

FORMING TECHNOLOGY OF COATED SHEET METAL

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ABSTRACT

The current article investigates production technology of holes and subsequently threads in parts from the thin steel sheets, which are coated, with layer of fireproof (fire resistant) Zn, modified by element Al (for samples of T type) and Mg element (for samples of M type). This procedure is important and well founded for the use of thin steel sheet for the threads products. However, applying protective layer in some way influences the threading technology. This issue is investigated here experimentally by combination of forming and machining technology, which conditions respect standard practice in industrial companies. In the first case we applied classical technology of drilling a hole and thread cutting with a tap. In the second case, hole was made by forming technology and thread is made by cutting tap. From the experimental results it can be derived more general conclusions related to the behaviour of the surface - coated material during threading.

Key words: cutting, sheet metal forming, hole, thread

1. INTRODUCTION

The combination of forming and machining technology for threading have their advantages and are often used in industry. Applied material is usually not corrosion resistant and corrosion protection is realized by coating. However, these metal coatings also affect the threads forming technology.

2. IDENTIFICATION OF THE PROCESS

Current experiments were realized with standard technological processes. Samples of the coated materials were cut from sheet blanks of the size 100 x 100 x 2 mm [1, 2, 3, 4]. Because of this size, it was necessary to equip single-purpose machined clamping fixture jig (picture 7).

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2.1 Description of the method

For the manufacture of threads in thin materials, which are typically sheets or various profiles, the preferred method is the thermal drilling in order to prepare a hole in an optimal way for subsequent thread, which then can be made by forming technology or machining. The industry is known under the names of related companies using this technology: Thermdrill, Flowdrill, Drabus etc. The principle of the method is captured in Figure 1 [5]. The drill here is not standard but a specially shaped conical forming point from sintered carbide. Thus, it is a sequence of well defined phases, which is needed in serial production using CNC machines.

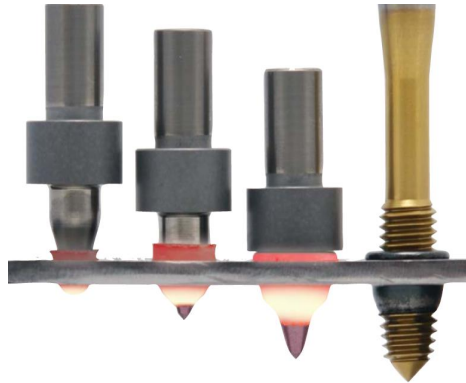


Fig. 1 - Phases of the thermal forming of the hole and the subsequent forming of the thread [8]

2.2 Used tools

Overview of the tools used in experiment is given in the Tab. 1.

Table 1i Used tools [20]

tool	dimension [mm]
forming point	Ø 5
drill	Ø 5
cutting tap	M6

Durability of forming tools according to catalogue data is significant - tens of thousands made holes - which falls within the typical mass production. Even so the manufacturers recommend the use of special processing fluids the experiment has a character of piece (single) production and process liquid was therefore used by manual dosing.

2.3 The process parameters

Recommended operating modes for the tools are given by the manufacturers's documentation. In the Table 2 database of Flowdrill companies for metric threads is presented [5].

Table 2i Recommended operating modes (selection)

thread M	forming tool		forming tap		input [kW]	t _{as} [s]
	Ø	speed	dimension	speed		
2	1,8	3200	M2	2000	0,5	2
3	2,7	3000	M3	1350	0,6	2
4	3,7	2600	M4	1000	0,7	2
5	4,6	2300	M5	800	0,8	2
6	5,4	2000	M6	650	1,0	2
8	7,3	1750	M8	500	1,3	2
10	9,2	1500	M10	400	1,5	3
12	10,9	1200	M12	330	1,7	3
16	14,8	1100	M16	250	2,2	4
20	18,6	800	M20	200	2,7	5

Note: Due to the short production times t_{as} are not listed as standard minutes, but seconds.

For the production of threads in the samples, the working mode of the Table 3 and Table 4 were used , by adjusting it to the general-purpose machine FNK 25A.

Table 3i Modes in the forming experiment [20]

number of sample	forming tool		cutting tap	
	Ø	speed	dimension	speed
ZnAl (1.)	5	2800	M6	280
ZnMg (2.)	5	2800	M6	280
ZnAl (3.)	5	4500	M6	90
ZnMg (4.)	5	4500	M6	90

Table 4i Modes in the machining experiment [20]

number of sample	drill		cutting tap	
	Ø	speed	dimension	speed
ZnAl (1.)	5	900	M6	90
ZnMg (2.)	5	900	M6	90

Drilled holes and formed holes on the sample are compared. It is visible that cut thread looks at each hole different.

