

Evaluation of the influence of the shear gap size on the tear-off angle size when shearing electrical sheets

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ABSTRACT

The article deals with the evaluation of the influence of the shear gap size on the tear-off angle size when shearing electrical sheets. Electrical sheets, thanks to their magnetic properties, are used in various industries. One of the technologies for processing these materials is shearing. During shearing, the quality of the sheared surface is evaluated, among other things, which in the case of electrical sheets can also be evaluated by the tear-off angle size. The aim of this paper is therefore to analyze the influence of the shear gap size on the shearing quality of electrical sheets at different shear gap sizes evaluated by the tear-off angle size. The sheared surfaces cut at a shear gap size of 1% and 10% of the thickness of the cut material for three types of electrical sheets were examined.

Keywords – tear-off angle, electrical sheet metal, shearing, shear gap

Date of Submission: 01-11-2025

Date of acceptance: 10-11-2025

I. INTRODUCTION

Electrical steel is a type of low-carbon steel, sometimes referred to as electrical steel, lamellar steel, silicon steel or transformer steel. Electrical steel refers to magnetic material made from cold-rolled sheets with a high percentage of silicon. Cuttings from such sheets, also called lamellae, are assembled to form transformer cores or stator and rotor parts of electric motors. Shearing electrical steel sheets affects the magnetic properties of the sheets. The quality of the sheared surface is influenced by various factors, including the shear gap, i.e. the distance between the shearing edges of the shear punch and the shearing die in the shearing tool. The choice of shear gap depends mainly on the thickness of the material being sheared and its mechanical properties. A correctly selected shear gap is the gap at which the desired quality of the sheared surface is achieved while at the same time expending minimal force and work. The size of the shear gap affects the stress-strain state of the material during shearing, the distribution of the plastic zone, as well as the resulting characteristics of the shear surface, including the tear-off angle. The aim of this paper was to assess the influence of the size of the shear gap on the size of the tear-off angle for three types of electrical sheets used to produce rotary machines. Samples for assessing the quality of the shear surface were sheared from experimental materials at 1% and 10% shear gap.

II. MATERIAL USED IN THE EXPERIMENT

The article evaluates 3 types of electrical steel with different chemical compositions. The material tested was marked as A with a thickness of 0.5mm, material B with a thickness of 0.35mm and material C with a thickness of 0.5mm. The experiment investigated the effect of the size of the shear gap of 1% and 10% of the thickness of the sheared material on the size of the tear-off angle. The sizes of the tear-off angles obtained experimentally and by process simulation were compared.

Tab. 1 shows the chemical composition of the investigated materials.

Tab. 1 Chemical composition of the investigated materials A, B a C [%]

Material	Fe	C	Si	Mn	P	S	Cu	Al	Cr	Mo	Ni	V	Ti	Nb	Co
A	96,25	<0,002	2,637	0,294	0,014	<0,002	0,014	0,676	0,02	0,028	0,017	0,006	<0,002	0,017	0,026
B	96,28	<0,002	2,651	0,266	0,016	<0,002	0,018	0,646	0,024	0,03	0,018	0,006	<0,002	0,015	0,025
C	98,220	<0,002	0,892	0,385	0,095	<0,002	0,018	0,195	0,029	0,024	0,029	0,008	<0,002	0,018	0,038

III. EXPERIMENTAL METHODOLOGY

Uniaxial tensile test

The uniaxial tensile test was performed according to STN EN 10002-1. The coefficient of normal anisotropy (r) according to the STN ISO 10274 standard and the strain hardening exponent (n) according to the STN ISO 10275 standard were also measured. To measure the mechanical properties of the tested materials, five samples were produced from each material in the directions of 0° , 45° and 90° with respect to the rolling direction. The average values of the mechanical properties of the tested materials obtained by uniaxial tensile testing are shown in Tab. 2.

