 kN/mm. Comparing with force rolling data, given in [2], N=2-6 kN/mm under 1%<ε<2%, we get that roll interaction is implemented under initial plastic deformation of microroughness in real contact area. So, surface roll microtopography will essentially effect the process of deformation in real contact area.

According to data [3] changes of roll hardness achieves 40%, moreover, higher the initial surface roll hardness the less its increase. Tgθ changing, according to our data achieves 50%. So, the rolling process can be accompanied either by transfer of surface work roll microtopography on the back up rolls (if they have less hardness), or from back up rolls on the work rolls if back up rolls with increased hardness are used.

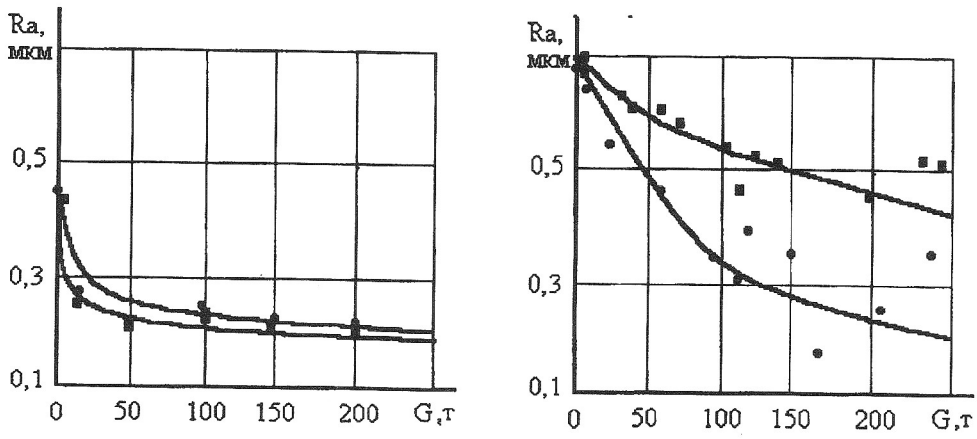


Fig. 2. - Strip surface roughness changing under rolling on 2-h (a) and on 4-h (b) roll mills with 500-mm work roll diameter

Really, if back up rolls have hardness of 200-250 HV less than work rolls then character of changing of work roll roughness is the same under rolling on both 2-h rolling mill and on 4-h rolling mill ($dHV/HV>dtg\theta/tg\theta$). Data get on 2-h and 4-h roll mills with 500-mm work roll diameter are given in fig 2.

Strip roughness changing under rolling on back up rolls with increased hardness (800-900 HV) before and after their rolling is shown in fig 3. Lower gear back up roll is polished and after rolling in of grinding work roll their roughness is changed in accordance with back up rolls roughness ($dHV/HV<dtg\theta/tg\theta$). After rolling of both work and back up rolls (fig 3b) work roll surface roughness is changed identically, a bit increasing in the process of rolling. It can be explained by the fact that initial surface roughness of back up rolls was higher.

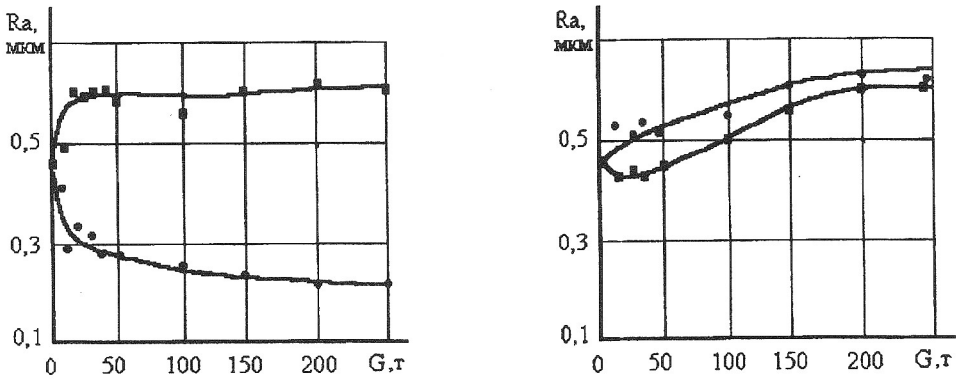


Fig 3. Strip surface roughness changing under rolling before (a) and after (b) back up rolls rolling.

Taking into consideration that hardness under rolling of low carbonaceous sheet does not exceed 70-80 HB get $N_1'=10^{-4}$N/mm; $N_2'=0,2$ kN/mm; $N_3=0,5$kN/mm. Comparing with rolling loading we get, that phase II is implemented even under rolling and phase II can be implemented only under small pressing ($\varepsilon<1\%$). Almost complete transfer of work roll roughness on the strip surface should be observed at this phase. Really as it was stated by many authors, e.g. [4] imprint ratio under rolling is close to unity already under $\varepsilon>2\%$.

5. CONCLUSION

Problems of formation of surface microtopography of rolls and rolled strip under rolling have been analyzed in the paper. It is shown theoretically and it is confirmed experimentally that formation of work roll surface microgeometry takes place in work roll – back up roll contact under rolling on 4-h and multi-h mills with back up rolls with increased hardness. Work roll roughness under rolling is transferred on strip surface under its "smear" along rolling direction.

6. REFERENCES

1. I. Kragelsky, N. Michin: Machine friction knots. Reference book. -Moscow. Mashinostroenie. 1984.

2. A. Tretyakov, E. Tretyakov, G. Mgachova: Rolling and quality of thin sheet. –Moscow. Metallurgia. 1977.

3. Strength of rolling rolls. /P. Poluchin, V. Nikolaev, V. Poluchin, N. Tolpeeva. –Alma-Ata. Nauka. 1984.

4. V. Mazur. Production of high quality surface sheets. –Kiev. Technika. 1982.

ZAJEDNIČKI EFEKAT HRAPAVOSTI RADNIH I PODPORNIH VALJAKA

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REZIME

Kada se analizira stvaranje mikrotopografije površine lima najčešće se u obzir uzima samo uticaj kontakta između radnih valjaka i lima. Međutim, eksperimentalni podaci pokazuju da je mikrotopografija fenomen znatno složeniji i da na nju utiču kako radni tako i podporni valjci. Naime, hrapavost podpornih valjaka utiče i na hrapavost radnih valjaka, a na taj način i na hrapavost lima. U radu je data analiza različitih faza interakcije između radnih i potpornih valjaka u zavisnosti od porasta pritiska u kontaktnoj zoni.

Problem postojanja mikrotopografije površine valjaka i valjane trake analiziran je u ovom radu teoretski i eksperimentalno. Teoretski je određeno, a eksperimentalno potvrđeno da i u kontaktu radni valjci-potporni valjci dolazi do stvaranja promene mikrotopografije. Hrapavost radnih valjaka preslikava se na valjanu traku u pravcu valjanja.

Eksperimentalna istraživanja su vršena sa radnim valjcima prečnika R=250mm i potpornim valjcima prečnika R=650mm, tvrdoće HV=600.

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INVERTED EXTRUSION – AN UPPER BOUND APPROACH

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ABSTRACT

The Upper Bound solution of inverted extrusion of aluminium is presented in this paper. The main process parameters have been obtained. The influence of the geometry of the specimen and friction on the total load and on the each load component has been investigated and analysed. Relevant conclusion for the future work in this field has been made.

1. UPPER BOUND ANALYSIS

In the process of inverted extrusion a cylindrical billet is placed in to the chamber and pressed by a punch which contains a central circular hole. This type of extrusion involves symmetric flow about an axis. Inverted extrusion has been investigated by a number of authors [1], [2], [3]. [4]....In this paper Upper Bound method has been applied in order to determine the main process parameters.

In order to perform the Upper Bound analysis of the inverted extrusion, the whole volume of deformation was divided into 3 regions with uniform velocity fields. In Fig.1 process of inverted extrusion is shown with all necessary geometrical data. Workpiece is divided into regions 1, 2 and 3. Associate velocities in every region are:

Region 1

Axial velocity

$$v_z = -\frac{v_0}{H} z$$

Radial velocity

$$v_r = -\frac{v_0}{2H}\left(r - \frac{R_1^2}{r}\right)$$

Region 2

Axial velocity

$$v_z = \frac{R_1^2 - R_0^2}{HR_0^2} v_0 z$$

Radial velocity

$$v_r = -\frac{R_1^2 - R_0^2}{HR_0^2} v_0 \frac{r}{2}$$

Region 3

Axial velocity

$$v_z = \frac{R_1^2 - R_0^2}{R_0^2} v_0$$

Radial velocity

$$v_r = 0$$

Surfaces of friction (A_1, A_2, A_3, A_4, A_5) and surfaces of velocity discontinuities are shown in Fig. 1.

