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Assessment of the Cutting Surface Quality by Microscopic Analysis

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---*ABSTRACT*---

This work deals with the assessment of the quality of the cutting surface using microscopic analysis. In the theoretical part of the thesis, the knowledge related to electrical sheets produced by different manufacturers is presented. A very important parameter of cutting technology is the cutting gap. It has a major influence on the formation of the cutting surface and its shape. It also influences the actual hardening of the material during cutting and the distribution of the individual zones on the cutting surface. The experimental part of this work is focused on the measurement of the plastic shear zone, which is one of the main parameters for evaluating the quality of the cutting surface. It is characterized as the ratio of the shear zone thickness to the fracture zone thickness.

KEYWORDS; - *cutting,cutting gap, shearing, shear zone,fracture zone*

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I. INTRODUCTION

Today, the emphasis is on efficiency and optimization in all directions, whether it is the cost of individual production operations or the optimization of individual aspects of production and technological processes, which ultimately determine the competitiveness of products in the market.

At present, steels with higher strength properties are coming to the market and used in the industry, so it is necessary to thoroughly investigate their behavior and use suitable tool steels for their processing, machining. Since cutting is one of the most frequently used surfaces forming operations, it is necessary to know its principles, regularities, and correct setting of conditions during the cutting process.

Silicon steels are the essence of electrical appliances, and they provide the best combination for electricity distribution and transmission. Desired properties of these steels are low magnetic losses, high permeability, and induction and low magnetostriction. Low magnetic losses reduce heat generation and power consumption, a high permeability and induction result in reduced size and mass of the parts, and low magnetostriction decreases the noise (manifested as buzzing) in transformers and large capacity machines. [1]

The silicon content increases the electrical resistance, reduces the electrical losses caused by eddy currents and magnetic hysteresis. Alloys of iron and silicon, characterized as magnetic hard, are used for transformer sheets, while for dynamo sheets, materials characterized as magnetic soft are used. These are characterized by a simple change in the direction of magnetization and low energy losses associated with remagnetization.

Recently, sheet metal has been extensively used in various industries such as electronics, automotive, aerospace, etc. Most commonly, shearing is used as the primary process to reduce the rolled sheet to a shape as close as possible to the desired product shape. Other manufacturing processes must be used to achieve the final shape of the product. In most cases, the most accurate dimensions and the shortest product manufacturing process are required, which has a favorable impact on the production costs and the usability of the product. During the shearing process, unwanted burr formation occurs on the shearing surfaces. The aim of every manufacturer is to produce semi-finished products with as few burrs as possible.[2]

Nowadays, the industry places various demands on components created by shearing. One of them is the requirement of a burr-free cutting edge, which allows better processing of components with a more economical result in the work process and their safer handling. Efforts are therefore being made to reduce burr formation to avoid subsequent deburring. Currently, this process is carried out in a further component processing step such as mechanical deburring [3], belt grinding [4], sliding surface grinding [5], or burr pressing [6]. Material removal during the shearing process results in lower dimensional accuracy [7]. All these additional technical processes are labor, time and cost intensive.

The shear cutting process is one of the most economical separation processes since it combines high production rates with low costs. The quality of the shear cut edge depends on the material properties, material thickness, die clearance, cutting edge radius, tool wear and shear cutting strategy. [8]

In general, the shearing surface of the materials that have undergone shear deformation due to the compressive stress of punch and die are composed of 4 parts: rollover, burnish zone, fracture zone and burr. An ideal shearing surface is created by 100% of the burnish zone, and without rollover, fracture zone or burr. At the beginning of the shearing process, elastic and plastic deformations usually occur, which subsequently produce rollover and burr. Burr after shearing process is the plastic deformity, which remains on the surface and lowers the products quality by influencing roughness and accuracy. In addition, burrs on the surface of inside or outside cut-outs can affect negatively to the cost efficiency of products and the safety of the workers.[9]

II. CUTTING PROCES

Rotating electrical machines are characterized by the variability of the magnetic induction flux. For this reason, the sheets used for their production must be isotropic. The material of stator and rotor made from electrical sheets should have an isotropic structure after final processing. However, the plastic deformation accompanying the cutting process worsens the magnetic properties of the finished electrical sheet products. The production of rotors by cutting electrical sheets is therefore always accompanied by the occurrence of an area with other magnetic properties.

A burr is formed (Fig. 1), the formation of which cannot be prevented during the cutting of electrical sheets, therefore the plates for the rotors and stators are sometimes subjected to an additional deburring operation. The influence of burr on the blades of rotors and stators, on the output characteristics of the electric motor is unfavorable.