Tab. 2 Mechanical properties of the tested materials

Material	Thickness [mm]	R_e [MPa]	R_m [MPa]	A_{80} [%]	r [-]	n [-]
A	0.5	247.7	497	22.3	1.002	1.232
B	0.35	382.3	494.3	18.9	1.157	0.176
C	0.5	296.3	438	34.5	1.170	0.248

Simulation of the shearing process

The aim of the simulation was to investigate the influence of the size of the shear gap on the size of the tear-off angle as a selected parameter of the shearing surface profile. The process was carried out to predict the influence of the size of the tear-off angle on the quality of the shearing surface when shearing electrical sheets. From the application module, Sheet metal forming and the Cutting process type were selected. The procedure consisted of defining the material properties obtained by uniaxial tensile testing, Cockcroft-Latham was defined as the failure model. Furthermore, in the cutting process, the press, the orientation of the tool and its kinematics, the friction coefficient, the defined temperature of the sheet and the tool (shear punch, shearing die, blankholder), the type of elements and their initial number, the blankholder force, and the “cutting plane” in which the simulation itself will take place were set. In our case, a 2D simulation was chosen. The sheared sheet and tools were rotationally symmetrical. The simulation of the shearing process was then calculated in the defined plane (Fig. 1).

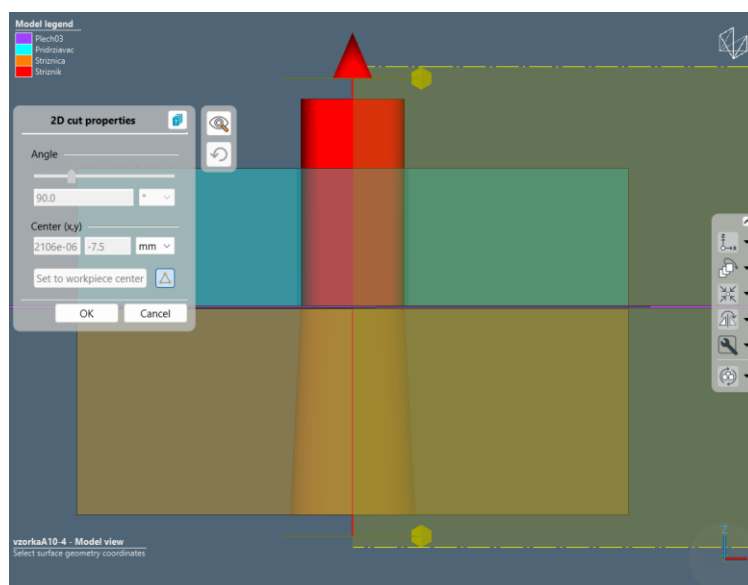


Fig. 1 Defining the cutting plane

Subsequently, it was necessary to define the mesh, where the mesh size was selected as 0.09 mm. In the place where the cutting occurred, a finer mesh was created in the Refinement boxes for a more accurate calculation, as can be seen in Fig. 2.