Based on assumed velocity field and by applying standard Upper Bound routine the total power of the process can be obtained as:

$$\dot{W}_{tot} = \dot{W}_i + \dot{W}_s + \dot{W}_f = \dot{W}_i = \frac{2}{\sqrt{3}} k \int_V \sqrt{\frac{1}{2} \dot{\varepsilon}_{ij} \dot{\varepsilon}_{ij}}\, dV + \int_{A_s} \tau_s |\Delta v|\, dA_s + \int_{A_f} \tau_f |\Delta v|\, dA_f$$

$$\dot{W}_{tot} = f(D_0, D_1, H, \mu, k, v_0) \tag{1}$$

where are:

$\dot{W}_i$ – internal power of deformation

$\dot{W}_s$ – power at the surfaces of velocity discontinuities

$\dot{W}_f$ – power due to friction losses

Total average punch pressure is:

$$p = \frac{F}{A} = \frac{\dot{W}_{tot}}{v_0 A} = \frac{4\dot{W}_{tot}}{v_0 \left(D_1^2 - D_0^2\right)\pi} = p_{i1} + p_{i2} + p_{s1} + p_{s2} + p_{f1} + p_{f2} + p_{f3} + p_{f4} + p_{f5} \tag{2}$$

where are:

p_{i1}-pressure due to internal power of deformation in region 1
p_{i2}- pressure due to internal power of deformation in region 2
p_{s1}- pressure due to power at the surface A_6 of velocity discontinuity
p_{s2}- pressure due to power at the surface A_7 of velocity discontinuity
p_{f1}- pressure due to power of friction losses at surface A_1
p_{f2}- pressure due to power of friction losses at surface A_2
p_{f3}- pressure due to power of friction losses at surface A_3
p_{f4}- pressure due to power of friction losses at surface A_4
p_{f5}- pressure due to power of friction losses at surface A_5

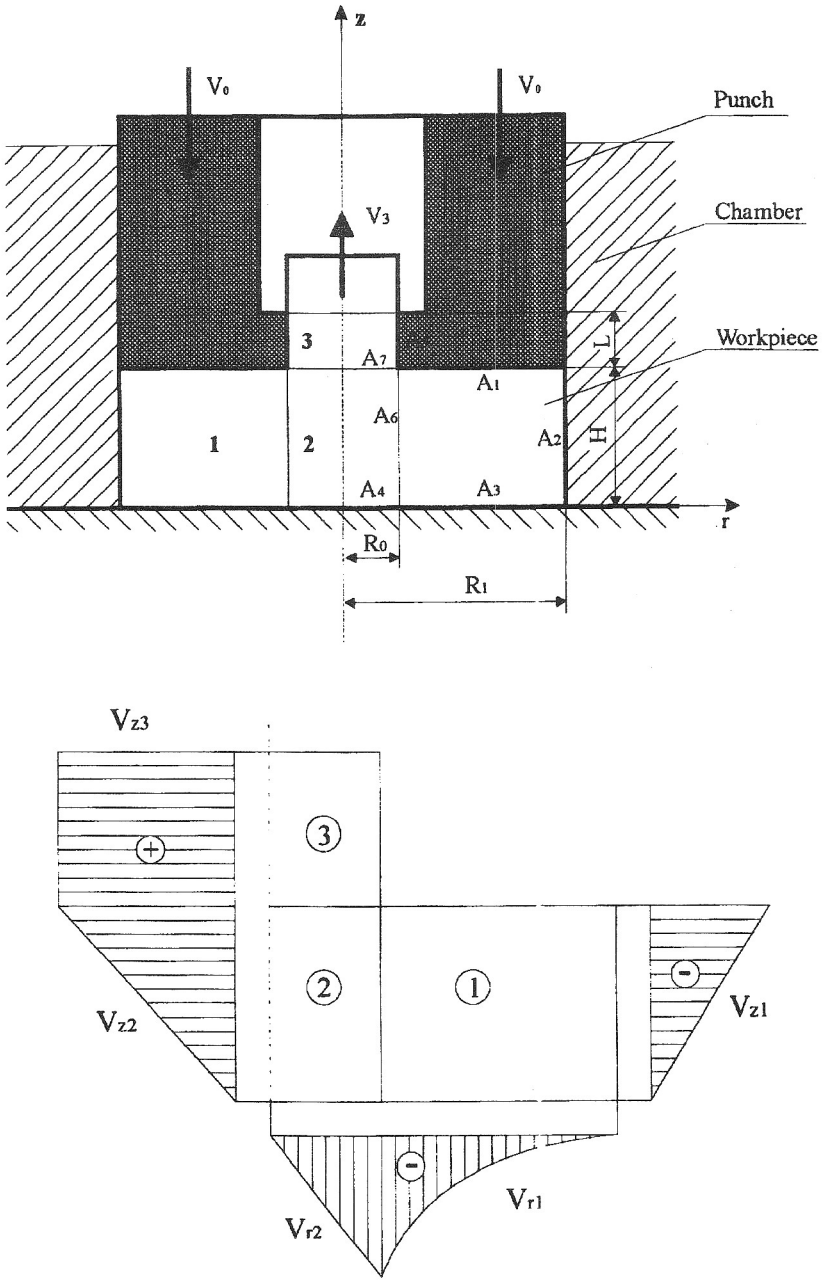


Fig 1 – Deforming region and velocity field

2. ANALYSIS OF THE INFLUENTIAL PARAMETERS

The influence of the three different parameters on total pressure and pressure components have been analysed:

a) D_0/D_1 ratio (D_0 – opening diameter, D_1 - billet diameter, Fig 1)
b) H_0/D_1 ratio (H_0 – initial height)
c) coefficient of friction μ

2.1 D_0/D_1 ratio

In order to investigate the influence of the D_0/D_1 ratio on the total relative pressure and pressure components this ratio has been varied between 0.1-0.9. Billet diameter was 28mm, coefficient of friction 0.1 at initial height of the billet 20mm. The analysis has been carried out for the deformation increment when H=10mm.

The variation of real total relative pressure, nominal total relative pressure as well as pressure components with respect to the D_0/D_1 ratio are given in Fig.2 (real total pressure occurs at the surface A_1 whereas nominal total pressure occurs at the bottom surface of the tool).

As it can be seen from Fig.2 , the D_0/D_1-p/k curve exhibits one turning point (minimum) at D_0/D_1=0.64 whereas the pressure components show different behaviour in respect to D_0/D_1 ratio:

- p_{i1}/k, p_{f1}/k, p_{f3}/k, p_{f5}/k decrease with increase of D_0/D_1
- p_{i2}/k keeps constant during deformation
- p_{s1}/k changes in the same way as curve p/k (it exhibits a minimum)
- p_{s2}/k, p_{f2}/k, p_{f4}/k increase with increase of D_0/D_1

The pressure components p_{s2}/k, p_{f1}/k, p_{f2}/k, pf3/k have very small influence on the total pressure and therefore they are not shown in Fig. 2.

2.2 H_0/D_1 ratio

This part of analysis was made for:

- μ=0.13
- $H=H_0$=20mm (initial height)
- D_0=9mm
- D_1=28mm

In Fig. 3 the total relative pressure versus H_0/D_1 ratio is presented as well as some of the most significant pressure components. The component p_{s1}/k is significantly influenced by H_0/D_1 whereas other components are either constant or insignificantly influenced by H_0/D_1 ratio. As result of this, total pressure also increases with increase of H_0/D_1 ratio, as it is shown in Fig. 3.

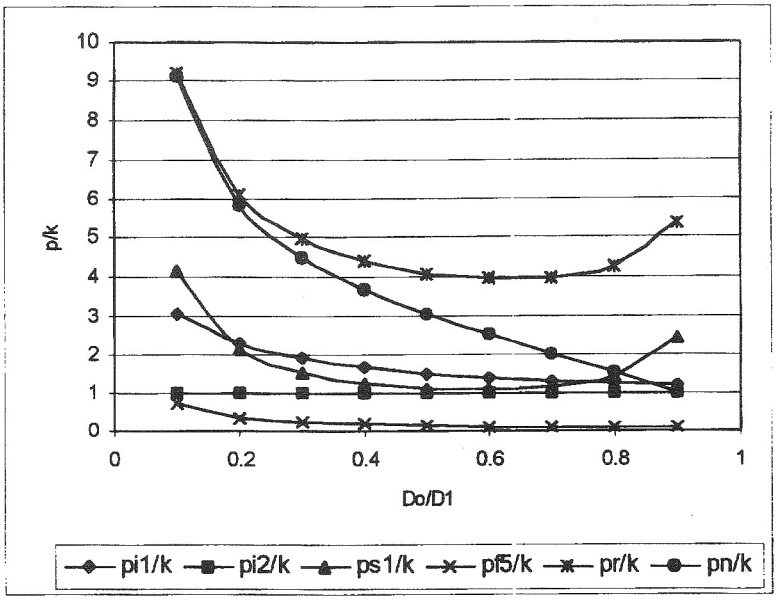


Fig.2 - Change of p_r/k and its components and p_n/k as a function of D_0/D_1 ratio

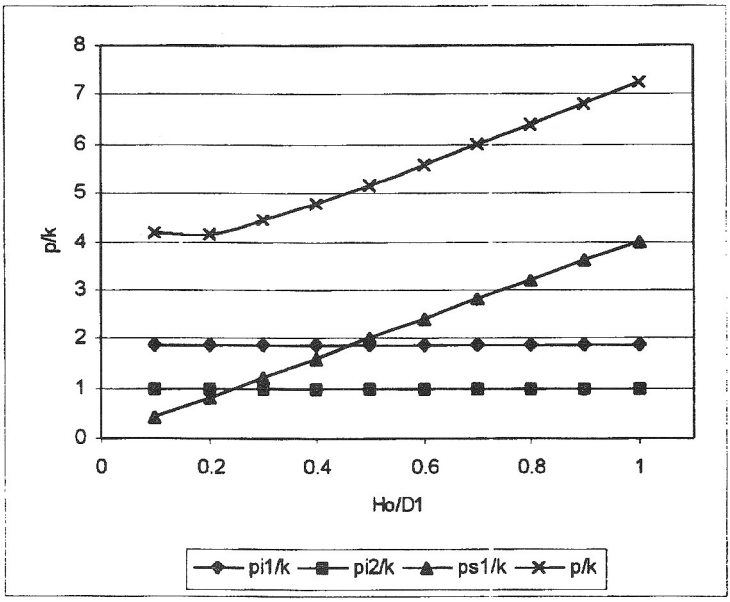


Fig. 3 - p/k and its components versus H_0/D_1 diagram

2.3 Coefficient of friction μ

Influence of friction on the total pressure and some of the pressure components is presented in Fig. 4. This analysis was made for: D_0=9mm, D_1=28mm, H_0=20mm, H=10mm. In the range of μ = 0.05-0.15 the rise of total pressure is approximately 9%.

