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# EXPERIMENTAL ANALYSIS OF STRESS - STRAIN STATE CIRCULAR SAW BLADE OF LARGE SIZE EXPOSED TO IMPACT LOADS

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## ABSTRACT
*During the cut-off workpiece, cogs of a circular saw blade suffer high impact loads. Therefore, influence of the shock to the deformation of the circular saw blade should not be neglected. The aim of this thesis is to analyze the tension and to check if the deformation of the circular saw blade behaves according to Hook 's law. Experimental tests were carried out with a striking pendulum which simulated the process of cutting off the workpiece in industrial conditions. To measure the stress - strain state have been appliedstrain gauges, sensor displacement and acceleration sensors. Tests were carried out with different numbers of cogs in engagement with the workpiece.*
**Keywords:** cutting off, circular saw blade, impact load, stress and strain

## 1. INTRODUCTION
During the cut-off, the material of the circular saw blade is exposed to various stresses, including: the effect of centrifugal force, the effects of the circumference of the saw, the effects of different sizes and shapes of cogs and the material of the disc, from the cutting force of the contact (shock) the circular saw blade makes with the workpiece, from compound circular saw blade and the clamping plate and of residual stress [1]. This experiment simulated the impact of the circular saw blade to the workpiece in case the circular saw blade is not spinning fast enough.
Shock is a very complex phenomenon and it is impossible to define completely without introducing certain hypotheses about the structure of the body [2]. Impact force operates in a very short time interval and reaches a certain value. In the process of shock, impact force increases from zero to some maximum value, and then decreases to zero at the time of termination of the contact. Therefore, the collision phenomenon is connected with the deformation of the body about the point of contact, where they must take into account the elastic properties of the body.
Of these stresses, this paper is based on the interaction of a circular saw blade and the workpiece wherein was applied strain gage method stress and strain measurements on selected critical areas of the circular saw blade, while simultaneously measuring the displacement and acceleration.
Of the measured displacement and the known material properties, such as Young's modulus of elasticity and Poisson's number, in this paper are defined the absolute values and direction of these stresses. During the measuring,it is assumed there is a linear relation between the tension and deformation (in the linear-elastic range i.e. in the scope of the Hook's law $\sigma = \varepsilon E$ ), where there is: $\sigma$ - the normal stress at the point of measurement on the disc [MPa], and $\varepsilon$ - strain at the point of the strain gauge [microns/m].
During the examination of the structure in which is the planar state of stress (case of circular saw blade as a thin plate of constant thickness burdened resistance processing)are required at least two strain gauges (which are arranged perpendicular to each other) and that in the case of known major directions of stress. After the measured major strain $\varepsilon_1$ and $\varepsilon_2$, by Hook's law it can be calculated by the main normal stresses in the measured point [3]:

$$\sigma_{1,2} = \frac{E}{1-\upsilon}\cdot\frac{\varepsilon_a+\varepsilon_c}{2} \pm \frac{E}{\sqrt{2}(1+\upsilon)}\sqrt{(\varepsilon_a-\varepsilon_b)^2+(\varepsilon_c-\varepsilon_b)^2} \qquad \text{... (1)}$$

and the angle $\varphi$ of principal stress direction [4] is determined by the angle $\Psi$ according to the expression

$$tg\psi = \left|\frac{2\varepsilon_b-\varepsilon_a-\varepsilon_c}{\varepsilon_a-\varepsilon_c}\right|\left|\frac{N}{D}\right| \qquad \text{... (2)}$$

As normal and tangential tensions are actingin asection of the circular saw blade, it is necessary to determine the equivalent tension, which includes various effects of tangential tensions to the tension status. Thus, the equivalent (reduced) tension is a normal uniaxial tension, in which the construction in terms of strength has the same effect as acting multiaxial stress.
Equivalent stress is calculated according to the hypothesis of the maximum specific deformation work (Huber, von Mises, Hencky) wherefor ductile material, as it is the material of the circular saw blade, for biaxial load, the next expression is valid:

$$\sigma_{ekv} = \sqrt{\sigma_1^2-\sigma_1\sigma_2+\sigma_2^2} \qquad \text{...(3)}$$

## 2. EXPERIMENTAL TESTING

Experimental tests were carried out in pilot plant terms to console model of circular saw blade (CSB) 1900mm diameter and 10 mm thickness (Figure 1).

*Figure1. Console modelassembly CSB*

*Figure2. CSB with a impact pendulum, strain gauges and acceleration sensors*

*Figure 3. Encoder movement CSB*

To measure the stress-strain state in dynamic conditions, an impact pendulum is applied (Figure 2) with a force sensor attached to its piston. Moving the piston from its equilibrium position at defined distances (1100 ÷ 1500) mm from the impact zone in steps of 100 mm simulated the impact load on the circular saw blade over theholder and steel plates that emulate resistance in forming sawdust (Figures 4, 5).

