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Influence of Double Layer Configuration on the Quality of the Sheared Edge of Blanks Produced from Soft Electrical Steel

Martin Matej Benda [1,*], Emil Spišák [1], Peter Mulidrán [1], Ľuboš Kaščák [1]

[1] Institute of Technology and Materials Engineering, Faculty of Mechanical Engineering, Technical University of Košice, Mäsiarska 74, 040 01 Košice, Slovakia

Abstract: Blanking in double layered configuration is unexplored technology producing blanks with quality of the sheared edge that cannot be predicted accurately using same criteria as in prediction of blanks produced by conventional blanking as each layer in configuration is blanked under different conditions. While the top layer is in contact with the set geometry of the punch and blankholder, the die is replaced with bottom layer. In the case of the bottom layer, it is in contact with set geometry of the die and the punch is replaced with the top layer. Research on double layer samples and conventional samples was conducted. Samples were observed under Keyence microscope and double layer samples were compared to the samples of conventional blanking. These observations revealed shortcomings of the double layer configuration in the form of greatly increased dishing deformation, difference in the sheared edge for each layer of the configuration and decrease in the quality of the sheared edge on the bottom layer of the configuration.

Keywords: electrical steel, double layer blanking, punching

1. Introduction

Increased interest in electric vehicles and support of e-mobility by the European Union lead many of the automotive producers into diversifying their production capabilities in this sector, mainly electric vehicle drives. Production of electric motors is complicated mainly because of their iron cores which are made of a thin laminations stacked together [1,2]. Important parameter of these laminations are its electromagnetic properties which are directly influenced and changed by production methods. Even small iron core losses caused by production are critical because they affect the overall performance of the electric vehicle [3,4].

Based on the comprehensive review of Paltanea et. al. [5] blanking is the preferred method for production of the laminations for electric motors. This is thanks to its much higher production capabilities in comparation with other methods which outweigh the negatives of affecting material and its electromagnetic properties through the mechanical stresses induced into the material during the blanking process [6,7]. Blanking has some drawbacks in comparison to the others production methods, mainly the quality of the sheared edge influencing electromagnetic properties and decrease in its quality as shearing edges of the tool become dulled [8,9,10]. Mucha et. al. [11] researched use of additional TiN coating on the punch to increase durability of the tooling ensuring quality of the blanked parts from electrotechnical steel.

Even though blanking is the most productive method, production lines of the electric motors call for an increased volume of production capable of fully covering

*** Corresponding author:** Martin Matej Benda, ***E-mail address:*** *martin.matej.benda@tuke.sk*

their needs while decreasing the overall production costs. One way to solve this problem is blanking in double layer configuration.

Blanking in double layer configuration is an innovative modification of conventional blanking by adding a second layer of material on top of first layer, without joining these parts by mechanical joining or bonding. The results of such configuration are two deformation processes until the eventual fracture of the material. This effectively doubles the production capabilities of one press at a time bringing the future of e-mobility ever closer [12].

The greatest disadvantage of this innovation is that the change in technology is based on negating the common rule of the blanking process by partially replacing the tooling respectively to the deformation process of each layer. In the case of the top layer, the die is replaced by the bottom layer, while in case of the bottom layer, the punch and blankholder are replaced by the top layer. These replacements of the tooling don't share the geometry and material characteristics of the tooling materials, which means that predictions of the resulting quality of sheared edge cannot be done as in case of conventional blanking. Based on the previous research on double layer blanking of electrical steel with high silicone content we can predict different sheared edge between each layer in the double layer configuration, different outer and inner diameters of each sample and overall increase in dishing deformation of the double layer samples in comparison with conventional blanking [12].

2. Materials and Methods

2.1. Material used in experiment

Thin, soft electrical steel with silicone content of 0.74% was used in experimental work. Chemical composition of the used steel is shown in Table 1. Nominal thickness of the chosen steel was 0.5 mm.