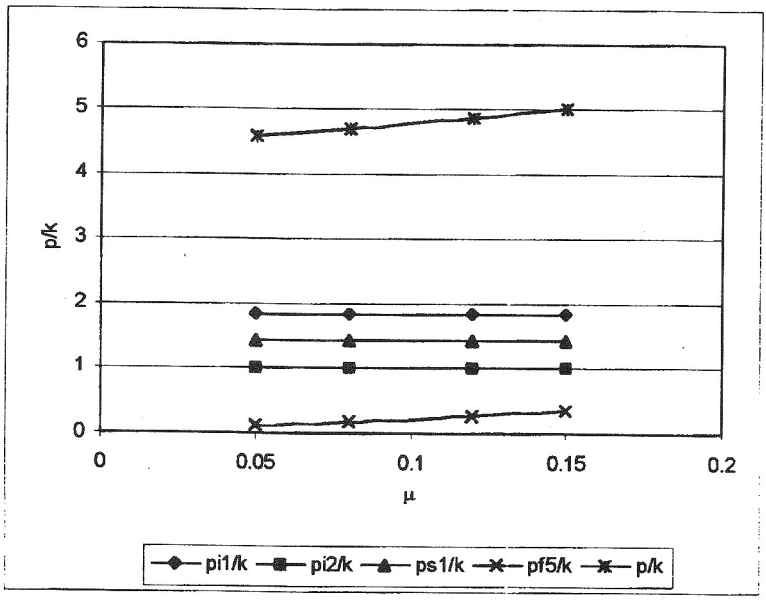


Fig. 4 - p/k and its components versus μ diagram

3. CONCLUSION

The process of inverted extrusion has been analysed theoretically. The method of analysis was Upper Bound. By applying the classical Upper Bound procedure, total load/pressure as well as the load/pressure components were determined.

The most significant influencing factors on the total load/pressure have been analysed. These factors are: reduction, height to diameter ratio and coefficient of friction. As far as reduction ratio is concerned the minimum of load/pressure has been detected for D_0/D_1=0.64. The height of billet (H_0/D_1) and coefficient of friction (μ) influence the pressure in the similar way: by increasing of H_0/D_1 and μ the total pressure increases too.

Obtained results have to be confirmed by experimental or/and by other methods. Special attention should be paid to the investigation of, so cold, minimal depth of deformation.

4. LITERATURE

1. Avitzur B:
   Metal Forming: Processes and Analysis, McGraw-Hill, New York 1968.
2. Plancak M., Francuski P.:
   Analiza kombinovanog procesa sabijanja-istiskivanja, Zbornik radova Instituta za proizvodno mašinstvo, Novi Sad, 1991. pp 89-101
3. Kudo H.:
   Some analytical and experimental studies of axi-simetric cold forging and extrusion–I, Int. J.Mech.Sci. Pergamon Press Ltd., 1960. Vol. 2, pp 102-127
4. Mielnik:
   Metalworking-Science and Engineering, McGraw-Hill Inc., New York 1991.
5. Newnham J. A., Rowe G.W.:
   An analysis of compound flow of metal in a simple extrusion/forging process, Journal of the Institute of metals, 1973., Vol. 101, pp.1-9
6. Brayden L., Monaghan J.:
   An analysis of closed-die extrusion/forging, Journal of Materials Processing Technology, 26(1991), pp.141-157
7. Vickery J., Monaghan J.:
   An upper-bound analysis of a forging-extrusion process, Journal of Materials Processing Technology 55 (1995), pp. 103-110

PRILOG ISTRAŽIVANJU SUPROTNOSMERNOG HLADNOG ISTISKIVANJA PUNIH OBRADAKA

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REZIME

U radu je data teoretska analiza procesa suprotnosmernog istiskivanja punih obradaka. Analiza je sprovedena metodom gornje granice. Ukupna zapremina tela podeljena je na tri regiona sa uniformnim brzinskim poljem. Koristeći definisano brzinsko polje, pomoću standardne procedure metode gornje granice, određena je ukupna deformaciona sila kao i pritisak na donjem delu alata i na aktivnom elementu – žigu.

Analizirani su i uticaji sledećih faktora procesa na gore navedene veličine:

- *odnos D_0/D_1 (D_0 prečnik otvora u žigu; D_1 – prečnik pripremka)*
- *odnos H_0/D_1 (H_0 početna visina pripremka)*
- *koeficijent trenja μ*

Zaključeno je da u dijagramu p/k-H_0/D_1 postoji minimum.

Sa povećanjem početne visine pripremka raste i velčina pritiska na dno alata kao i na čelo žiga.

Porast koeficijenta trenja takođe utiče na povećanje gore navedenih velićina.

U daljem radu na ovoj problematici predviđena je primena i drugih metoda u analizi kao i eksperimentalna verifikacija procesa.

Posebno razvijenom metodom planira se i određivanje naponsko-deformacionog stanja po zapremini obratka.

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ESTABLISHING CORRELATION BETWEEN THE GRAIN MICRODEFORMATION AND THE OBJECT MACRODEFORMATION

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ABSTRACT

The problem-solving of the stress/strain analysis in the plastic deforming processes can be carried out in many ways. Almost all the methods can be reduced to an analysis of the theoretical and experimental results, obtained by some mathematical model as well as by experimental testing of the plastic deforming process. The ultimate goal is to get to know stress distribution, deformations, deformation velocity and likewise within the volume of the material that is being plastically deformed. The aim of this paper is the determination of the above given parameters themselves by tracing the grain structure microdeformation at the volume deforming.

1. INTRODUCTION

The basic idea of this paper is based upon the well-known visioplasticity method given a new approach. It is known that this method, in its experimental part, requires physical separation of the workpiece and placing the coordinate networks for following degrees of deformation. The separation itself disrupts the continuity of the workpiece material volume in the vicinity of the meridian section at which the deformation is being followed. On the other hand, the procedure of placing the measuring network and reading of characteristic displacements has many limitations that finally give rise to an error in the results. Almost never does it seem possible to place a coordinate network with such a small basic cell that all the displacements are recorded properly. Parts of the volume where there is a distinct change of the material flow direction (deformation focus) condition a completely irregular shape of the basic cell so that the analysis results become useless. This especially becomes prominent at the plastic deforming analysis of the tools with complex cuts where the material has irregular paths while fulfilling the mold hollow. Similarly, the very process of displacement readings has an immanent error that later gives the analysis results with a smaller or bigger error.

In order to avoid all these shortcomings, the starting assumption is that the very structure of the material being deformed can be used for an analysis. Namely, the metal grain structure, though of very irregular shape, gets deformed under the impact of the deforming force and of the tool walls; consequently, it obtains an oriented structure - deformation texture. This points to the fact that the grains of the given metal sample being deformed also undergo a deformation proportionate to the external load conditions. Moreover, on the basis of the parameters of the grain material structure at the cross-section before and after deformation the data about magnitude and degree of the deformation can be obtained at the cross-section points of the deformed volume.

2. EXPERIMENTAL DEFORMING CONDITIONS

In order to illustrate this method, the chosen procedure is uni-direction extrusion at axisymmetrical stress state whole equilibrium equations are as follows:

$$\frac{\partial \sigma_r}{\partial r}+\frac{\partial \tau_{zr}}{\partial z}+\frac{\sigma_r-\sigma_\theta}{r}=0 \qquad \frac{\partial \tau_{zr}}{\partial r}+\frac{\partial \sigma_z}{\partial z}+\frac{\tau_{zr}}{r}=0 \tag{1}$$

This is a pseudo-stationary deforming process that can be said to take place at constant tool velocity. The necessary assumption is that the process is stationary, namely, the recognition that at one point of the deformed volume there are no changes of kinematics and stress parameters during the process [6,10]. In other words, at some particular point of the deformable volume there is one single deformation and stress state; what is being looked for is a consequence or manifestation of this state through component displacements in the meridian planes (θ = const.), so that it can be physically described. Likewise, it can be stated that for this level of research, the upper tool part has constant deformation velocity [7,11] during the process. This fact alleviates further analysis since relative velocity at any point of the meridian section exclusively depends upon the given point's displacement in the axial and radial direction, unlike time (v = ds / dt, t = const.). The determination of these displacements and deformation velocities, at the level of the grain structure and due to the plastic deforming, is done on the basis of the structure picture at the already-defined measurement places at the meridian section of the extruded workpiece. These statements are assumptions for solving the upper system of equations as well as for obtaining axial stress gradient in the process of extruding metal in the planes z = const. [5,10,11]:

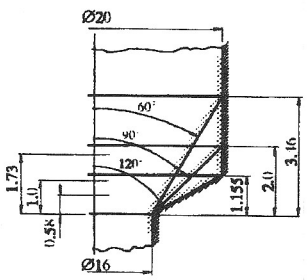


Fig.1 Deformation focus geometry

$$\frac{\partial \sigma_z}{\partial r}=\frac{2}{3}\sigma_i\left|\frac{\partial}{\partial r}\left(\frac{\dot{\varepsilon}_z-\dot{\varepsilon}_r}{\dot{\varepsilon}}\right)-\frac{\dot{\varepsilon}_r-\dot{\varepsilon}_\theta}{r\cdot\dot{\varepsilon}}-\frac{1}{2}\frac{\partial}{\partial z}\left(\frac{\dot{\gamma}_{zr}}{\dot{\varepsilon}}\right)\right| \tag{2}$$

The matrices' angle is located within the range of 60° (fig.1.). The choice and defining of the measurement places at the cross-section of the extruded and deformed workpiece must satisfy several criteria. Since it is an axisymmetrical stress and deformation state [6,14], it is sufficient, for observing and following deformations, to remain in the midst of the meridian section (fig.2.). At this cross-section, the part chosen for a deformation state analysis is a transitory conical one as well as a part of the meridian section immediately above the conical part at the receiver (fig.2). In order to cover the overall given surface, the measurement places with the z coordinate constant are chosen along the workpiece axis. Since dealing with very small dimensions, at the very deformation focus there are three different levels, the input section, the deformation focus center and the output section (fig.2). Immediately above the deformation focus, at the receiver, three more levels are formed with the z coordinate constant at the distance 1,5 mm. In the radial direction - in order to cover the above-mentioned surface - five measurement places with mutually different distances in the deformation focus and constant distances in the material receiver are chosen [10,11].