During winding of the coil and during electric motor operation, the insulation may be broken, the winding may be short-circuited, and the rotor of the electric motor may burn out. Then, it is necessary to cut these sheets with the smallest possible burrs, of course, while maintaining the conditions of economy of production. At the same time, the requirements for electric motors stipulate that the size of the burr of the cut sheets, for stators and rotors, in small and medium-sized electric motors, should not exceed 10% of the nominal thickness of the sheet used. [12]

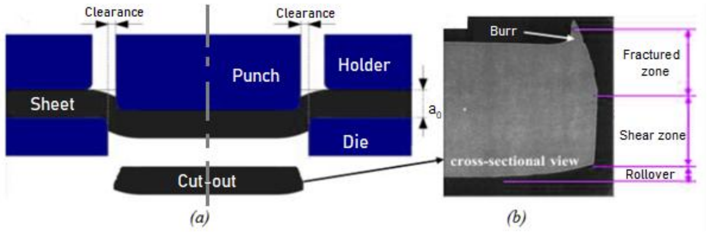


Fig. 1: Schematic of the cutting process and different zones of the cutting edge

The table 1 shows the real values of punch diameters (figure 2) at 1,3,5 and 7% cutting gap. The correctness of the punches dimensions was tested using a digital micrometer and a Zeiss industrial coordinate measuring device.

Tab. 1: Parameters of the cutting gap and punches

Cutting gap thickness to sheet thickness [%]	**Diameter ø of larger punch [mm]**	**Diameter ø of smaller punch [mm]**
1	25,003	15,039
3	24,983	15,019
5	24,963	14,989
7	24,943	14,979

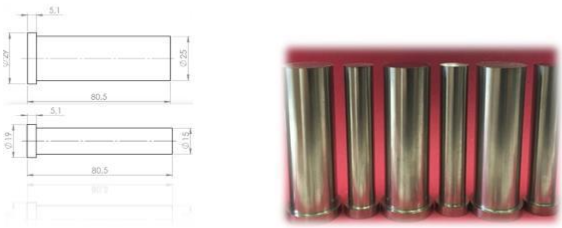


Fig. 2: Punches

III. MATERIAL

For the needs of experimental verification of cutting conditions of electrical sheets, 2 types of electrical steels from different manufacturers were used. The individual sheet metal parameters are recorded in the Table 1.

Table 1. Sheet metal parameters

Samples	**Embraco designation**	**Dimensions [mm]**	**Sheet thickness [mm]**	**Presence of coating Y/N**
Sample C	A.M. 036 S1S M450-50K	1130x1150	0,50	Y
Sample D	034 USS S3S-M350 -50A	880x1060	0,50	N
Sample E	T.K 033 S1S- M450 -50PP	1050x1110	0,50	N

Electrical sheets were characterized (table 2) by a thickness of 0.5 mm, hardness at the level of 65 to 95 HRB, density at 7.65 to 7.75 g / cm3, tensile strength 380 to 620 N / mm2 and an elongation of 10 to 20%.

Tab. 2: Characteristics of materials

Material designation	**Sheet thickness [mm]**	**Hardness HBR**	**Density [g/cm^3]**	**Rolling direction characteristics**	
				Tensile strength [N/mm^2]	**Elongation[%]**
S3S	0,50	75-95	7,65	520-620	10-20
S1S	0,50	65-85	7,75	380-550	10-20

The largest producers of electrical steel in Europe are ThyssenKrupp Bochum, Arcelor Mittal Luxemburg, VoestAlpine Austria, Wälzholz Hagen. As for the Asian producers operating on the European market, they are BaoSteel, WuGan and TaiYuan.

The reason for the chemical analysis (tab.2, 3 and 4) was to make sure that the delivered semi-finished products had the same chemical composition as the one declared by the manufacturer for the semi-finished products.

Tab. 3: Chemical composition of M450-50K steel in %

C	**Mn**	**Si**	**P**	**S**	**Al**	**Cu**	**Ni**	**Cr**	**As**	**Ti**	**V**
0.0026	0.609	0.148	0.089	0.0075	0.117	0.017	0.021	0.028	<0.001	0.001	0.001
Nb	**Mo**	**Co**	**Sn**	**Sb**	**W**	**B**	**Ca**	**Zr**	**N_2**	**O_2**	**Als**
<0.002	<0.002	<0.002	<0.002	<0.002	<0.003	0.0002	<0.0002	<0.001	0.0024	0.0021	0.115