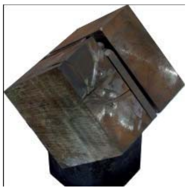


*Figure4. Holder of coged plates*

*Figure5. Coged plates with 2, 3, 5 and 6 cogs*

## 3. TEST RESULTS

Due to the volume of testing, this thesis presents the typical diagrams for one testing only and it is an attack on the two cogs, and the complete results are shown in Tables 1 and 2. Due to mechanical failure during initial testing, deformation could not be registered on the strain gauge M5.

*Table1. The values of peak stress at the reference impact loads*

| The case of impact load | Impact force | Maximum equivalent stress MPa The measurement site | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | M1 | M2 | M3 | M4 | M6 | M7 | M8 | M9 | M10 | M11 | M12 | M13 | M14 |
| Z2 - 1200 | 6676 | 13 | 44 | 76 | 25 | 1 | 6 | 7 | 15 | 12 | 8 | 23 | 19 | 2 |
| Z2 - 1300 | 7707 | 16 | 56 | 295 | 41 | 4 | 9 | 11 | 18 | 14 | 12 | 25 | 95 | 3 |
| Z2 - 1400 | 8508 | 22 | 58 | 355 | 61 | 3 | 15 | 25 | 36 | 17 | 15 | 31 | 136 | 10 |
| Z2 - 1500 | 10424 | 133 | 173 | 488 | 121 | 2 | 59 | 85 | 105 | 22 | 3 | 51 | 244 | 41 |
| Z3 - 1200 | 6855 | 9 | 14 | 37 | 19 | 2 | 6 | 1 | 39 | 41 | 7 | 128 | 15 | 5 |
| Z3 - 1300 | 8087 | 6 | 98 | 211 | 66 | 1 | 23 | 62 | 61 | 86 | 10 | 130 | 94 | 13 |
| Z3 - 1400 | 9645 | 14 | 103 | 299 | 96 | 3 | 41 | 59 | 75 | 20 | 41 | 164 | 124 | 14 |
| Z3 - 1500 | 10774 | 19 | 124 | 385 | 114 | 4 | 56 | 110 | 89 | 54 | 18 | 183 | 193 | 17 |
| Z5 - 1200 | 6401 | 5 | 35 | 61 | 15 | 1 | 3 | 1 | 3 | 5 | 1 | 17 | 14 | 1 |
| Z5 - 1300 | 7660 | 34 | 88 | 190 | 60 | 1 | 31 | 76 | 46 | 28 | 6 | 140 | 87 | 3 |
| Z5 - 1400 | 8813 | 36 | 108 | 235 | 80 | 2 | 51 | 91 | 77 | 33 | 4 | 186 | 122 | 11 |
| Z5 - 1500 | 10813 | 110 | 140 | 294 | 111 | 3 | 72 | 81 | 98 | 74 | 107 | 23 | 136 | 12 |

*Table2. Test results of circular saw blade*

| The case of impact load | Impact force | Measurement results | | |
|---|---|---|---|---|
| | | acceleration | | displacement |
| | | acceleration sensor AS1 | acceleration sensor AS2 | displacement sensor DSCSB |
| | N | mm/s$^2$ | mm/s$^2$ | mm |
| Z2 - 1200 | 6676 | 0,408÷2,119 | 0,381÷1,007 | 0,058 |
| Z2 - 1300 | 7707 | 2,938÷3,040 | 2,275÷2,280 | 0,197 |
| Z2 - 1400 | 8508 | 1,571÷5,573 | 2,510÷5,625 | 0,222 |
| Z2 - 1500 | 10424 | 3,272÷5,656 | 2,004÷3,971 | 0,280 |
| Z3 - 1200 | 6855 | 0,464÷0,554 | 0,297÷0,377 | 0,120 |
| Z3 - 1300 | 8087 | 0,830÷1,007 | 0,287÷1,320 | 0,137 |
| Z3 - 1400 | 9645 | 2,964÷3,042 | 2,959÷5,646 | 0,150 |
| Z3 - 1500 | 10774 | 2,250÷4,362 | 1,612÷2,450 | 0,244 |
| Z5 - 1200 | 6401 | 0,402÷1,503 | 0,261÷0,657 | 0,143 |
| Z5 - 1300 | 7660 | 3,470÷3,674 | 1,884÷4,665 | 0,154 |
| Z5 - 1400 | 8813 | 6,100÷7,232 | 3,788÷5,406 | 0,237 |
| Z5 - 1500 | 10813 | 4,795÷4,978 | 0,369÷2,332 | 0,369 |

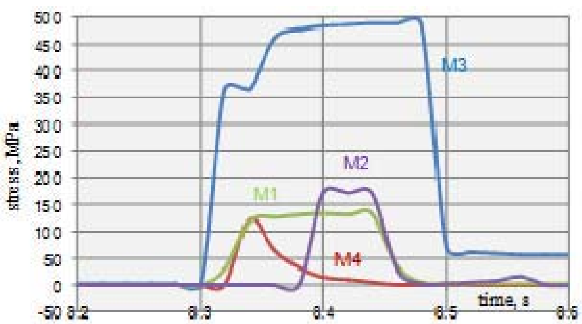



*Diagram 1. Stresses at measuring points M1 ÷ M4 on impact on two cogs – test 1500*