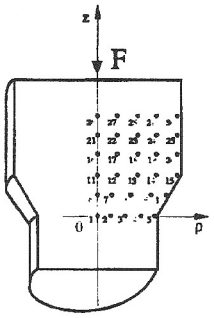


Fig.2 Recording places

3. MICRODEFORMATION AT THE GRAIN LEVEL

Following and analyzing of deformations in the grain structure can be carried out by traditional metalographic procedures, by comparing the structures of the prepared samples (polishing and chemical etching) by means of calibration defined by the Standards (ASTM) or by direct measurement through the microscope spider lines.

For the problem to be solved at all, the mentioned procedures and the grain deformation following do not give much hope. First of all, the number of measurement to be performed in order to obtain reliable results would not by any means justify the method. Further, the measurement itself and the choice of characteristic size of the grain structure that would serve as the basis for making conclusions about the deformation magnitude and kind are limited by the quality and capabilities of the available equipment. The complexity of the problem itself springs from the fact that the objects dealt with are of irregular and diverse shapes both in the space and in the section plane [2,15,16]. Due to these irregularities, no conclusion can be derived by measuring individual samples. The method requires a great number of objects, that is, measurement of a great amount of grains at the cross-section of the deformed sample. Likewise, since the grain structure represents tiny objects to be measured - order of their size being a hundredth part of a millimeter - such measurement places at the cross-section of the deformed sample have to be much more numerous, in this case 30, in order to have an insight into degree of deformation throughout the material volume.

In order to solve the presented problem in the best possible way, that is, to obtain results as accurate as possible, the software solution of the Media Cybernetics Company has been adopted. Their program package ImageProPlus 2.0 offers a possibility for a comprehensive picture analysis. It assumes, first of all, recognition of details and characteristic shapes against the given criteria in the picture, a geometric analysis of the shape in the picture, analyses

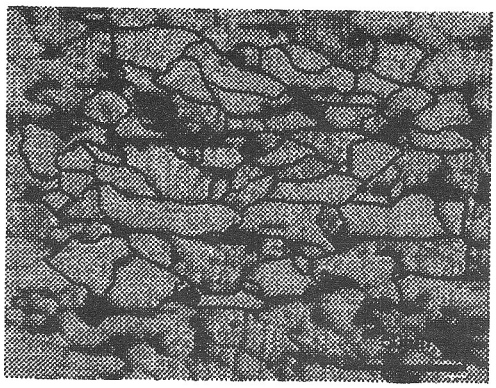


Fig.3 Matrix with an angle of 120°, Recording place 11

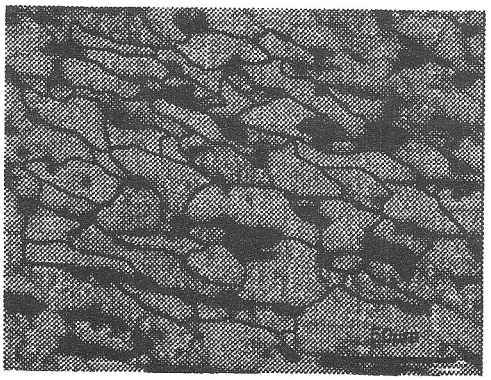


Fig.4 Matrix with an angle of 120°, Recording place 13

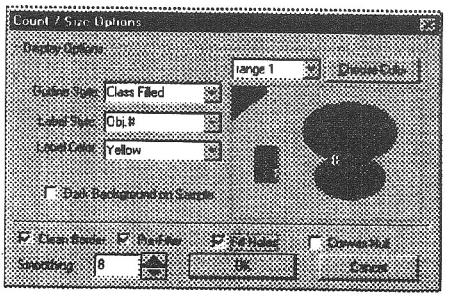


Fig.5 Parameters for oject recognition

regarding color, illumination, contrast and so on. As a result of these analysis, the data about the picture are obtained that can be completely statistically processed; they can serve as the basis for deriving the required conclusions [15].

For an analysis of the metal grain structure the input information is a picture of that structure at the selected place of recording the sample (Fig. 3, Fig. 4). It is obtained by means of a light microscope and transmitted to the computer by the electronic CCD camera. In the picture, thus obtained, it is easy to distinguish lighter fields of ferrite structure as well as darker fields of pearlite (Fig. 3 Fig. 4). The transition between these fields in the picture represents a borderline of the grain structure.

The software recognition of the borderline between the grains represents an important step in the formation of the picture that will later be analyzed. In the obtained pictures of the grain structure there are great irregularities in shape, size and grain area so that the process of the grain separation is primarily conducted with respect to parts of the grain borderlines that are already clearly distinguished in the picture and in the previously made structure pictures [13,15] Thus, the picture of the sample structure at the chosen recording place is obtained and can be analyzed according to the given pre-determined criteria.

Since the pictures of the grain structure can be considerably complex with great irregularities, the criteria must be defined against which the object recognition will be carried out. For these reasons, the program is equipped with a whole set of auxiliary functions (fig.5) that offer a possibility of adjusting the recognition procedure to the concrete sample (removal of border objects, filling of dark fields if emerging within the object, smoothness of the curve by which the object borderline is followed, object identification, etc.)

The metal grain structure following as well as analysis and comparison belong to the geometric analysis. This means that, at the grain level as the basic and initial form of observation, it is necessary to analyze changes of the geometric parameters through which the sizes of the grain deformations can be given later. The number of parameters that can be chosen in the program is great; it can serve for very detailed analyses (Fig. 6)

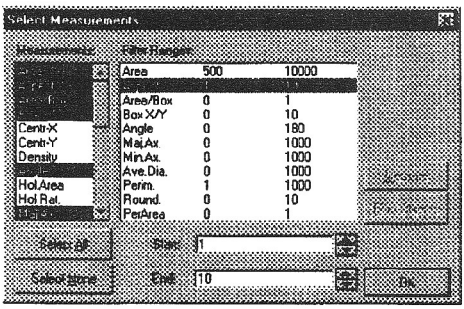


Fig.6 Choice of parameters in the program

For the sake of making the grain deformation analysis as reliable as possible, the following parameters in the programs are chosen to be used as means of performing a geometric analysis of the grain structure, namely, Area, Aspect, Area/Box, Box X/Y, Angle, Maj. Ax., Min. Ax., Ave. Dia., Perim., Round. and Per. Area. The very name of every parameter points to its meaning as well as the value obtained by the geometric analysis of the given shape.

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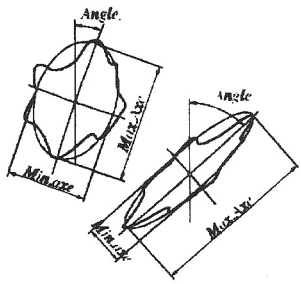


Fig.7 Grain Parameters

In order to conduct a successful deformation analysis at the grain structure level the most important parameters are surely Angle, Maj. Ax. and Min. Ax. Namely, all the deformations existing at the macro level, depending upon the deformation process dealt with, manifest themselves at the grain level through direct change of these three parameters. Only in the special stress cases (ideal pressure and pure extension) it is possible to say that there would be no grain swinging. Any real deforming process will cause, in the grain structure, swinging toward the given surface conditions of loading and the material flow limitation during the plastic deforming process. The orientation angle of the grain structure is obtained through the parameter angle. The mentioned angle for every object represents an angle between the vertical direction and the main axis of the given object in the clockwise direction (Fig. 7). Knowing this angle, the other angles

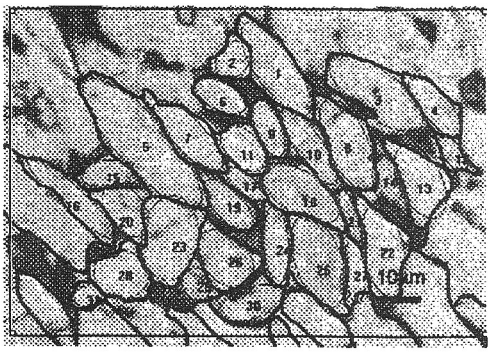


Fig.8 Matrix with an angle of 90°, Recording Place 9, Identified grains approximated by elliptical shapes

can easily obtained, for instance, the grain structure swing angle with respect to the direction of the force action or with respect to the border surface upon which the deforming process takes place and so on. The other two mentioned parameters, namely, Maj. Ax. and Min. Ax. define changes of the shape, that is, elongation and shortening of the basic object being analyzed. The plastic deforming at the macro level will inevitably cause dimension changes of the grains themselves in the workpiece structure as well, that is, their elongation and shortening. All these random and irregular forms of the grain structure, by establishing particular parameters in the program, can be approximated in the first approximation by the circle, that is, the ellipse as the second order curve that can follow the dimensions but not the shape. By such an approximation