3. CHARACTERISTICS OF TEST SAMPLES

The samples are coated with a layer of heat Zn modified by element Al (sample marked T) and elements Mg (sample marked M).

3.1 Sample type Zn (marked T)

Basic material sample according to EN 10204 is in quality DX51, which has the following experimentally determined characteristics:

- $R_m = 386 \pm 2$ MPa,
- $E = 1,799 \pm 0,042$ GPa,
- $R_{eH} = 365 \pm 3$ MPa,
- $R_{eL} = 345$ MPa.

The elemental composition of the surface layer is shown in Table 5. An electron scanning microscope VEGA II XMU (TESCAN) in conjunction with x-ray, energy-dispersive micro analyzer QUANTAX 800 (BRUKER) with SDD detector type was used. Measuring method of EDS was performed 3 times at an acceleration voltage of 15 kV. On the surface of the sample elements C, O, F, Al, Si, P, K, Ti, Mn, Fe, Zn were identified. Beside the dominant element Zn, Al also largely occurs. This also corresponds to the chemical composition of the X-ray spectrum.

Table 5i Elemental analysis of the surface layer (wt. %)

Spectrum	Al	Si	P	K	Ti	Mn	Fe	Zn
1	44,6	0,8	2,6	0,3	1,0	1,2	0,8	48,7
2	41,8	0,9	2,7	0,4	0,9	1,2	1,1	51,2
3	43,1	0,7	2,5	0,3	1,1	0,9	0,8	50,6
Mean value:	43,1	0,8	2,6	0,3	1,0	1,1	0,9	50,1
Sigma:	1,4	0,1	0,1	0,0	0,1	0,1	0,2	1,3
Sigma mean:	0,8	0,0	0,0	0,0	0,1	0,1	0,1	0,7

The morphology of the surface is visible in the picture in Figure 2. Measurement of thickness was performed by Elcometer device and thickness distribution is recording is in Figure 3.

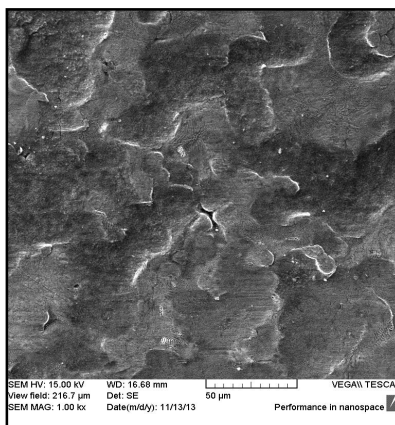


Fig. 2 - Surface morphology of sample type ZnAl (marked T) [20]

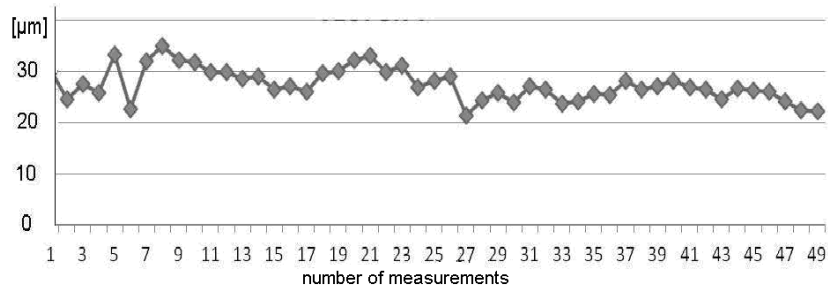


Fig. 3 - Thickness measurement of the coating layer of the sample type ZnAl (marked T) [20]

Estimation of the middle value of coating thickness was found to be 27.48 micrometers. The hardness measurement was made by device ZWICK Hardness Tester No. 3212. The middle value of hardness is 96 HV5 with a standard deviation of 1.63 [9].

