METHOD OF DETERMINATION OF THE BOUNDARY STRENGTH OF PRESSED SHEETS OF CAR BODIES FOR CATEGORIES TO 1300 CM^3

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DOI: 10.17973/MMSJ.2017_03_2016154

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Pressed steel sheets, in this case compacted vehicle bodies represent the structure diversity of the non-homogeneous material. There is necessity to determine the shear strength for the development of the construction of new processing equipment (cutting) of steel sheets. To calculate the shear strength it is necessary to know the ultimate firmness of the material. For homogeneous materials this parameter is normally available in the tables. The article discusses the experimental detection of boundary strength of pressed metal of vehicle bodies. To gain some relevant statistical evaluation the samples of the car body have been divided into three groups according to the engine capacity. The experiment was evaluated by the following statistical methods, analysis of variance using the AIC criterion and Grubbs test for outliers. According to the analysis of the measured parameters the resulting mathematical model, which is used for determination of optimal values of boundary strength, has been established. The resulting mathematical model can be used to determine the boundary strength, which serves as an input parameter for the calculation of shear strength required for the development of new equipment designed for the processing of scrap metal, with cutting.

KEYWORDS

boundary strength, car bodies, steel, Grubbs test, non-homogenous material

1 INTRODUCTION

Studies carried out in recent times unequivocally emphasize that the era of rich and relatively cheap resources is coming to an end. Even today many companies face increases in the costs associated with obtaining basic materials. The lack of raw materials and the cost instability connected with this has an unfavourable impact on the development of the economy. There exist a number of ways to react to the looming situation. The main method could be described as support for the effective usage of resources, which enables the securing of higher value with lower outlays in order to use resources in a long-term sustainable way and to reduce undesirable effects on the environment. If, therefore, waste is to be accepted as a source of secondary raw materials which it will be possible to reintegrate into the economy, it will be necessary to devote constant attention to material recovery, which can contribute to a significant degree to a reduction in the exploitation of primary raw materials and at the same time provide new opportunities, among others those which may be considered as the most important, in other words opportunities of an economic character. In my work I will concentrate in particular on the reprocessing of old vehicles, with a concentration on the minimization of the volume of the chassis and its handling from the very beginning right up to its dispatching for final processing. One part of the work looks at facilities for the handling of the vehicle body, with the final share and the quality of the metal waste conditioned by the requirements of the processors.

2 PLAN OF THE EXPERIMENT

In this section of the article I focused on the planning of an experiment whose goal is the determination of the actual shear strength of presently operating facilities for shearing the chassis of old vehicles. The entire section dedicated to the planning of the experiment can be divided into several interrelated parts:

- Selection of experimental equipment
- Description of the experimental equipment
- Description of the principle of the experiment
- Description of the experimental samples

2.1 Selection of experimental equipment Subchapter

The basic criterion for the selection of an experimental facility was the constructional composition of the shearing equipment, which must correspond to the technical principle of shearing with inclined knives. Another criterion was the availability of such a facility. Equipment from the Acros-Henschel CIV600 firm satisfies the stated criteria.

Figure 1. CIV 600 Experimental **e**quipment

2.2 Description of experimental equipment

A machine from the Acros-Henschel firm, the CIV 600, was selected to carry out the experiment. The main criterion for the selection of this equipment was its constructional composition, which corresponded to the desired technical shearing with inclined knives. A second but not less essential criterion was the availability of this equipment. It is equipment designed for the complete processing of a variety of metal waste and scrap.

Table 1. Basic dimensions of the CIV 600 machine

Basic dimensions of the CIV 600 machine		[mm]
Length of the machine	**A**	12 500
Width of the machine	**B**	2 500
Height of the machine	**C**	3 355

Principle of CIV 600 compacting

The basic principle is the hydraulic pressing of two wings which close into each other from the outer side, creating inside a compressing chamber of a square shape. Movement of the compressing material into the shearing area is managed by a hydrometer (sliding block), which is fitted in the back part of the compacting area.

Principle of CIV 600 shearing

The shearer is manufactured as a massive cast, to which the knives are fixed at a certain angle since it involves technological cutting with inclined knives. The machine allows for the setting of the shearing gaps at optimal dimensions.