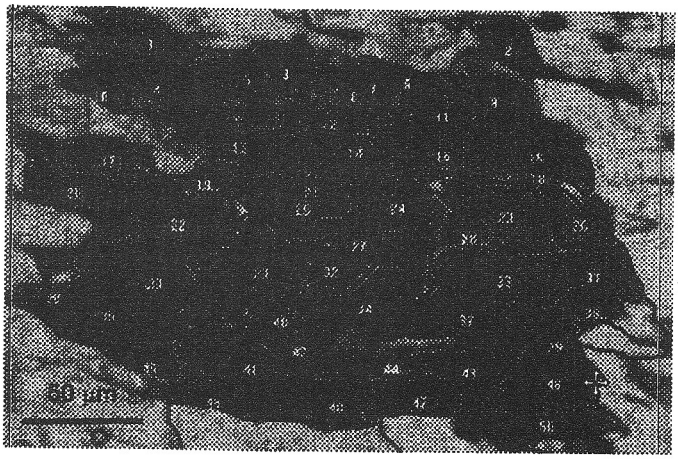


Fig.9 Identified Grains at Place Number 4, Angle of Extrusion 60°

the magnitudes of the two main ellipse axes are obtained by which the deformations of every grain, individually in two normal directions, can be achieved (Fig.7). These are, at the same time, the parameters that can serve for a complete deformation analysis within the deformed sample volume at the grain structure level.

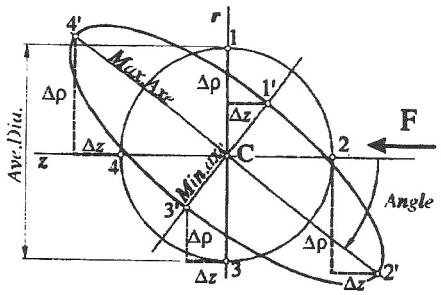


Fig.10 Characteristic Displacements in the Planes θ= const. of the Virtual Grain

The defined geometric parameters and their changes in the meridian section represent information upon which the kinematic deforming process is based at the uni-direction extrusion. Upon the chosen number of grains, within the picture of the structure processed by the software (Fig.9), the previously mentioned parameters are obtained for each grain, that is, the parameters that are later statistically processed. The result of the statistic processing (Table 1) for the defined number of grains is one average grain (Fig.10) whose geometric characteristics represent average values of respective parameters of the chosen grain structure sample upon one of the twenty recording

places with respect to the meridian section of the extruded pieces at various tool angles.

The analysis done so far leads to the conclusion that further work requires the knowledge, at each chosen recording place, of the characteristics of exactly this imagined grain. On the basis of its dimensions and geometric characteristics (Fig. 10) the conclusion about the deformation magnitude and degree is made.

Table 1. Geometric Characteristics of an Imagined Grain at Place No. 4, 60°

Stats	Area	Aspect	Ar/Box	Box	Angle	Maj. Ax.	Min. Ax.	Av. D.	Perim.	Roun.	Per. Ar.
Min	515	1.417	0.283	1.167	71.70	54.54	11.56	28.605	121.184	1.34	0.001
(Obj #)	38	29	8	29	29	18	38	40	40	24	38
Max	7252	5.783	0.768	4.3077	38.71	176.4	75.45	92.05	427.19	5.50	0.023
(Obj #)	35	12	47	38	41	13	29	35	27	8	35
Range	6737	4.366	0.484	3.14	57.1	121.8	63.88	63.44	306.01	4.15	0.021
Mean	3087.0	2.923	0.553	2.062	104.67	102.97	37.64	57.99	266.09	2.05	0.009
Std Dev	1742.4	0.9161	0.107	0.649	13.25	32.04	13.17	15.37	80.215	0.63	0.005
Sum	15435	146.15	27.64	103.1	5233.7	5148.8	1882.4	2899.9	13304.9	102.8	0.498
Samples	50	50	50	50	50	50	50	50	50	50	50

4. KINEMATIC PARAMETERS OF THE EXTRUSION PROCESS

In order to obtain a kinematic field within the deformed volume [7,11], the procedure described in the paper provides for direct acquisition of information concerning very small-scale displacements $\Delta\rho$, Δz, for four defined points at the formed model (Fig.10). The referential grain structure of the non-deformed workpiece for calculating deformation with an increase of the grain number manifests an exceptional uniformity at the cross-section. For this reason, the initial grain structure state, for each recording place, will be represented by the diameter of the circumference Ave. Dia. (Fig. 10). This average diameter is slightly different from one recording place to another so that taking of its value as constant for the whole cross-section only increases error in the analysis. For these reasons, the magnitude and direction of the above mentioned displacements are obtained on the basis of deformation and change of shape of the grain itself. Since the grain itself has no precisely defined geometry that could be followed before and during the deforming, the kinematic analysis is reduced to following of a greater number of grains at one recording place on the basis of which reliable values are obtained for further calculation (Table 1). Such an approach gives approximations of displacements and changes of the geometric grain size, at the chosen points of the deformed volume cross-section, through a virtual grain model (Fig. 10) whose initial and final shapes are exactly known. With the problem stated in this way, it is inevitable that all the parameters are accompanied with an inevitable error that, along with an increase of the grain number perceived in the analysis, has an ever decreasing value.

According to the illustration given in Fig. 10, with respect to the fact that the value of the grain structure swing is always, in this case, within the range from 0° to 90°, the component displacements, regarding their absolute value, will have the following values:
for the point 1 (3) :

$$\Delta\rho = \frac{Ave.Dia.}{2} - \left(\frac{Min.Axe.}{2}\cdot cos\ Angle\right)$$
$$\Delta z = \frac{Min.Axe.}{2}\cdot sin\ Angle \qquad (3)$$

for the point 2(4) :

$$\Delta\rho = \frac{Maj.Axe.}{2} \cdot \sin Angle$$
$$\Delta z = \left(\frac{Maj.Axe.}{2} \cdot \cos Angle\right) - \frac{Ave.Dia.}{2} \qquad (4)$$

Therefore, the observed points' displacements are completely defined through four parameters sufficient for this level of analysis.

Table 2. Kinematic Analysis (α = 60°)

Obj.	$\Delta\rho$ (1)	Δz (1)	$\Delta\rho$ (2)	Δz (2)	$V_G(\rho)$	$V_G(z)$	$\|\varepsilon_\rho\|$	$\|\varepsilon_z\|$
	1	2	3	4	5	6	7	8
1	8.10	0.73	1.65	17.78	23.45	11.79	2.440	0.276
2	8.98	2.36	5.42	18.63	28.04	16.54	0.155	2.063
3	9.03	1.98	5.05	20.80	28.33	14.92	4.530	14.880
4	10.79	4.77	13.04	20.81	36.85	22.20	9.859	17.350
5	14.68	11.33	32.42	13.11	55.38	38.42		1.761
6	7.53	1.15	2.51	14.59	22.18	11.63	2.334	6.816
7	8.74	2.05	4.84	18.87	27.16	15.34	5.569	6.737
8	11.35	5.24	14.39	20.83	39.02	23.55	2.309	22.872
9	11.13	10.48	23.39	5.69	43.94	32.26	6.450	9.298
10	14.71	13.45	31.88	2.77	57.67	39.45		2.188
11	7.42	2.34	4.96	15.18	23.25	15.58	2.069	1.284
12	8.50	3.51	8.19	18.06	28.17	19.25	6.771	3.116
13	11.29	10.40	23.46	14.29	44.29	36.81	3.493	1.885
14	13.22	12.75	29.50	3.51	52.60	37.66	1.261	3.143
15	12.02	13.11	27.09	4.39	49.60	38.18		14.813
16	6.62	2.85	5.52	14.30	21.29	17.50	2.383	3.255
17	5.20	1.82	3.15	12.03	15.62	14.58	8.553	1.291
18	7.94	11.21	18.96	7.29	35.98	33.98	9.139	12.875
19	14.49	14.02	33.09	5.41	57.73	42.37	17.262	11.908
20	5.30	2.40	4.11	11.80	16.64	15.96		6.995
21	5.70	1.21	2.22	12.44	16.34	12.62	0.229	2.379
22	5.81	1.33	2.48	12.32	16.89	12.64	0.699	0.267
23	6.05	2.15	3.93	11.91	18.55	14.67	2.964	1.633
24	6.46	6.56	11.34	9.70	25.61	24.51	1.362	10.373
25	7.64	6.58	12.11	12.53	28.85	26.45		9.735
26	5.81	2.63	4.58	11.57	18.34	16.19	0.590	
27	6.14	0.77	1.43	13.67	16.93	12.24	0.787	
28	6.03	2.59	4.48	12.76	18.81	17.12	3.013	
29	4.67	0.15	0.25	9.60	11.63	8.95	1.713	
30	5.55	1.26	2.19	10.49	15.71	11.85		

The previous research, due to the initial measuring network deformation, required the formation of special "standardized network" [9,10,11], while further analysis required the formation of a network of the recording places that preserve the z coordinate constant. Thus new node points are obtained at which the kinematic field parameters are defined. In this case, this is not necessary since the deformed grain structure has no effect upon the choice of the recording place, that is, at the cross-section there is no additional recording network that would be deformed under the action of the force. At the chosen places, where the grain structure deformation is recorded, only one imaginary grain is formed, approximated by an elliptical shape, that represents a deformation of the observed grains in the material structure at that particular point of the deformed piece cross-section.