3.2 Sample type ZnMg (marked M)

Basic material of sample according to EN 10204 in quality DX51, which has the following experimentally determined characteristics:

- $R_m = 407 \pm 2$ MPa,
- $E = 1,835 \pm 0,143$ GPa,
- $R_{p0,2} = 339 \pm 2$ MPa,

The elemental composition of the surface layer is shown in Table 6. The electron scanning microscope VEGA II XMU (TESCAN) in conjunction with x-ray energy - dispersive micro analyzer QUANTAX 800 (BRUKER) with SDD detector type was used. Measuring method of EDS was performed 3 times at an acceleration voltage of 15 kV. Elements C, O, Mg, Al, P, Fe, Zn were identified the dominant element here are ZnAl, enriched with Mg, which increases corrosion resistance without increasing the thickness of the coating. The results are also confirmed by the X-ray spectrum. Surface morphology captures the image in Figure 4. Measurement of thickness was performed by Elcometer device, and it is shown in Figure 5.

Table 6 Elemental analysis of the surface layer (wt. %)

Spectrum	Mg	Al	P	Fe	Zn
1	5,5	6,1	2,8	1,4	84,1
2	5,8	6,2	2,8	0,9	84,3
3	5,9	6,4	3,5	1,3	82,9
Mean value:	5,7	6,2	3,0	1,2	83,8
Sigma:	0,2	0,2	0,4	0,3	0,8
Sigma mean:	0,1	0,1	0,2	0,2	0,4

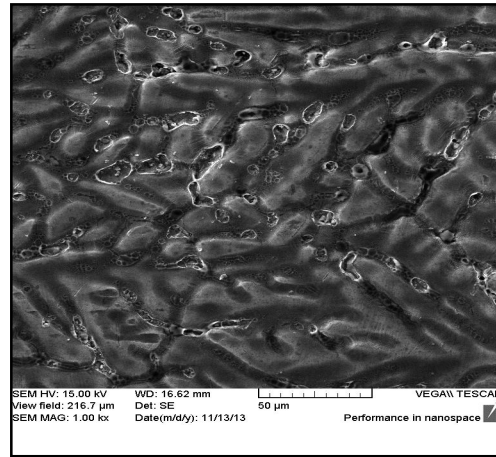


Fig. 4 - Surface morphology of sample type ZnMg (marked M) [20]

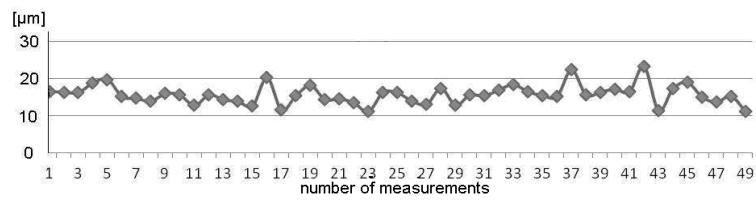


Fig. 5 - Thickness measurement of the coating layer of sample type ZnMg (marked M) [20]

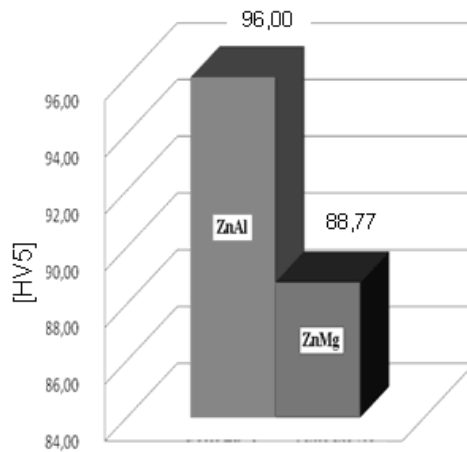


Fig. 6 - Hardness comparison of the two samples in HV5 [20]

4. EXPERIMENT

The experiment was carried out using machine FNK 25A, Fig. 1 under the conditions specified in the Table 3 and Table 4. Principal phase of the experiment are shown in Fig. 7, Fig. 8 and Fig. 9.

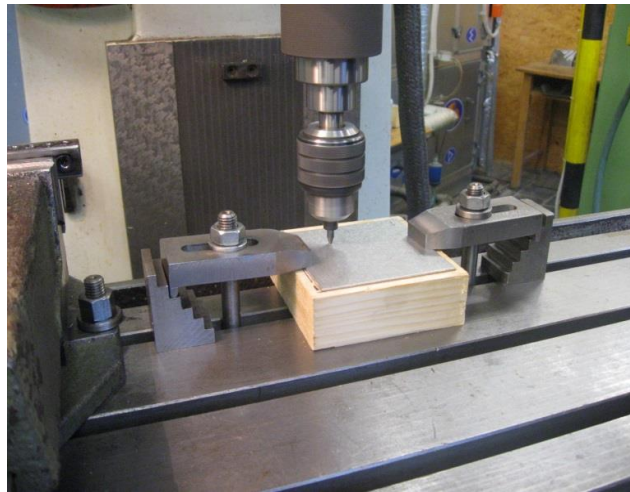


Fig. 7 - Start forming the hole [20]