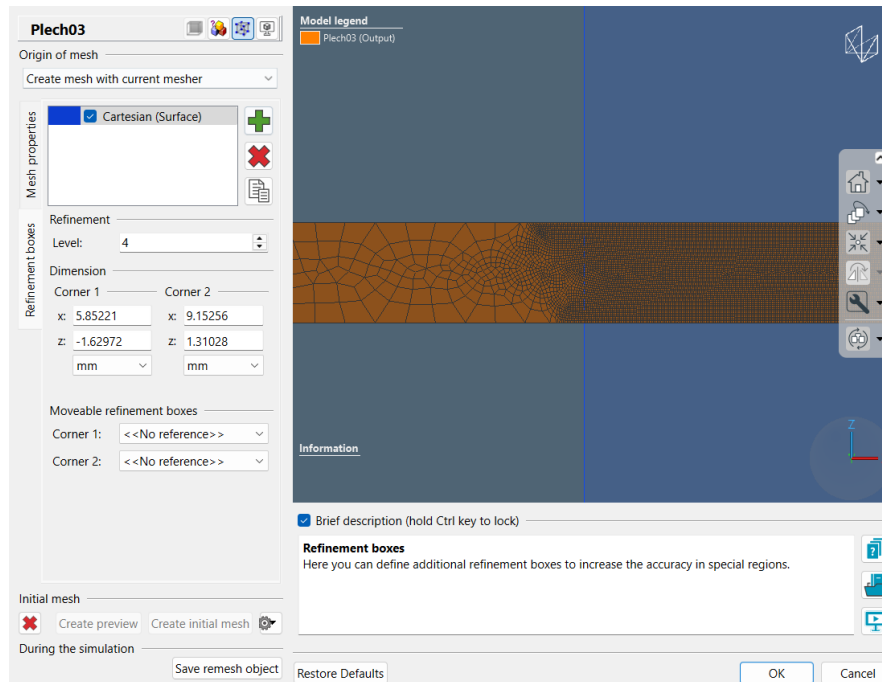


Fig. 2 Defining the sheet metal mesh

After adjustments and control, 2 simulations were performed for all experimental materials with different shear gaps to obtain the size of the tear-off angle. SolidWorks software was used to determine the tear-off angle. Experimental measurement of the tear-off angle on the shear surface by microscopic analysis was performed on a Keyence VHX-5000 digital microscope. Fig. 3 shows the experimental measurement of the tear-off angle of material sample A.

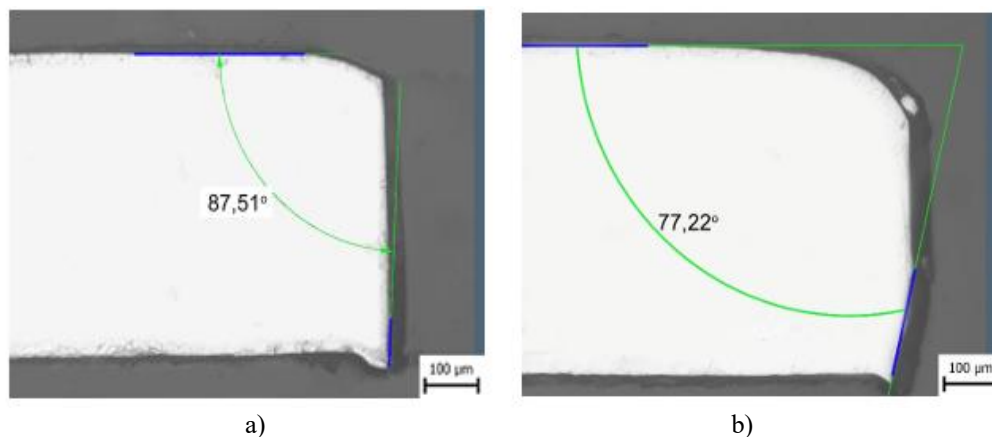


Fig. 3 Size of the tear-off angle for material A a) with 1% shear gap, b) with 10% shear gap

Fig. 4 shows the simulation and measured tear-off angle for sample material A, and in Tab. 3 the measured tear-off angle values from the experiment and simulation are compared.