2.3 Principle of the experiment

The principle of the experiment consists in determining the actual shear strength during the cutting of the compacted metal chassis of old vehicles. The monitored value of the experiment is the pressure in the hydraulic valves necessary to deduce the power capable of shearing non-homogenous compacted material. Another monitored value is the thickness of the compacted metals. In order to be able to determine the shear strength with the deduced parameters it was necessary to perform the following transformations of the values into SI system units:

a) The calculation of the pressure for the force by the determination of the area of the hydraulic cylinders on which the force acts. This is a basic calculation of the pressure for the force.

b) The compacting thickness determined from the value of the maximal lift of the hydraulic cylinders and the subtracted value, which was measured with an interferometer.

Another parameter which influences the process of shearing non-homogenous metals from the compacted bodies of the old cars is the cross section of the compactor, which changes in dependence on the cutting point of the chassis. It can be assumed that at places with a reinforced body, the compacted material too will be stronger. In order to obtain the most precise values possible for a statistical evaluation, the cutting cycle used a span of 100 mm along the entire car chassis, the smallest movement possible for the given experimental equipment.

All the monitored values can be visually checked on the display which is part of the equipment. From the machine's control unit these are copied onto a USB device. The visual control display is shown in Fig. 2, with the monitored parameters highlighted.

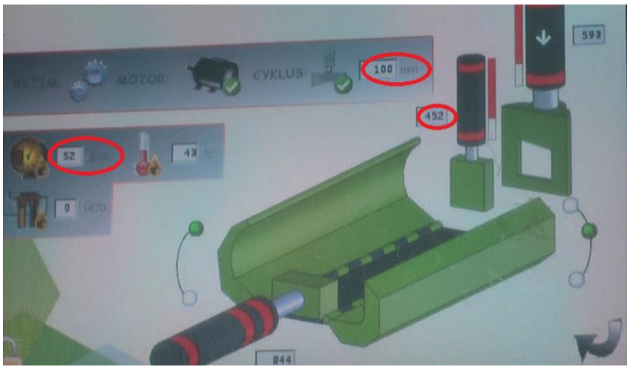


Figure 2. Display of the CIV 600 experimental equipment for visual control of the monitored parameters

2.4 Description of the experimental samples

Involved was a sample of the usual processing of the chassis of old cars, and so it is possible to claim that the experimental sample fully corresponds to the actual portfolio of written-off vehicles destined for processing in Slovakia.

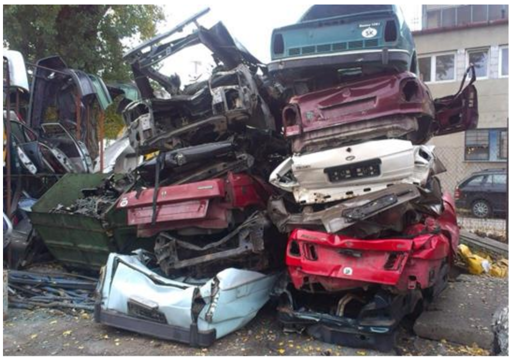


Figure 3. Experimental samples

3 DESCRIPTION OF THE EXPERIMENT

The preparation of the vehicles was carried out in harmony with the standard usual in this authorized company. This means that the samples were completely stripped so that it would be possible to run the experiment according to the plan that was created on the basis of previous analyses. About 30 cuts were made on each sample vehicle, with the cycle set at 100 mm. intervals. The experimental samples were transported to the working premises by a scraper loader controlled by an employee of the company where the experiment was carried out. After loading, the chassis was compacted under a previously set pressure. The compacting pressure was set at a constant value. The criterion of pressure value was defined with respect to the size and shape of the compacting area. After the compacting, the compacted material is moved to the shearing space by a rear hydraulic block. The course of the pressures in the hydro-motors of the shearing equipment during the shearing period was recorded. The shearing thickness of the compacted material was recorded by means of laser interferometers built into the machine. So the monitored values were the pressure during shearing and the corresponding thickness of the sheared material. Both monitored values could be visually checked on the machine's display and were automatically recorded on a USB device. The final phase after the shearing was the delivery of the outcome pieces to the sheared material stores.