2.2. Experimental setup and equipment

Progressive experimental blanking tool has been chosen to observe the influence of the double layer configuration in blanking operation on the sheared edge of the soft electrical steels. Experimental tool can be seen on Figure 1.

Blanks have the shape of toroid as this shape is favorable for use in the Epstein Frame device for subsequent research on electromagnetic properties. Hydraulic press used for experiment have nominal force of 200 kN. The diameters of the dies were: Ø25.013 mm and 15.049 mm. The diameters of the punches were: Ø25.003 mm and Ø15.039 mm.

Figure 1: Blanking tool

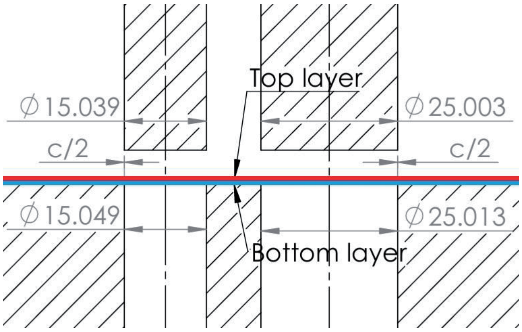

Figure 2: Layout of the double layer configuration (top layer is red and bottom layer is blue)

Two configurations were used in the experiment, conventional single layer configuration and double layer configuration. Double layer configuration consisted of second layer of same material doubling the nominal thickness of blanked configuration. Resulting shear gap percentages and nominal

Table 1: Chemical composition of electrical steel (weight %)

Fe	C	**Si**	Mn	P	S	Cu	Al
98.29	<0.002	**0.744**	0.329	0.071	0.004	0.036	0.182
Cr	Mo	Ni	V	Ti	Nb	Co	
0.033	0.037	0.034	0.012	<0.002	0.031	0.086	

thickness of blanked configuration respective to experimental configuration is shown in table 3. Layout of the double layer configuration is shown at Figure 2.

Table 2: Nominal thickness of blanked material and shear gap size

Configuration	Shear gap c (mm)	Nominal blanked thickness tn (mm)
Single layer	0.01	0.5
Double layer	0.01	1 (0.5+0.5)

Each layer in configurations has been marked by differently colored line for identification during experiment.

3. Results and Analysis

Samples produced by double layer blanking were noticeably deformed by dishing deformation as they were easily observed with a naked eye. Because of this, samples were measured with calibrated caliper before they were prepared for study under the microscope. Afterwards, samples were cast in resin and grinded down to the center of the sample. Keyence microscope was used to observe and study the sheared edge on the inner shape of the samples.

3.1. Dishing deformation

Three pieces of each of the samples were carefully measured with electronic calibrated caliper at 4 points and then the average value was calculated, illustration of this measurement is on Figure 3. Resulting deformation is present in the form of difference from the nominal thickness t_n of the material, which is 0.5 mm. This measurement is not perfect as it is influenced by the burr produced on the samples.

Measurements of the dishing are in table 3.

Table 3: Measurement of dishing on the samples

Sample	Specimen	Avg. measurement t_v (mm)	Dishing increment t_i (mm)
Single Layer	1	0.59	0.09
	2	0.584	0.084
	3	0.593	0.93
Double layer Top	1	1.26	0.76
	2	1.262	0.762
	3	1.253	0.753
Double layer Bottom	1	1.2	0.7
	2	1.24	0.74
	3	1.21	0.71

Measurements of the samples confirmed the increase in dishing deformation with an increase of approximately 7 times the dishing of the single layer on all 6 measured samples produced by double layer configuration. We have seen small difference in measurement between layers of the double layer configuration as the top layer had considerable burr formed as it was clearly noticeable by a touch.

3.1. Sheared edge

All three samples were observed under the microscope and the surface of the sheared edge was measured. Sample 1 was the result of conventional blanking with shear gap of 1%.

Sheared edge can be seen on Figure 4.