By knowing the radial and axial velocity components in the defined points it is also possible to determine the deformation velocities $\dot{\varepsilon}_\rho$, $\dot{\varepsilon}_z$, $\dot{\varepsilon}_\theta$ and $\dot{\gamma}_{z\rho}$. If it is assumed that the distances between the structure recording points are sufficiently small, the expressions can be made equal:

$$\frac{\partial v_\rho}{\partial \rho} = \frac{\Delta v_\rho}{\Delta \rho} \frac{\partial v_z}{\partial z} = \frac{\Delta v_z}{\Delta z} \tag{5}$$

that is, the deformation velocities can now be determined through the following expressions:

$$\begin{aligned} \dot{\varepsilon}_\rho &= \frac{\partial v_\rho}{\partial \rho} = \frac{\Delta v_\rho}{\Delta \rho} = \frac{(V_r)_{z,\rho+1} - (V_r)_{z,\rho-1}}{2 \cdot \Delta r} \\ \dot{\varepsilon}_z &= \frac{\partial v_z}{\partial z} = \frac{\Delta v_z}{\Delta z} = \frac{(V_z)_{z+1,\rho} - (V_z)_{z-1,\rho}}{2 \cdot \Delta z} \end{aligned} \tag{6}$$

that is,

$$\begin{aligned} \dot{\varepsilon}_\theta &= -\left(\dot{\varepsilon}_r + \dot{\varepsilon}_z\right) \\ \dot{\gamma}_{z\rho} &= \left(\frac{\partial V_\rho}{\partial z} + \frac{\partial V_z}{\partial \rho}\right) = \left(\frac{\Delta V_\rho}{\Delta z} + \frac{\Delta V_z}{\Delta \rho}\right) = \left|\frac{(V_z)_{z,\rho+1} - (V_z)_{z,\rho-1}}{2 \cdot \Delta \rho} + \frac{(V_\rho)_{z+1,\rho} - (V_\rho)_{z-1,\rho}}{2 \cdot \Delta z}\right| \end{aligned} \tag{7}$$

The range of the deformation velocities, at the points where the structure recording has been done, can be followed in Table 2, columns 7 and 8.

Regarding the fact that the border surfaces of the tool represent surfaces at which the deformation velocities have zero value, the obtained velocity field faithfully reflects the state within the material. The radial velocity component theoretically has zero value at the workpiece axis due to the fact that the process is symmetrical. The results in Table 2 show that, at these places, it has, almost at every level, z=const., namely, minimal value. Likewise, this component on the matrix wall has zero value and, with respect to the results in Table 2, the drop of this component immediately next to the matrix wall is obvious. The axial component of the deformation velocity has maximal value at the recording places with z=0, that is, at the output section of the deformation focus and at the recording places close to the conical surfaces of the tool [6,11]. Due to the reduction of the tool cross-section, there appears a considerable deformation in the grain structure in the axial direction so that at the recording places - in the output section - there is great elongation, while at the conical surfaces, in addition to the deformation texture swing toward the cone angle, there is a distinct sliding reflected in the grain length increase.

5. CONCLUSION

The above-described approach enables a stress/strain analysis within the material, regardless of the forming process itself. Any deforming procedure will cause changes in the material structure. This fact itself points to the conclusion that the material with its structure will always "contain" information about the load magnitude and size at the grain structure level. In

other words, the method provides the deformation to be followed before and during the deformation process. Also, this method further enables an analysis upon the deformed volume parts, namely, where it was not feasible by the procedures applied so far. These are transitory curvatures, thin walls of the finished parts, parts of small dimensions, critical places at which the material is destroyed and so on, namely, the parts obtained by the volume deforming procedures at which the material flow is considerable during the process. The very structure of the material being deformed directly affects the possibility of changing this procedure. If dealing with the material in which clear borderlines of the grain structure cannot be detected, the component displacement analysis will be impossible.

The real possibilities and advantages of the described method are achieved by raising all the obtained results to a higher level. Namely, the used experimental research projects require time consuming measurement and the result processing for the given deformation conditions at certain parameters. Since these technologies are characterized by completely different deforming conditions, from one case to another, the repetition of this procedure does not represent a proper solution. The artificial intelligence, that is, the neural network application offers much more opportunities in the realization and implementation of these analyses. By its training for the known deforming conditions, the parameters obtained at the output and for the given material, such systems can be made that will possess information about character and magnitude of the displacements in the grain structure. By establishing different deformation conditions at the input, for the same material, the network will provide for obtaining the grain structure parameters, that is, the plasticity parameters, without implementing the described structure.

REFERENCES :

1. Case J., Chilver L., Carl T. F. R.: Strength of materials & Structures, Arnold, London, third edition, 1996.
2. Foster B., Fookes B.: Image analysis for materials science, Advanced Materials & Processes, February 1996.
3. Gorni A. A.: The application of neural networks in the modeling of plate rolling processes, JOMe - Journal of materials, vol 49(4), 1997.
4. Hruby J., Lička S., Petruželka J.: Modelling the evolution of microstructure during railway whell forging, International conference on industrial tools, pp. 123 - 126., Maribor, 1997.
5. Johnson W., Mellor P. B.: Plasticity for Mechanical Engineers, Van Nostrand Reinhold Company, London, 1962.
6. Lange K.: Lehrbuch der Umformtechnik, Band 1, Grundlagen, Springer - Verlag, 1972.
7. Lange K.: Lehrbuch der Umformtechnik, Band 2, Massivumformung, Springer - Verlag, 1974.
8. Oyekanmi B.O. Hughes T.A. Bramley A.N.: A microstructural evaluation technique for deformation studies in metal forming processes, Journal of Materials Processing Technology, vol.21 pp. 79-89, 1990.

9. Plančak M.: Odnos između radijalnog napona na zidu matrice i srednjeg pritiska na žig u procesima suprotnosmernog istiskivanja čelika, Jugoslovenski časopis za obradu materijala deformisanjem, Novi Sad 1984.

10. Plančak M.: Određivanje napona u procesima hladnog istiskivanja metodom vizioplastičnosti Jugoslovenski časopis za obradu materijala deformisanjem, Novi Sad, 1985.

11. Plančak M.: Kinematika tečenja materijala u procesima hladnog istiskivanja čelika, Jugoslovenski časopis za obradu materijala deformisanjem, Novi Sad, 1986.

12. Plančak M., Šidjanin L.: Određivanje naponsko - deformacionog stanja po zapremini tela metodom merenja veličine zrna, Jugoslovenski časopis za obradu materijala deformisanjem, Novi Sad, 1982.

13. Schumann H.: Metallographie, Leipzig 1962., prevod Beograd 1965.

14. Stoiljković V.: Teorija obrade deformisanjem, Univerzitet u Nišu - Mašinski fakultet, Ni{ 1984.

15. Voort G. V.: Committee E-4 Grain size measurements, ASTM Standardization News, May 1991.

16. Voort G. V.: Grain size distributions, ASTM Standardization News, May, 1991.

17. Voort G. V.: Grain structure types, ASTM Standardization News, May, 1991.

USPOSTAVLJANJE KORELACIJE IZMEĐU MIKRODEFORMACIJE ZRNA I MAKRODEFORMACIJE PREDMETA

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REZIME

Rešavanje problema naponsko-deformacione analize u procesima plastičnog deformisanja moguće je izvesti na više načina. Gotovo sve metode svode se na analizu teoretsko eksperimentalnih rezultata, dobijenih nekim matematičkim modelom i eksperimentalnim probama procesa plastičnog deformisanja. Krajnji cilj je poznavanje raspodele napona, deformacija, brzina deformacija i sl. unutar zapremine materijala, koja se plastično deformiše. Upravo određivanje ovih parametara, pri zapreminskom deformisanju, praćenjem mikrodeformacija zrnaste strukture, je cilj ovoga rada.

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ON NEW INVESTIGATION METHODS OF SHEET SURFACE MICROTOPOGRAPHY RECEIVED AFTER METAL FORMING

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ABSTRACT

New investigation methods of sheet surface microtopography received under cold rolling are described in the article. Investigation has been done by means of statistical functions: the function of probability density, autocorrelation function, the function of spectral density.

The facts and information have been received at Automation Complex for Surface Microtopography Research (ACSMR).

1. INTRODUCTION

More than forty working characteristics of any make depend on its microtopography, e.g.: friction, wear out, adhesion, welding, etc.

Methods of microtopographical surface regulation have been changed due to the needs of technics. It is possible to set out three stages of the regulation:

1. Visual comparison with standard.
2. Contact and optical methods of determination of average parameters of surface microtopography (roughness parameters), such as average roughness (average arithmetical of absolute profile ordinates), root-mean-square roughness, roughness step, slope angle of microedges, etc.
3. Contact and optical methods of determination of statistical functions of surface microtopography, such as: the function of probability density, autocorrelation function, the function of spectral density.

Very soon it turned out that standards which had the same height parameters of profile had different sight under different types of forming (turning, planing, grinding, electroerosional forming, etc.). It turned out inexpedient to create different standards for each type of forming, so other means of profile fixing with contact and optical devices have been developed.

At first devices of such type determined one parameter of roughness - Ra, then several, at present modern devices determine more then twenty heights and steps parameters. Also filters were set at these devices for limiting step parameters. It allowed to filter partially highfrequent components of the profile, which at the present are called roughness and lowfrequent component - corrugation.

According to modern theory surface microtopography can be presented as superposition of chance and determined fields [1]. Statistical functions can give full presentation of chance and determined fields characteristics: the function of probability density, autocorrelation function, function of spectral density [1,3,4]. Many roughness parameters at present are considered as point characteristics of these statistical functions. So parameter Ra determines gravitation center of distributional function of profile ordinate, correlative length determines fallspeed of autocorrelation function, square of spectral function characterizes parameter Rq^2, etc.