Figure 4. Illustration of shear levels

4 ASSESSMENT OF THE MEASUREMENT OF THE BOUNDARY STRENGTH OF THE COMPACTED MATERIAL

This part was focused on an assessment of the results of the experiment for finding the boundary strength of non-homogenous compacted material. For the needs of my dissertation I will identify this value with the sign τMP (boundary strength of the non-homogenous compacted material). In the calculation of the actual boundary strength, I began with the generally known theoretic calculation of shear strength.

$$F_{St} = \frac{a_0^2}{\mathrm{tg}\lambda}\tau_{\mathrm{MP}} \qquad (1)$$

Where :

a_0 [mm] is the thickness of homogeneous shear material

λ [°] angle of inclination of the knife

τ_{MP} [MPa] boundary strength for non-homogenous material

After the transformation of this relation for the conditions of the experiment, where we worked with non-homogenous compacted material from the chassis of old vehicles, we obtained the following relation:

$$F_{St} = \frac{H^2}{tg\lambda}\tau_{MP} \qquad (2)$$

Then:

$$\tau_{MP} = \frac{F_{St}.tg\lambda}{H^2} \qquad (3)$$

Where :

H [mm] is the thickness of the non-homogenous sheared material, measured value,

λ - [°] angle of inclination of the knife, $\lambda = 10°$,

τ_{MP} [MPa] boundary strength for non-homogenous material

The thickness of the compacted material was calculated according to the following relation:

$$H = H_{P2} - H_{P1} \qquad (4)$$

Where :

H_{P2} equals the value 618 mm, which represents the value of the movement of the clamper at zero thickness of sheared material

H_{P1} is the monitored value of the movement of the clamper when shearing the experimental sample.

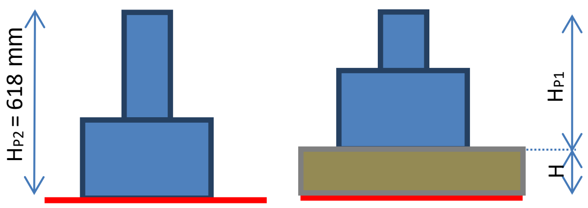
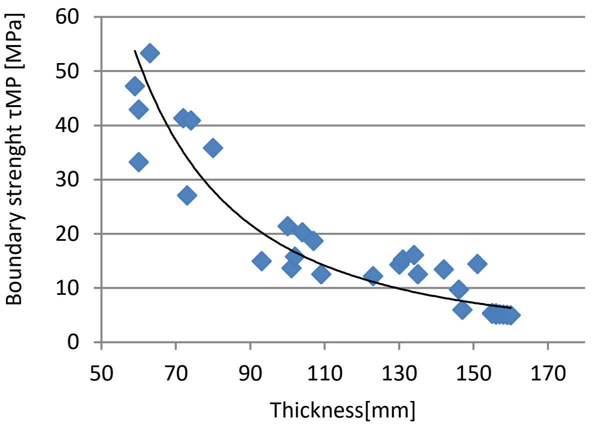


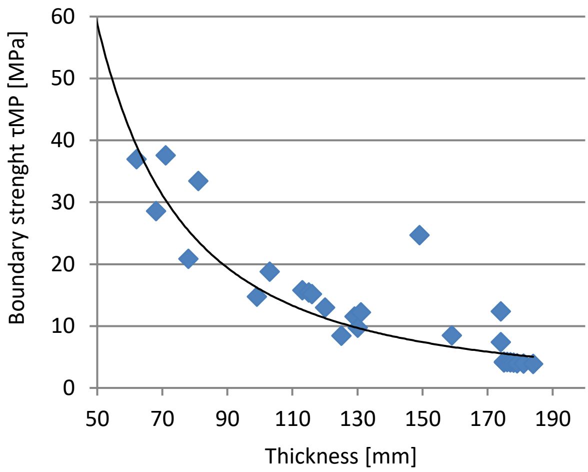
FIGURE 5. Diagram of the principle of calculation of sheared thickness