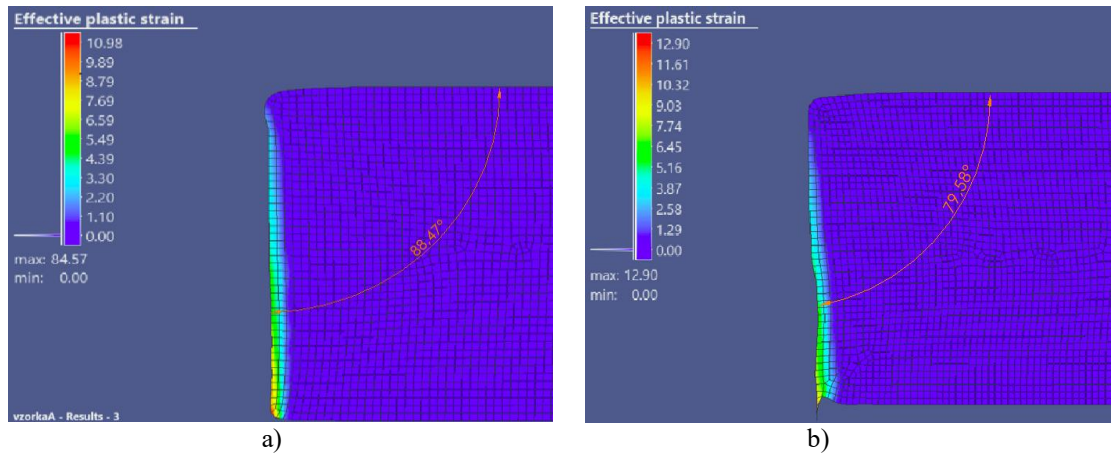


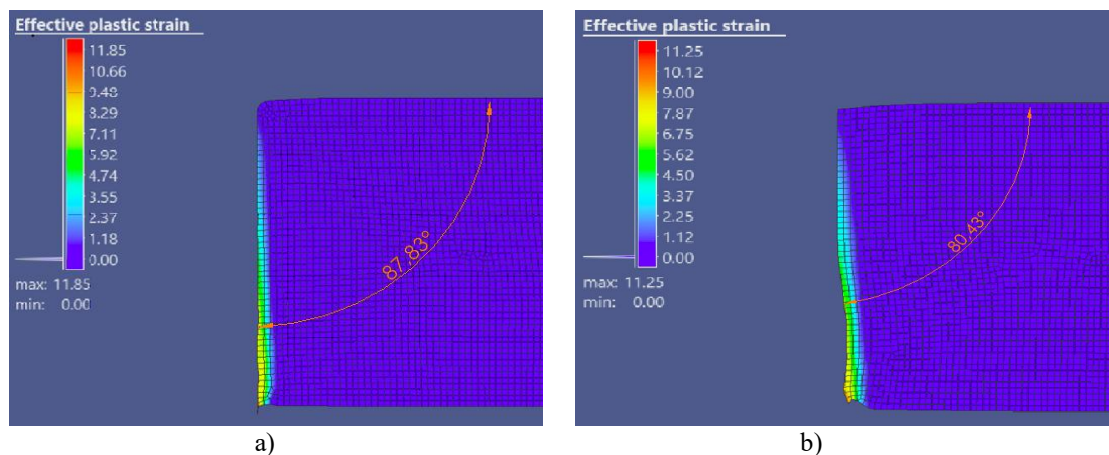
Fig. 4 The value of the tear-off angle from the shearing simulation of sample A
a) with 1% shear gap, b) with 10% shear gap

Tab. 3 Measured values of the tear-off angle of the material sample A

Sample	Shear gap [%]	Tear-off -experiment [°]	Tear-off -simulation [°]	Tear-off angle difference [°]
A	1	87.51	88.47	0.96
	10	77.22	79.58	2.36

From Tab. 3 it follows that the tear-off angle at 10% shear gap was smaller than at 1%, both in experimental measurement and in process simulation. At 10% shear gap, the difference in tear-off angle in experiment and simulation was 2.36°. At 1% shear gap, the difference in tear-off angle in experiment and simulation was only 0.96°. From Fig. 4 it is possible to read the size of the effective plastic deformation, where at 1% shear gap its highest value was 10.98 and at 10% shear gap the measured value was 12.90.

Fig. 5 shows the simulation and measured tear-off angle for sample material B, and Tab. 4 compares the measured tear-off angle values from the experiment and simulation.



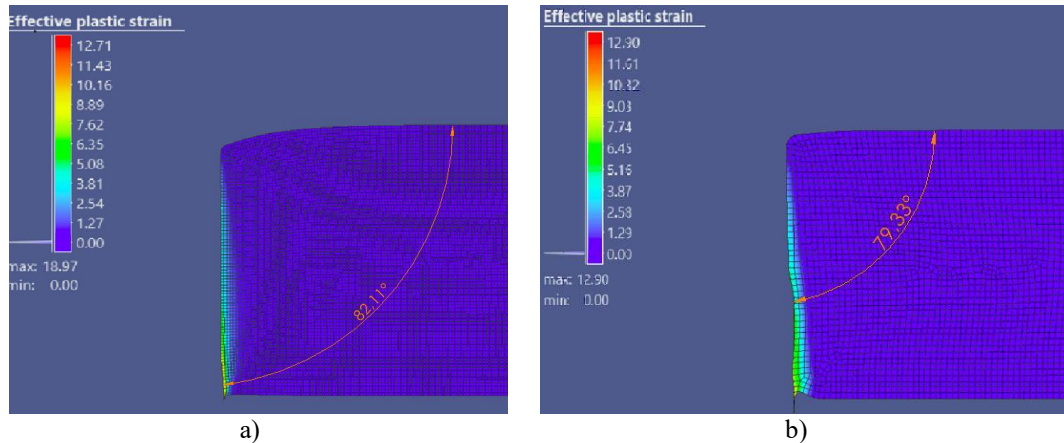
Obr. 5 The value of the tear-off angle from the shearing simulation of sample B
a) with 1% shear gap, b) with 10% shear gap