Tab. 4: Chemical composition of M350-50A steel in %

C	**Mn**	**Si**	**P**	**S**	**Al**	**Cu**	**Ni**	**Cr**	**As**	**Ti**	**V**
0.0023	0.268	2.419	0.014	0.005	0.388	0.014	0.006	0.022	<0.01	<0.001	<0.01
Nb	**Mo**	**Co**	**Sn**	**Sb**	**W**	**B**	**Ca**	**Zr**	**N_2**	**O_2**	**Als**

<0.002	<0.02	<0.02	<0.002	<0.02	<0.003	0.002	<0.002	<0.01	0.002	0.0021	0.115

Tab. 5: Chemical composition of M450-50PP steel in %

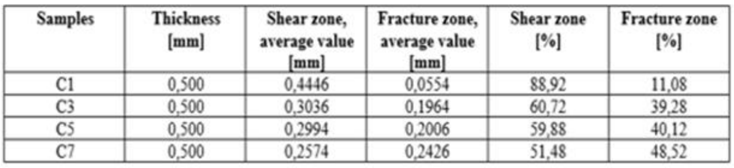
C	Mn	Si	P	S	Al	Cu	Ni	Cr	As	Ti	V
0.003	0.209	1.630	0.046	0.001	0.138	0.013	0.018	0.030	<0.01	0.002	<0.01
Nb	**Mo**	**Co**	**Sn**	**Sb**	**W**	**B**	**Ca**	**Zr**	**N_2**	**O_2**	**Als**
<0.02	<0.02	<0.02	<0.02	<0.02	<0.03	0.002	<0.002	<0.01	0.0024	0.0021	0.115

The chemical analysis showed that the parameters were consistent with those of the manufacturers.

IV. EXPERIMENTAL VERIFICATION OF CUTTING SURFACE BY MICROSCOPIC ANALYSIS

Table 6 and Figures 3, 4show the microscopic analysis of samples C1-C7. As was mentioned above, the designation C is for sample from sheet M450-50K. The samples show the quality of the cutting surface as a function of the cutting gap (clearance). Cutting gaps for the purposes of for the experiment were chosen at 1,3,5,7 % of the thickness of the sheet.

Tab. 6: Results of microscopic analysis of sample C



Samples	Thickness [mm]	Shear zone, average value [mm]	Fracture zone, average value [mm]	Shear zone [%]	Fracture zone [%]
C1	0,500	0,4446	0,0554	88,92	11,08
C3	0,500	0,3036	0,1964	60,72	39,28
C5	0,500	0,2994	0,2006	59,88	40,12
C7	0,500	0,2574	0,2426	51,48	48,52

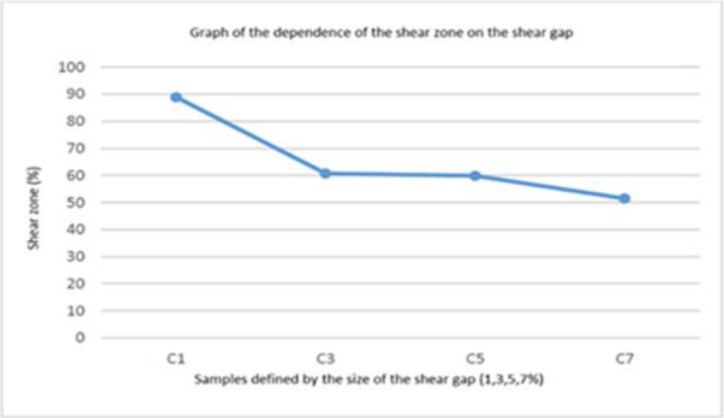


Fig. 3: Graph of the dependence of the shear zone on the cutting gap

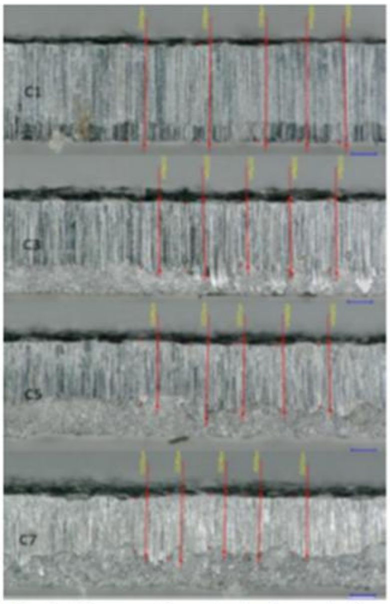


Fig. 4: Microscopic analysis of sample C

Table 7 and Figures 5, 6 show the microscopic analysis of samples D1-D7. As was mentioned above, the designation D is for sample from sheet M350-50A. The samples show the quality of the cutting surface as a function of the cutting gap (clearance). Cutting gaps for the purposes of for the experiment were chosen at 1,3,5,7 % of the thickness of the sheet.