As with samples 1, 2 and 3 I processed and assessed all measured results from the experiments for all 12 experimental samples of the category of automobiles with a volume capacity of up to 1300 cm3. From the graphs shown above it follows unambiguously that with reducing thickness of the compacted material the boundary strength of this non-homogenous material increases. This phenomenon can be explained in the following way. The set pressure on the clamper is constant, in our case at a value of 320 bars, which represents 32 MPa. It can be explained simply that the clamper compacts until it reaches precisely this value. The more plastic the compacted material, the more it compacts, and accordingly the more its properties approach the properties of homogenous material. Prior to the shearing phase, compacting of the chassis takes place by means of the clamper. The compacting of the chassis itself is the process in which there occurs a random arrangement of the individual particles of the car body. And this "chaotic" arrangement to a significant degree influences the boundary strength τ_{MP} of the sheared non-homogenous material.



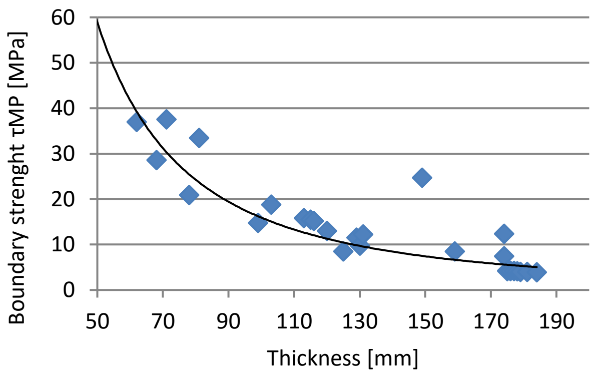
$R^2 = 0,8549$

Figure 6. Dependency boundary strength-sheared thickness of sample 1



$R^2 = 0,8917$

Figure 7. Dependency boundary strength-sheared thickness of sample 2



$R^2 = 0,8917$

Figure 8. Dependency boundary strength-sheared thickness of sample 3

5 STATISTICAL ANALYSIS OF THE RANGE OF BOUNDARY STRENGTH VALUES OF COMPACTED MATERIAL IN THE CATEGORY UP TO 1300 CM³

A statistical analysis of the range of the boundary strength of the sheared material in dependence on its thickness includes:

- ✓ The resultant mathematical function describing the dependency between boundary strength and sheared thickness for the individual volume categories and for all categories together.

- ✓ A graphic illustration of the dependency between boundary strength and sheared thickness for the individual volume categories and for all categories together.
- ✓ Analysis of the results of the Grubbs test of outlying values
- ✓ Tables of measured and calculated values for all experimental categories.
- ✓ A graphic illustration of the dependency between boundary strength and sheared thickness for the individual samples.
- ✓ Assessment of the executed statistical analyses.

Resultant power function in the form:

$$y = a.x^k \qquad (5)$$

Where :

a, k – numerical values of the exponential equation
µ A – result uncertainty.

The parameters of this function are stated in the following table 2.

Table 2. Parameters of this function

Equation $y = a.x^k$			**Uncertainty** µ A
Up to 1300 cm³	a	4.47 E4	6.5 E3
	k	-1,7	0,037

In tab. 2 are presented the real values of the resultant function for the dependency between boundary strength and thickness of the sheared material for automobiles with an engine volume of up to 1300 cm3.

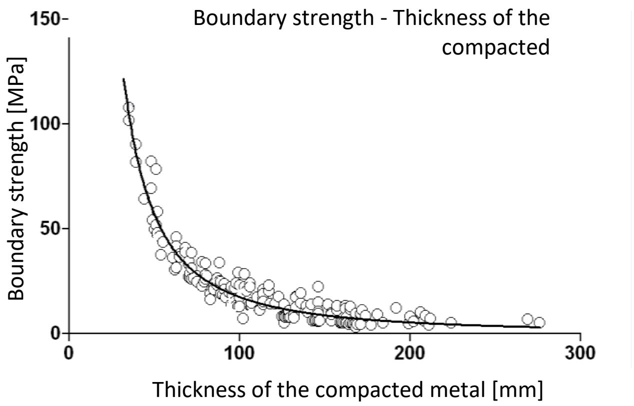


Figure 9. Dependence of boundary strength – thickness of sheared material for volume capacities of up to 1300 cm³.