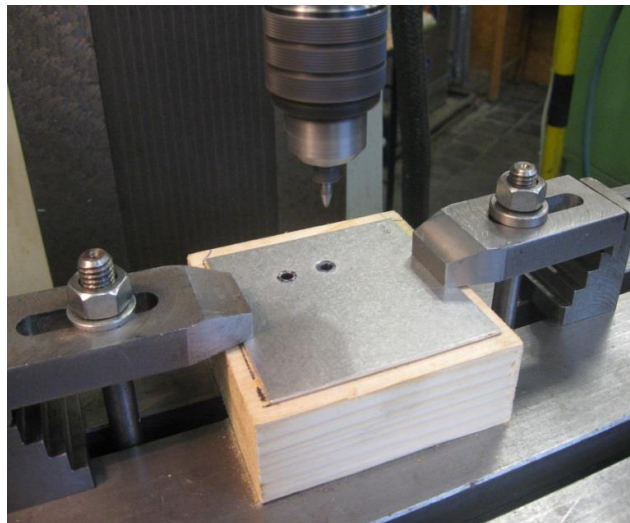


Fig. 8 - Course forming operations after two holes

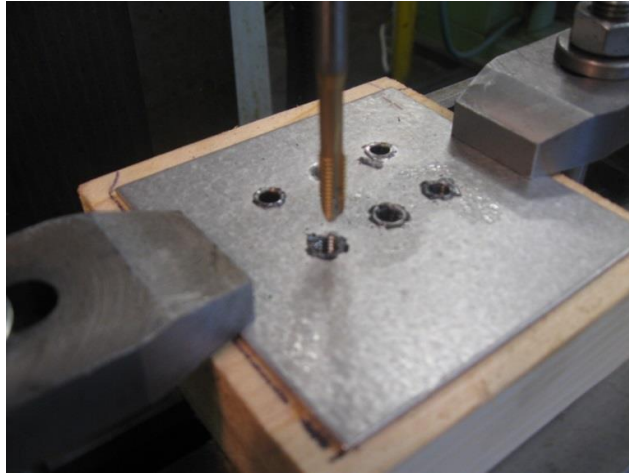


Fig. 9 - Tapping (threading) [20]

5. EVALUATIONS OF SAMPLES

All combinations of manufactured threads depicts the image of Fig.10. The samples ZnMg marked M are on the left side, and samples ZnAl marked T on the right. They both are made by forming technology. It is visible that among the samples of the type T and M there are significant differences.

Holes on the outer rows are made by machining. All threads are manufactured by machining.

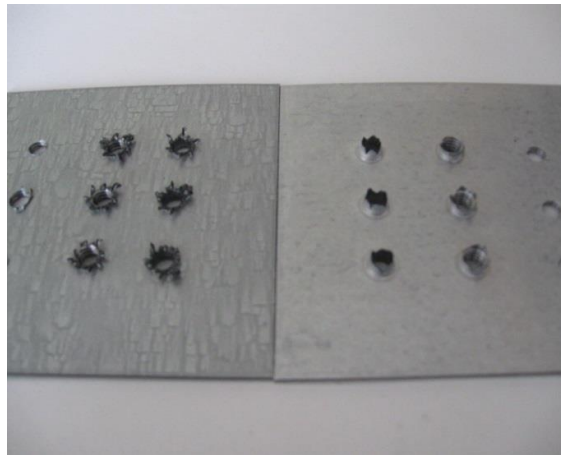


Fig. 10 - Overview of the threads produced in the samples [20]

5.1 Formed hole, cut thread

The result of this variant for sample ZnAl marked T is captured in Figure 11, where the first phase after forming of hole is shown, and Figure 12, where the final state after tapping is given.