Sample 2 was the top layer of the double layer blanking operation, and it can be seen on Figure 5.

On sample 2 we can see big burr formed, extending the shear profile by 20% and its profile copies the profile of the rollover zone of sample 3. This deformation is the result of the bottom layer

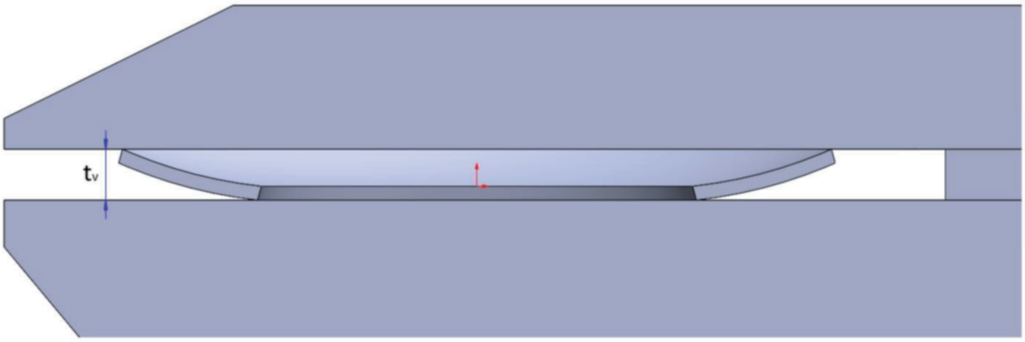

Figure 3: Measurement of dishing with calibrated caliper

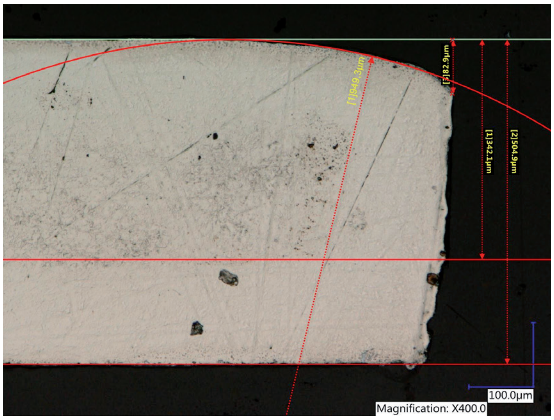

Figure 4: Sample 1 – Conventional blanking

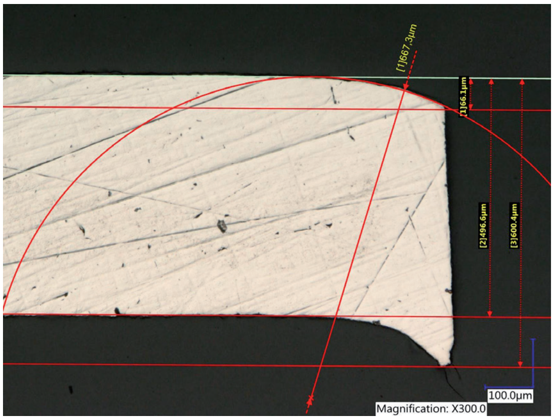

Figure 5: Sample 2 – Double layer blanking top layer

which acts as the die for the top layer deforming under the pressure producing its rollover zone. Rollover on sample 2 makes a small part of 13% and is even smaller than on sample 1 and its radius value being 29.7% smaller than radius produced by conventional blanking. This is due to the fact that for this part of the cutting process, overall thickness of blanked material is thickness of both layers combined which results in lesser rollover deformation before punch enters the material. Burnished zone makes most of the profile, which is 86% and it is extending up to half of the burr.