5.1 Results of the Grubbs test of outlying values

The values of the measured thicknesses of the sheared material, along with the assigned calculated values of boundary strength, were used as test input parameters. The thickness values were graduated in 15 mm intervals. The thickness ranges that are not stated in the test results are homogenous, as confirmed in the performed test. For the calculated ranges, the relevant maximum value and also the alpha coefficient were determined. The maximum value is the outlying value and it may also be claimed that it is an exceptional value. The alpha coefficient represents the probability that we are rejecting the stated hypothesis. Essentially it is the probability of the occurrence of an outlying value in the given category of sheared thicknesses.

Test results:

Automobile engine volume up to 1300cm³

Thickness range of the sheared material [mm]/86-100: max. value =33.8; alpha= 0.05

Thickness range of the sheared material [mm]/116-130: max. value =23.11;alpha= 0.05

Thickness range of the sheared material [mm] / 146-160: max. value =22.44; alpha= 0.01

6 CONCLUSIONS

The boundary strength of a material is easily accessed information for a material that is homogenous, but I needed to know the boundary strength of compacted metal, which was a demanding task. Since the tables that form a usual part of the life of every engineer did not help, I had to proceed with an experimental determination of the boundary strength. In the first step it was necessary to experimentally determine the size of the shear strength. In my dissertation are a detailed description and a plan, as well as the methods and equipment used in the performed experiment. The result of the experiment was the determination of the shear strength necessary to cut the compressed metal. After further mathematical calculations it was possible to find the boundary strength of the sheared material (a detailed method of the calculation of the boundary strength is stated in the dissertation work). The results of the experiment for measuring the shear strength as well as the boundary strength were assessed by the standard methods. It was necessary to logically divide the sheared samples to achieve a reliable statistical evaluation. After the division of the samples, 3 groups appeared, these being:

- Engine volume up to 1300 cm³
- Engine volume from 1300 cm3 up to 1900 cm³
- Engine volume over 1900 cm³

In this paper I dealt exclusively with an assessment of the measured data in the category up to 1300 cm³.

ACKNOWLEDGMENTS

The research presented in this paper is an outcome of the project No. APVV-0857-12 "Tools durability research of progressive compacting machine design and development of adaptive control for compaction process" funded by the Slovak Research and Development Agency.

REFERENCES

[Akaike 1976] Akaike, H. Canonical correlation analysis of time series and the use of an information criterion. In: Mehra RK, Lainiotis DG (eds) System Identification: Advances and Case Studies, Academic Press, New York, pp 27-96

[COM/2007/0575 2007] Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions

[Dulebova 2011] Dulebova, L. et al. Recycling technologies in the automotive industry. (in Slovak), Journal of Engineering Magazine, June 2011, Vol. 6, No. 2., pp 50-56 ISSN 1335-2938

[Hladis 1999] Hladis, J. Logistics process dismantling of vehicles and their economic usefulness. (in Slovak), Journal International journal of machine tools & Manufacture, January 1999, Vol. 39, pp 1001-1016, ISSN-0890-6955

[Kovac 1978] Kovac, A., Jenkut, M. Forming machines (in Slovak), Bratislava: Alfa Publisher, 1978, 577 p., 302 0553

[Majer 2015] Majer, M. et al. Product specification for steel and cast iron scrap. (in Slovak) 2015

[Pilc 2014] Pilc, J., Stancekova, D. Fundamentals of machine tools. (in Slovak), Zilina: Publisher University of Zilina, 2004. 108 s. ISBN 80-8070-281-0

[Pokusova 2012] Pokusova, M. et al. Current Status perspectives waste of old vehicles in Slovakia, In: TOP 2012 - Technique of Environmental Protection, ed. Proceedings of the TOP, June, 2012. Bratislava: Slovak University of technology, pp 439-449. ISBN 978-80-227-3723-4

[Soos 2012 a] Soos, L., et al. Research technologies progressive recovery of waste from old cars, Final report of the project. Bratislava : Slovak University of technology Publisher, 2014.

[Soos 2012 b] Soos, L., Kolejak, M., Urban, F. Biomasa - renewable energy source. Bratislava : VERT Publisher, 2012. ISBN 978-80-970957-3-4

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