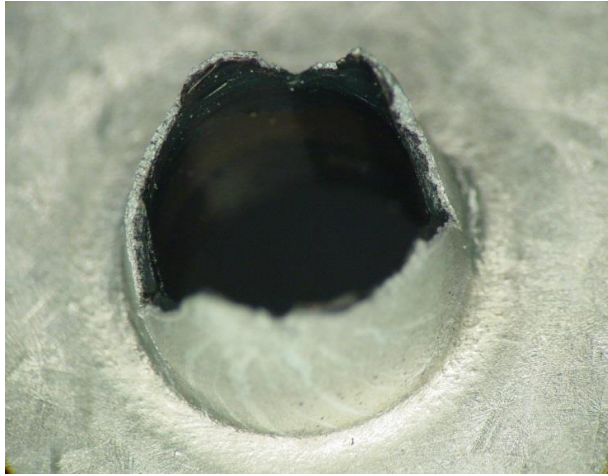


Fig. 11 - The appearance of produced hole by the sample ZnAl marked T



Fig. 12 - The appearance of the produced thread by the sample ZnAl, marked T[20]

Figures 13 and 14 show the results for the variant of ZnMg sample (M).



Fig. 13 - The appearance of produced hole by the sample ZnMg marked M[20]



Fig. 14 - The appearance of the produced thread by the sample ZnMg marked M[20]

5.2 Drilling a hole, cut thread

This combination of two technologies (Fig.10) gives standard results that are no different from those described in the sources [10, 11, 12, 13] and therefore there are not elaborated here.

6. DISCUSSION

In this work the samples were not manufactured on a CNC machine where the resulting quality was higher due to a well-defined repeatable automatic working cycle [14]. High-quality process fluid, hand-applied during working cycles, i.e forming operations of the type CIMTAP CLF companies Cincinnanti Milacron (Fig. 15) were applied. Machining operations of thread cutting type ECOCUT 532LE was performed by companies Fuchs (Figure 10). Produced threads showed different quality. The most preferred results were obtained for a sample of ZnAl marked T (Fig. 12). In contrast, the sample ZnMg marked M is not recommended for cases where a thread has to be in force-loading operation (Fig. 14). Possible uses of this material from a technical point of view, is in consumable products, such as household washing machine etc. Sheet covers of this type of product is usually exposed to a more humid environment, including dew and the influence of enrichment of the surface layer of Mg which makes material more resistant.



Fig. 15 - Used process fluid

The main contribution of thermal threading are short production times (in seconds), high load carrying capacity of threads and no waste, which is ecologically significant. Existing chip economy then is not so encumbered. When forming holes in the sheet are formed, sharp edges at the ends of the holes occur. This fact often does not meet the requirement of safety at work. In this case, it is necessary to use a different production method. Investments of thermal forming and threading are not high against cutting operations. In companies one can usually identify a suitable machine for this operation. Guidance in the selection of the possible types of machinery and equipment can be found in [19].

7. CONCLUSION

Production technology of holes and subsequently threads in parts from the thin steel coated sheets is presented in the current paper. Experimental work in order to investigate different sheet metal coatings in connection with threads manufacturing were conducted.

Following conclusion can be drawn:

- Applied surface layer has its justification as it protects the product against corrosion
- Each coating has a different chemical composition
- Surface layer has various influences on the forming of holes and threading technology
- In coatings of type M and type T different hole-edges appear
- The most preferred results were obtained for a sample of ZnAl marked T. In contrast, the sample ZnMg marked M is not recommended for cases where a thread has to be in force-loading operation
- Performed series of experiments confirmed the expected results

8. ACKNOWLEDGMENT

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DEFORMISANJE LIMOVA SA PREVLAKAMA

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REZIME

Ovaj rad istražuje postupak proizvodnje otvora i navoja kod delova od tankih čeličnih limova prevučenim tankim vatrootpornim slojem Zn, sa modifikovanim elementima aluminijuma (model T) i magnezijuma (model M). Ovaj postupak je veoma značajan i rasprostranjen u praksi, ali zbog zaštitnog sloja materijala dolazi do brojnih komplikacija u obradi. U okviru eksperimentalnih istraživanja ove problematike razmatrana su dva postupka izrade navoja i otvora, a prema proceduri koja odgovara standardnoj industrijskoj praksi. U prvom slučaju radi se o klasičnom postupku bušenja rupe i izradi navoja pomoću ureznice. U drugom slučaju kombinovane su tehnologije deformisanja i rezanja, tako da je rupa prvo izrađena probijanjem, a nakon toga navoj urezan pomoću odgovarajuće ureznice. Na bazi rezultata istraživanja izvedeni su određeni zaključci vezano za ponašanje površinskog sloja i prevlake pri izradi navoja.

Ključne reči: rezanje, deformisanje lima, otvor, navoj