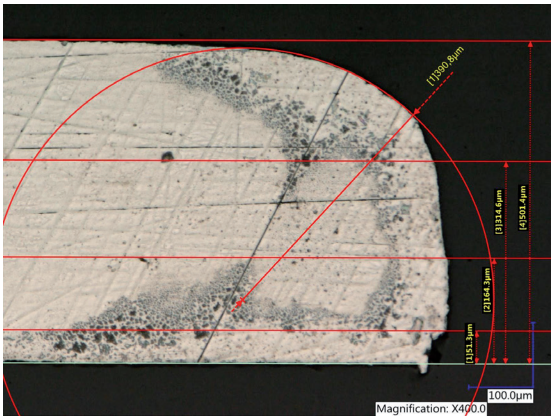

Figure 6. Sample 3 – Double layer blanking bottom layer

This is thanks to the bottom layer partly acting as counterpunch during the cutting. The fracture zone is located at the burr, taking half of its length.

Sample 3 was the bottom layer of the double layer blanking operation, and it can be seen on Figure 6.

On Sample 3 we can see negative impact of double layer configuration on the bottom layer as its sheared edge is completely different than the sheared edge of both previous samples. Rollover area consists of bigger area of the sheared edge than in conventional blanking, specifically 37% of the sheared profile. Radius of the rollover area is 41.2% value of radius on conventional blanking but its centerpoint is much closer to the sheared edge. This is due to the deformation of the material under blanking force which is distributed over an area instead of being concentrated on the shearing edge of the tooling. Burnished zone is divided into two parts, profile of the first part is at slightly different angle than second part which then continues until breakage occurs. Both parts of the burnished zone together make up 52% of the shear profile. Breakage makes 10% of the profile. Protrusion of the burr is just 3% which is much less than burr produced on the sample 2 of the top layer.

Values of all zones for the analyzed samples

Table 4: Percentage of respective shear zones measured on the blanked samples

Sample	Rollover	Burnished zone	Breakage	Burr	Burnished zone of Burr	Breakage of Burr
Sample 1	16.58%	51.84%	31.58%	-	-	-
Sample 2	13.22%	86.1%	-	20.08%	47.02%	56.38%
Sample 3	37.36%	52.66%	10.26%	3.08%	-	100%

are in Table 4. Percentages of rollover, burnished zone, breakage and burr are calculated from part of profile corresponding to the nominal thickness. Additionally, for sample 2, burnished zone and breakage is calculated from the length value of the burr itself.

4. Conclusions

Experiment provided us with an insight into the influence of the punching operation of double layered configuration blanking of the electrical steel material with lower amounts of silicone content. Investigation compared dishing deformation of samples and sheared edges produced by punching and the results of comparing these samples are:

– *Dishing deformation of the double layered samples is similar, their only difference produced by the burr created on the upper layer sample. When compared with the dishing produced on the conventional blanking sample, the dishing deformation is 7 times larger. This is problematic as it influences the stacking factor, it may result in damage on the surface of lamination by the adjacent laminations and it may produce obstacles for the stacking process.*

– *The sheared edge of each layer in double layered configuration is drastically different between each other as well as when compared to sample produced by conventional blanking. The top layer is showing much better sheared edge surface, with burnished zone making 86% of whole edge. On the other hand, the burr produced is much greater than in conventional blanking protruding by 20% of the original thickness. This burr may influence electromagnetic properties of the stack, stacking factor and there is a risk of damage to the isolation on the surface of the laminations by its edge. The bottom layer is highly deformed which will influence the electromagnetic properties.*

Because of these problems, the technology of the double layered configuration blanking needs to be further investigated and optimized and some of the possible changes which may improve the results of the technology are:

– *Fine blanking with counterpunch will help mainly with the dishing deformation as the counterpunch would stop the material from deforming into the space of the die.*

– *Using different batches of the same material for each layer of the configuration based on the hardness of it, especially if the harder material will be positioned as the bottom layer as it may have a positive influence on the resulting quality of the blanks.*

– *Using the different shapes of the tooling may yield improved results. Long and sharp chamfer on the die may result in more balanced dishing deformation and improved sheared edge.*

Acknowledgments

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