Tab. 7: Results of microscopic analysis of sample D

Samples	Thickness [mm]	Shear zone, average value [mm]	Fracture zone, average value [mm]	Shear zone [%]	Fracture zone [%]
D1	0,500	0,4342	0,0658	86,84	13,16
D3	0,500	0,3640	0,1360	72,80	27,20
D5	0,500	0,2732	0,2268	54,64	45,36
D7	0,500	0,2046	0,2954	40,92	59,08

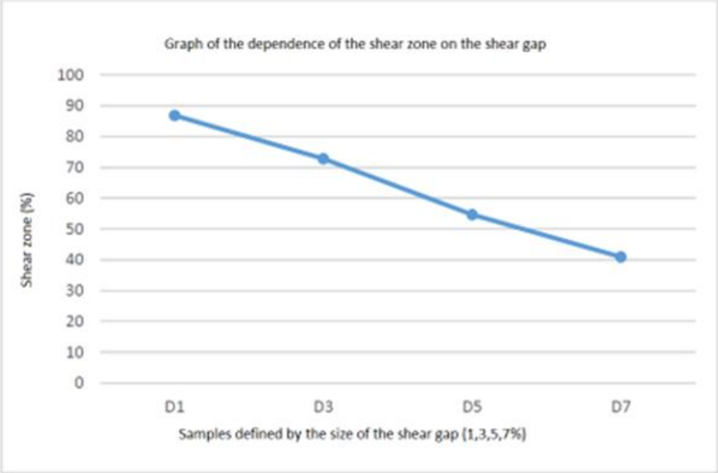


Fig. 5: Graph of the dependence of the shear zone on the cutting gap of sample D

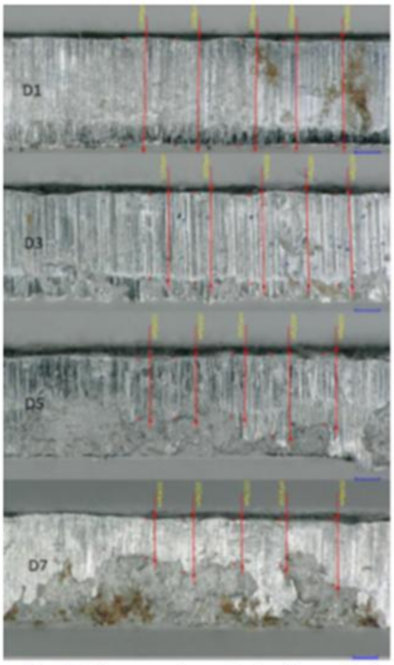


Fig. 6: Microscopic analysis of sample C

Table 8 and Figures 7, 8 show the microscopic analysis of samples E1-E7. As was mentioned above, the designation E is for sample from sheet M450-50PP. The samples show the quality of the cutting surface as a function of the cutting gap (clearance). Cutting gaps for the purposes of for the experiment were chosen at 1,3,5,7 % of the thickness of the sheet.

Tab. 8: Results of microscopic analysis of sample E

Samples	Thickness [mm]	Shear zone, average value [mm]	Fracture zone, average value [mm]	Shear zone [%]	Fracture zone [%]
E1	0,500	0,4526	0,0474	90,52	9,48
E3	0,500	0,2382	0,2618	47,64	52,36
E5	0,500	0,3086	0,1914	61,72	38,28
E7	0,500	0,2814	0,2186	56,28	43,72