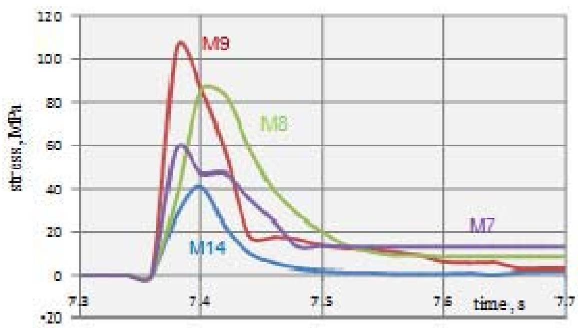
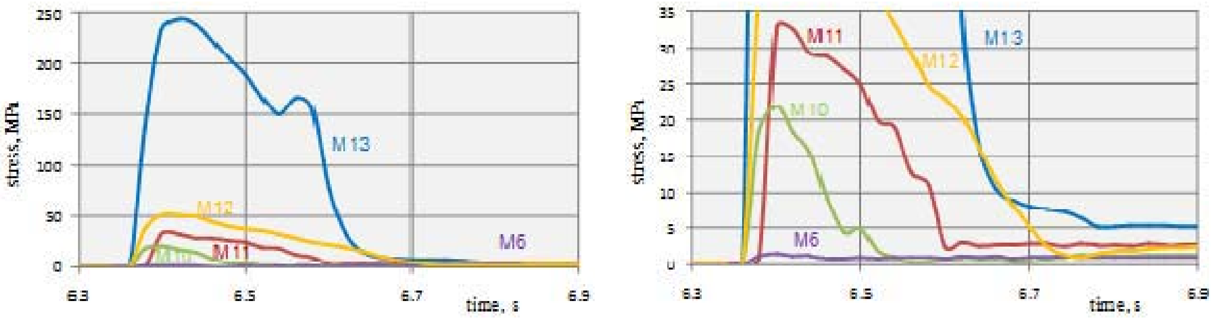



*Diagram 2. Stresses at measuring points M7, M8, M9, M14 on impact on two cogs – test 1500*




*a) The curves of stress* *b) Enlarged detail stress*

*Diagram 3. Stresses at measuring points M6, M10, M11, M12, M13 on inpact on two cogs – test 1500*

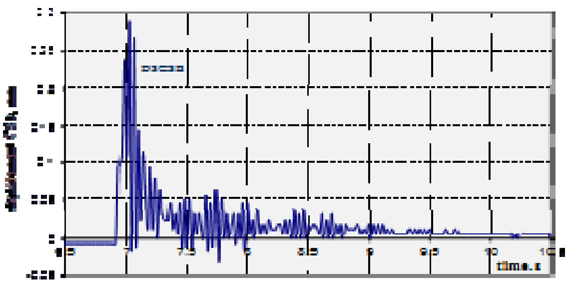


*Diagram 4. Displacement of circular saw blade on inpact on two cogs– test 1500*

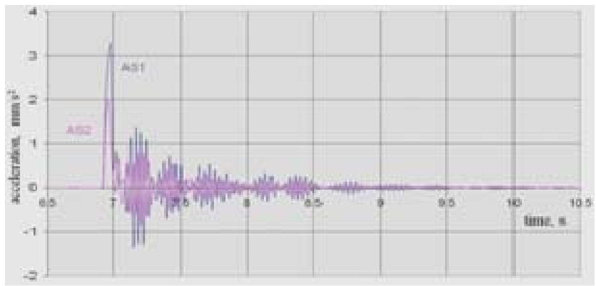



*Diagram 5. Accelerations of circular saw blade on inpact on two cogs– test 1500*

## 4. CONCLUSION

1. In the area between two cogs equivalent stresses have the highest values due to a sudden change in the geometry of the cog, which causes the appearance of stress concentration.
2. The largest measured equivalent stress was at the cog root M3 upon impact on the two cogs- test 1500 which amounted to 488 MPa.
3. At striking point, impact force stress is theoretically infinitely large, because the final forces are acting on an infinitely small area. In reality, at the striking point there is some material flow, so the result is that the force is distributed by the final surface.
4. With the cessation of application of impact loads, deformations of circular saw blade records toothing did not fully offset, as there were plastic deformations. Thus, the strain did not behave as stated by Hook's law, according to which the normal tension is proportional to axial deformation. As normal tension exceeded theyield point of the material, there have been permanent (irreversible) deformations. Point yield is the level of stress that is greater than that which may be made elastic. Since the material of the circular saw blade at this point deformed without crash, it is a plastic or ductile deformation.
5. Diagrams 4 and 5 present circular saw blade flutter, ie. the case when the angular frequency of free vibrations is not very different from the circular frequency of forced vibrations.

## 5. REFERENCES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