It has turned out that there are strict formulae of connection of all height, all step and mixed parameters for the profile which ordinates are distributed normally.

So method of surface microtopographical regulation by means of statistical functions includes not only the previous method but also allows to get completely new information about surface microtopography. Pioneering works in this field have been performed in machinery construction [4], below we use this method for characteristics of surface microtopography of makes received by methods of metal forming by pressure.

2. DEVICES FOR STATISTICAL FUNCTIONS' RESEARCH.

For complex research of surface microtopography in the Research Center "Microtopography" in Southern Ural branch of Russian Engineering Academy Automatic Complex for Research of Surface Microtopography (ACRSM)[6,7] has been developed. ACRSM is a hardware-software complex (fig. 1), including a table with a step engine-1, profilograph-profilometer-2, digit-analog converter-3, computer-4, control unit of step engine-5, dataplotter-6, printer-7. By means of the equipment of the complex it is possible to present surface microtopography as arrays of discrete reading. Software of the complex allows to calculate more than twenty average surface parameters and also statistical functions.

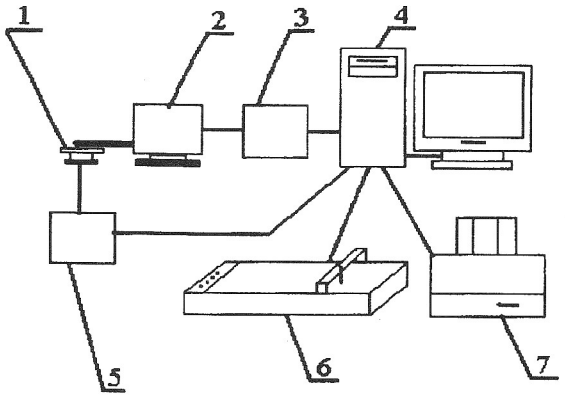
Unlike analogues [4,8] ACRSM allows to process not only ordinate array but its seven derived arrays:

- ordinates taken by module;
- square ordinates;
- average steps on peak;
- average steps on hollows;
- average steps of roughness;
- average angles of microedges slope;
- average squared angles of microedges slope;

It is possible to plot for these eight arrays: function of probability density, commutative functions, autocorrelation function, function of spectral density.

ACRSM brief technical characteristics:

- basic length, mm 0.08,0.25,0.8,8
- maximum length of track, mm 50
- radius of feeler's needle, mkm 10
- relative inaccuracy 0.5%
- number of discrete intervals per mm 200..1024



1-a table with a step engine; 2- profilograph; 3- analog-digital converter; 4- computer; 5-step engine control unit; 6- dataplotter; 7- printer.

Fig. 1. - Automatic Complex for Research of Surface Microtopography

3. EXPERIMENTS ACCESSIBLE ON ACRSM.

It is possible to research surface microtopography formed by: pressing, grinding, covering, deleting oxides, hot and cold rolling and other processes forming surface microtopography. We'll bring an example of forming sheet surface microtopography received under cold rolling.

3.1. Research of microtopographical changes under sheet skin-rolling.

Samples analyzed below were received on rolling mill 400 MMKZ under sheet rolling of sheet 08kp. Rolling conditions are: diameter of working rollers is 150 mm, material of working rollers is 45CKNM, initial roughness of working rollers is Ra=0.78 mkm with cutting length of 0.8 mm, rolling speed is 11mps, relative pressing is 2.2%, roughness of rolling is Ra=0.8..1.1mkm with cutting length of 0.8 mm.

Indices on graphs of fig. 2-6 correspond to the number of skin-rolling roll.

Profiles of scanning route with step of discretization are 1.95 mkm. It is seen in fig.2 that sheet microtopography in skin-rolling is changed.

Graphs of probability density functions of profile ordinate distributions depending on quantity of rolled metal are shown in fig. 3 and 4. Relative frequency of ordinate profile hitting into cluster are shown on vertical axis; quantiles on which profile ordinate of fig.3 are distributed are shown on horizontal axis, also they, taken by module, are shown in fig.4.

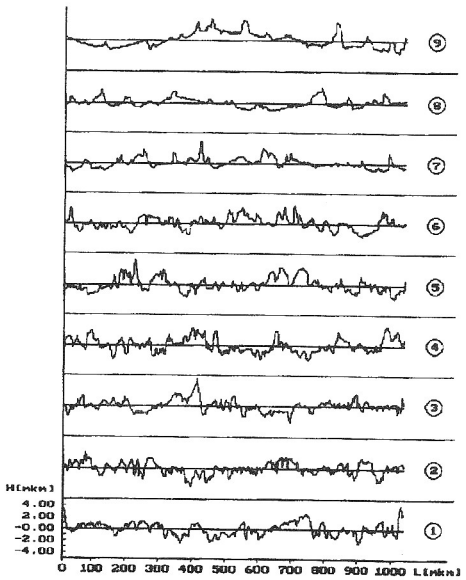


Fig. 2. - Profiles depending on quantity of rolled metal

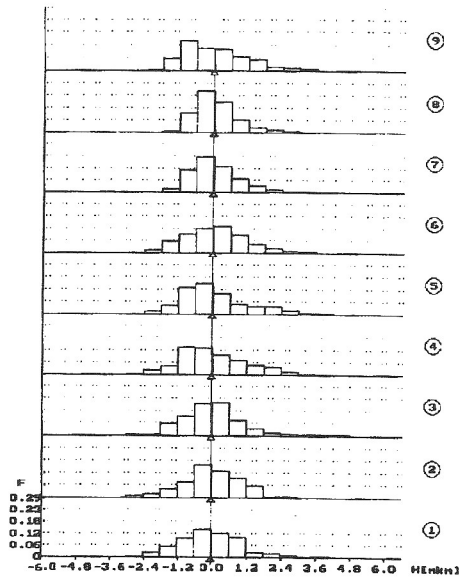


Fig. 3. - Histograms of profiles ordinates depending on quantity of rolled metal

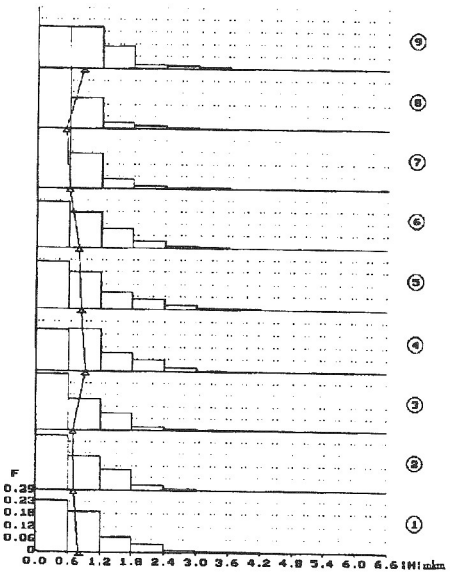


Fig. 4. - Histograms of profiles ordinates taken by module depending on quantity of rolled metal

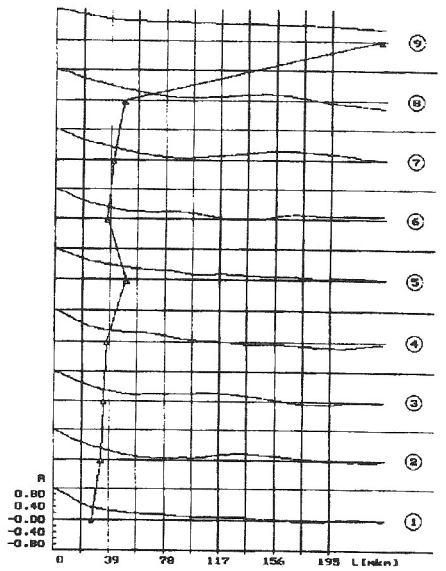


Fig. 5. - Autocorrelation functions depending on quantity of rolled metal

It is noticeable in fig.3 how sharply the form of histograms changes, but these changes are not so obvious in fig.4. The reason is very simple: histograms in fig.4 are folded in two, along zero meaning, histograms shown in fig.3. Histograms in fig.4 mix information of hollows and peaks of the profile; histograms in fig.4 contain objective information about the profile. Analysis of changes in profile ordinate histograms in rolling shows that grinding of deep hollow takes place under rolling and quite another process takes place when peak occur - their number is increased! These processes compensate each other in histograms of profile ordinate taken by module (fig.4) so centers of gravity changes in these histograms (marked in fig.4 by triangle), i.e. meanings of parameter Ra (table 1) practically are not noticeable. So probability density function allowed to notice a unique process of quantitative increasing of high peak in rolling, which had not been noticed under investigation of average parameters of surface microtopography.Graphs of autocorrelation functions of profile ordinates are shown in fig. 5, where the meaning of autocorrelation functions are put on vertical axis, intervals of correlative determination are put on horizontal axis, triangles show the length of correlation - τ, which is determined as length where correlation is reduced 2.7 times. Graphs show that length of correlation tends to increase with growth of rolled metal. Usually τ growth is explained by increase of profile determined component. It is really so, e.g. sharp τ growth for the ninth roll is explained by presence of harmonic components with small space periods, which is seen in spectral density graph (fig.6) and also occurrence of these harmonic components well conforms to roughness Sm parameter(table 1) for the ninth roll. However parameter Sm (table 1) does not react to harmonic components of microtopography of rolls 2,3,4,6,7,8 though they are clearly seen in spectral density graphs.