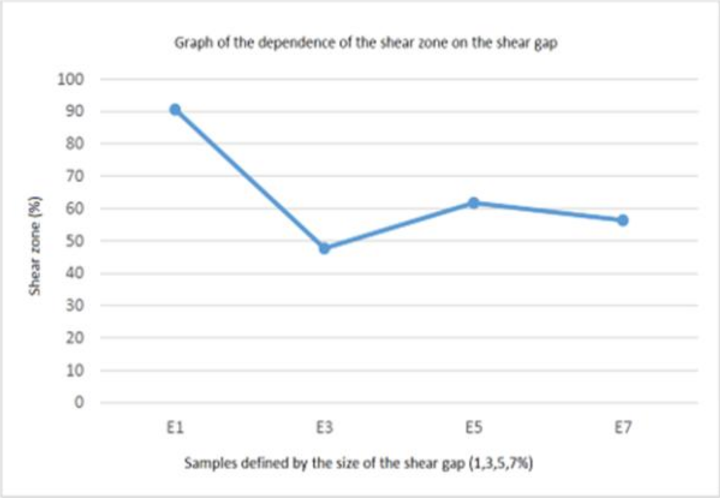


Fig. 7: Graph of the dependence of the shear zone on the cutting gap of sample E

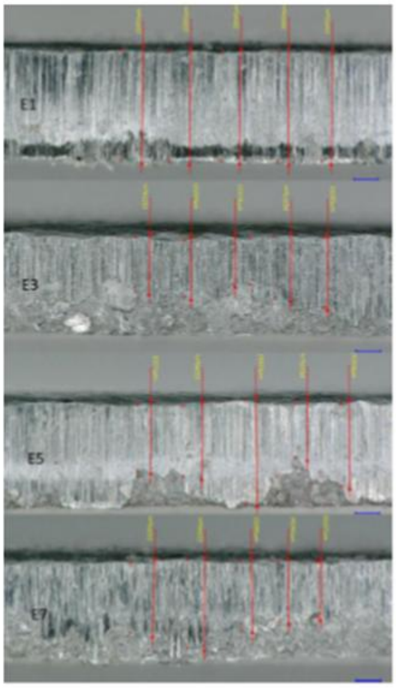


Fig. 8: Microscopic analysis of sample E

The microscopic analysis was carried out on a Keyence microscopy machine, namely Keyence VHX-5000. The quality of the shear area is defined by its "smoothness". This non-technical term is the ratio of the thickness of the shear zone to the fracture zone. The larger the shear zone, the higher the quality of the shear surface. In terms of the characteristics and behavior of electric motors, we assume that the larger the shear zone, the higher the elimination of undesirable phenomena such as short circuits, losses, and electric motor failures.

V. CONCLUSION

Based on the experimental results of the influence of the cutting gap on the quality of the cutting surface, the following conclusions can be established:

- when cutting electrical steel sheets in a tool with a cutting gap of 1% of the material thickness neither the chemical composition nor the mechanical properties have any influence on the quality of the cutting surface, which is characterized by the size of the shear zone,
- cutting materials in a tool with a cutting gap of 3% of the material thickness results in a reduction in the size of the shear zone, especially for materials with higher ductility values,
- when cutting sheet in a tool with a cutting gap of 5 and 7 % of the material thickness, the shear zones were reduced for all materials examined. The largest inhomogeneity of the shear zone was measured for the sheets with the highest ductility. In these sheets, the inhomogeneity is mainly due to the tearing off large grains of material during cutting.

Based on the experiments carried out, it is recommended to use cutting tools with the cutting gaps in the range of 1-2 % of the material thickness for smooth cutting of circular cutouts from electrical steel sheets (rotors and stators of electric rotating machines).

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REFERENCE

[1]. P. Rodriguez-Calvillo, Structure Development during Hot Rolling, Proceedings of 3rd International Conference on Magnetism and Metallurgy, Ghent University, Gent-Zwijnaarde, 2008.

[2]. Jyotiranjan Barik, VijayalaxmiSonkamble and K Narasimhan. Burr formation and shear strain field evolution studies during sheet metal blanking. IOP Conference Series Materials Science and Engineering. Vol. 418, no. 1 (2018), 012068.

[3]. Thilow A. Entgrattechnik Entwicklungsstand und Problemlösung. 4.Auflage; Ehningen bei Böblingen: Expert Verlag; 2012.

[4]. Osterrath H. Bandschleifen. Entwicklung und Anwendung in der Industrie - Chronologie eines Zerspanungsverfahren. Ehningen bei Böblingen: Expert Verlag; 1993.

[5]. Prüller H. Praxiswissen Gleitschleifen, Leitfaden für die Produktionsplanung und Prozessoptimierung. Wiesbaden: Vieweg+Teubner Verlag; 2012.

[6]. Klocke F, König W. Fertigungsverfahren Umformen. 5. Auflage; Berlin: Springer Verlag; 2006.

[7]. Bartz W E, Hintz H E. Gleitschlifftechnik. Ehningen bei Böblingen: Expert Verlag; 1989.

[8]. Spišák, E., Majerníková, J., Kaščák, Ľ., Slota, J. (2015). Influence of cutting on the properties of clippings from electrical sheets. Acta MetallurgicaSlovaca, Vol. 21, No. 4, pp. 302-310.

[9]. Vladimír Rohaľ, Emil Spišák. Evaluation of influence of cutting gap on the quality of the cutting surface when cutting of electrical steel. (2021). The international Journal of Engineering and Science. Vol. 10, No. 2, pp. 49-55.

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