Tab. 4 Measured values of the tear-off angle of the material sample B

Sample	Shear gap [%]	Tear-off -experiment [°]	Tear-off -simulation [°]	Tear-off angle difference [°]
B	1	84.67	87.73	3.06
	10	77.13	80.42	0.29

From Tab. 4 it follows that the tear-off angle was smaller at 10% shear gap than at 1%, both in experimental measurement and in process simulation. At 10% shear gap, the difference in tear-off angle in experiment and simulation was 0.29° . At 1% shear gap, the difference in tear-off angle in experiment and simulation was 3.06° . From Fig. 5 it is possible to read the size of the effective plastic deformation, where at 1% shear gap its highest value was 11.85 and at 10% shear gap the measured value was 11.25.

Fig. 6 shows the simulation and measured tear-off angle for material sample C, and Tab. 5 compares the measured tear-off angle values from the experiment and simulation.



Obr. 6 The value of the tear-off angle from the shearing simulation of sample C
a) with 1% shear gap, b) with 10% shear gap

Tab. 5 Measured values of the tear-off angle of the material sample C

Sample	Shear gap [%]	Tear-off -experiment [°]	Tear-off -simulation [°]	Tear-off angle difference [°]
C	1	80.09	82.11	2.02
	10	70.82	79.33	8.51

From Tab. 5 it follows that the tear angle at 10% shear gap was smaller than at 1%, both in experimental measurement and in process simulation. At 10% shear gap, the difference in tear angle in experiment and simulation was up to 8.51° . At 1% shear gap, the difference in tear angle in experiment and simulation was 2.02° . From Fig. 6 it is possible to read about the size of the effective plastic deformation, where at 1% shear gap its highest value was 12.71 and at 10% shear gap the measured value was 12.90.

IV. RESULTS

From the measurement results (Tab. 3 – 5) we can conclude that the largest tear-off angle in the experiment and simulation was achieved for experimental material A at a 1% shear gap. The smallest tear angle in the experiment and simulation was achieved for experimental material C at a 10% shear gap. Also, this material achieved the largest difference in tear-off angles at both shear gaps obtained in the experiment and in the simulation. The measured tear-off angles were larger for all three experimental materials at a 1% shear gap than at a 10% shear gap. From the above, it follows that the size of the shear gap affects the size of the tear-off angle and thus the quality of the shear surface. For all the materials investigated, the size of the tear-off angle in the process simulation was larger than in the experiment for both investigated shear gaps.

V. CONCLUSION

The aim of the paper was to verify the influence of the shear gap on the quality of the sheared surface assessed by the size of the tear-off angle in three electrical sheets with different chemical compositions. Shear gaps of 1% and 10% of the thickness of the sheared material were used. The experimentally measured results of the tear-off angle were compared with the shearing simulation in the Simufact Forming program, which was performed under the same input conditions as the experimental measurement.

When evaluating the tear-off angle in the shearing area, it can be stated that the smallest tear-off angles were measured at 10% of the shear gap in all the materials studied, both in the experiment and in the simulation.

The results of the experiment indicate that when shearing electrical sheets with a thickness of 0.5 and 0.35 mm of different chemical compositions, the gap between the shear punch and the shearing die clearly affects the quality of the sheared edge, in our case assessed by the size of the tear-off angle. The experiment showed that in the case of the tested thicknesses of electroplates with increasing shear gaps, the size of the tear-off angle decreases, which worsens the quality of the shear surface. This results in increasing magnetic losses in electroplate products.

ACKNOWLEDGEMENTS

The authors are grateful to projects KEGA 018TUKE-4/2024, VEGA 1/0330/24 and APVV-21-0418.

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