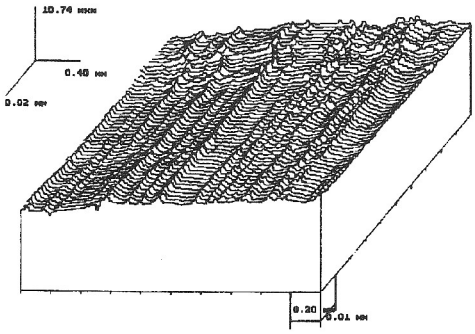


Fig. 4. - Surface microtopological map of the ninth roll

Power of harmonic is put on vertical axis of spectral density graphs (fig.6), space period is put on horizontal axis. Judging by these graphs the power of long wave spectrum under rolling is increased in sample №9 one can clearly pick out harmonics with period of 100 and 200 mkm, they are also quiet noticeable on the surface map of the ninth sample (fig.7). So autocorrelation and spectral power functions and as the proof of the right conclusion the surface map allowed to determine occurrence of determined component (autocorrelation function) of surface microtopography and also classify it as its harmonic component (spectral function, surface map).

It is seen in table 1 that average parameters of surface microtopography have no noticeable changes so they do not give information about the character of surface microtopography under rolling.

Table 1

Average parameters changes under rolling

roll N		1	2	3	4	5	6	7	8	9
height parameters,	Ra	0.81	0.72	0.70	0.87	0.84	0.79	0.61	0.53	0.86
mkm	Rq	1.03	0.93	0.94	1.11	1.10	1.00	0.80	0.69	1.07
Step parameters,	Sm	97.3	90.0	105.0	85.0	81.4	99.2	95.9	97.4	136.3
mkm	S_{peak}	3.13	2.42	3.03	3.42	3.13	3.95	3.70	3.70	3.95

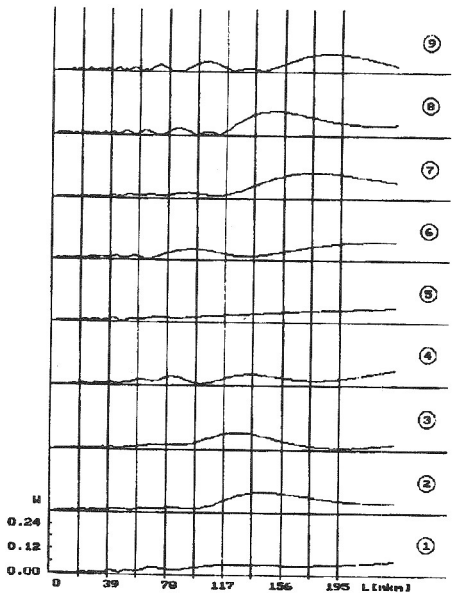


Fig. 5. - Spectral functions depending on quantity of rolled metal

3.2. "Rib" defect research.

"Rib" defect is visually well seen on the surface of sheet rolls under diffused illumination of alternative dark and light strips. The defect is often found at rolling mill 2500 SRS5 (sheetrolling shop №5) MMK, where sheet rolling of width 0.8..1 mm is done under pressing 0.5..1%.

Physical reasons for visual "rib" defect might be distinction of macro and micro sheet surface topography. So two hypothesis were suggested of the "rib" defect observation:

1. The defect is observed due to the distinctions of surface microtopography of dark and light strips.
2. The defect is observed due to the peculiarities of sheet surface.

For research of the "rib" defect character the filter was accepted as 0.8 mm. Evaluating area was taken just huge - 45X20 mm, which is maximum for profilograph. We'll remind for comparison that usually evaluating area of roughness is about 3X3 mm. Such great evaluating route of 45 mm was taken because observed rib period is 15..30 mm.

Surface maps are shown in fig.8 where a map with index "a" is a surface map taken without filters, map "b" is a map taken with lowfrequency filter. Vertical increase of profilograph ratio is 500, routes are taken along rolling axis

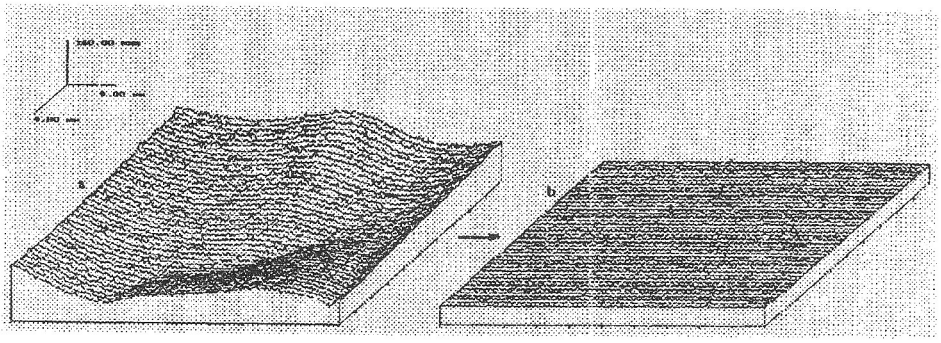


Fig. 6. - Surface maps: a) without filter b) with lowfrequency filter

Microtopographical analysis (table 2)(i.e. profile components with step parameters less than L_0) has shown that surface microtopography of both light and dark strips is approximately the same. It is obvious from comparison of values in table 2.

Table 2

Parameters of surface microtopography of light and dark strips

Evaluating route location	type of "rib" defect	Ra [mkm]	Rq [mkm]	tg θ [gra.]	Sm [mkm]	S_{peak} [mkm]
||	light	1.18	1.61	2.82	120	3.01
||	dark	0.97	1.56	2.72	124	3.07
⊥	light	0.95	1.28	3.53	111	30.5
⊥	dark	0.98	1.53	3.18	97	21.3

In table 2: signs "⊥" and "||" mean that evaluating route has been taken either perpendicular to or parallel to rolling axis; words "light" and "dark" mean visual type of "rib" defect; Ra, Rq - average arithmetic and average square deviation of microprofile from basic line; tg θ - is average angle tangent of microprofile inclination to basic line; Sm, S_{peak} is roughness step and average step on peak.

Approximate equality of parameters Ra, Rq, tg θ, Sm, S_{peak} (table 2) meant that reason to observe "rib" defect might be only surface macrotopography (i.e. roughly speaking profile components with step parameters more then L_0). Surface maps (of the type represented in fig. 8,b)showed that space period of the harmonic component of profile is 3 cm. Visual measurement of the value(distance between dark stripes is one) has approximately the same meaning. So hypotheses 1 has been rejected and further investigation has been done according to hypotheses 2.

4. CONCLUSION

Surface microtopographical research by means of statistical functions allows quiet a new observe the forming and changing mechanism of the microtopogrphy. It might be very important for the following goals:

- Research of the surface microtopographical formation in different topological formation in different technological process.
- Tougher regulation of surface microtopography for receiving determined working qualities of the surface (adhesion, friction welding, quality of covering, etc.).
- Perfection of technologies forming surface microtopography.

5. REFERENCES

1. A.P. Husu, Yu.R. Vitenberg, B.A. Palmov: Surface roughness. Chief edition of physics and mathematics literature "Nauka", 1975, p. 344.
2. V.K. Belov: Parameters of surface roughness and there control. Textbook, Magnitogorsk, MMMI, 1990, p. 54.
3. V.S. Lukyanov, Ya.A. Rudzit: Parameters of surface roughness. M-edition of standard, 1979, p.162.
4. T.R. Tomas: Rough surface. Longman Group Limited, 1982, p.261.
5. V.K. Belov, A.Yu. Lednov: Problems of surface microtopological measurement and there solving. Processing of solid and laminated materials: Interuniversity collection of articles, Magnitogorsk, MMMA, 1995, pp. 95-102.
6. V.K. Belov: Regulation of surface microtopology of rolled production. Works of the 1st congress of rolling mill operatives, M.: AO "Chermetinformatsia", 1996, pp.142-143.
7. V.K. Belov, A.Yu. Lednov: Automatic Complex for Research of Surface Microtopography - ACRMS. Automatic management of metallurgical processes, Interinstitute collection of articles, Magnitogorsk, 1996, pp. 79-84.
8. Muyamoto. Measurement of surface roughness by contact and noncontact means. Seimitsy Kikiy, 1985, v.51, №4, p. 12.

NOVA METODA ISTRAŽIVANJA MIKROTOPOGRAFIJE POVRŠINE LIMA DOBIJENOG OBRADOM DEFORMISANJEM

Belov V.K., Lednov A.Yu., Rudarrsko-Metaluška Akademia, Magnitogorsk, Rusija

REZIME

Kontrola i regulisanje mikrotopografije površine lima se menjala u skladu sa trenutnim zahtevima tehnike na tom polju, a prolazila je kroz tri faze:

- *vizuelno upoređenje sa etalonom (standardom)*
- *kontaktne i optičke metode za određivanje osrednjenih vrednosti*
- *kontaktne i optičke metoda za određivanje statičkih funkcija površine*

U ovom radu istraživana je mikrotopografija površine lima pomoću statičkih funkcija. Ovakav način analize mikrotopografije daje nove mogućnosti u oblasti mikroanalize površine. Globalni ciljevi koji se mogu postići ovom metodom su:

- *istraživanje mikrotopografije površine u različitim topografskim formacijama i u različitim tennološkim procesima*
- *uvođenje strožijih zahteva (standarda) u vezi kvaliteta površine*
- *usavršavanje procesa mikroanalize površine.*

*Istraživanja opisna u ovom radu izvršena su u istraživačkom centru **MIKROTOPOGRAFIJA** na Južnom Uralu-odeljenje Ruske Akademije Nauka, gde je razvijen poseban istraživački kompleks namenjen u te svrhe.*

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