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Stress Fields Optimization of Rotating Saw Blades

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Abstract. In practice, conventional saw blades are at the present optimized with different types of grooves. It has been found that by cutting various symmetrical shapes in the body of the rotational saw blades, vibration and noise are significantly reduced. On the other hand, by making such openings, the integrity of the discs will be weakened, causing an increase in the stresses induced by the centrifugal forces. These advantages can also be demonstrated by the experimental mechanics of rigid bodies by following certain procedures and selecting the appropriate experimental method. For this purpose, the work will compare 3 alternative designs of anti-vibration discs, which will be analyzed using the optical method of experimental mechanics, namely the PhotoStress method. The expected output will be an experimental analysis of the stresses arising from the centrifugal forces in the aforementioned alternative proposals.

Introduction

Based on the primary analysis of the time response of vibrations and the measurement of noisiness of the authors Kopecký and Rousek, an apparent relationship was found between the excessive vibration of the disc body and noisiness. In the area of n = 3200 and 3400 rpm, an apparent peak increase was noted of the disc noise signal by 5 to 7 dB above the standard noise level. An absolute increase reached a level of Lp = 99 dB. These conditions were gone with by unpleasant whistling. [1]

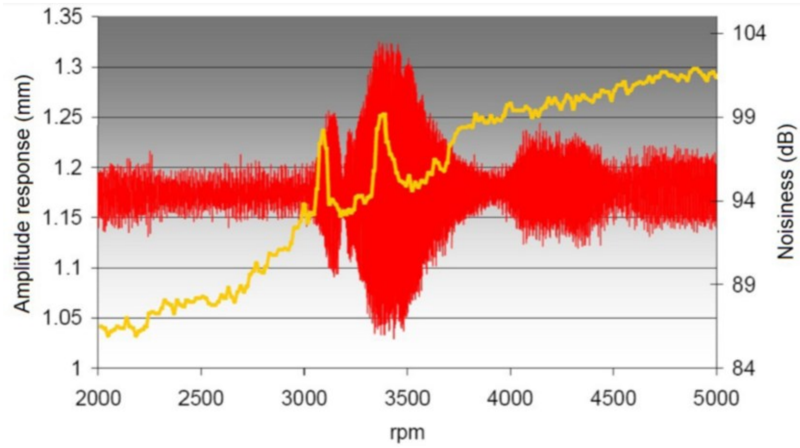

Fig. 1: Analysed saw blades [1]

Description of cutting forces in *x* and *y* directions are shown in Fig. 2. The forces are greater in both directions when the maximum number of teeth is in the workpiece just before time t2 and before cutting through the workpiece. As the blade passes the time t2 and is fed downward, the force reduces while the number of teeth that are in touch with the workpiece decreases. It is also shown that a dull blade requires greater force in both directions to cut a slot which shorten the tool life, increase the machining cost, and need to be replaced or re-sharpened. [2]

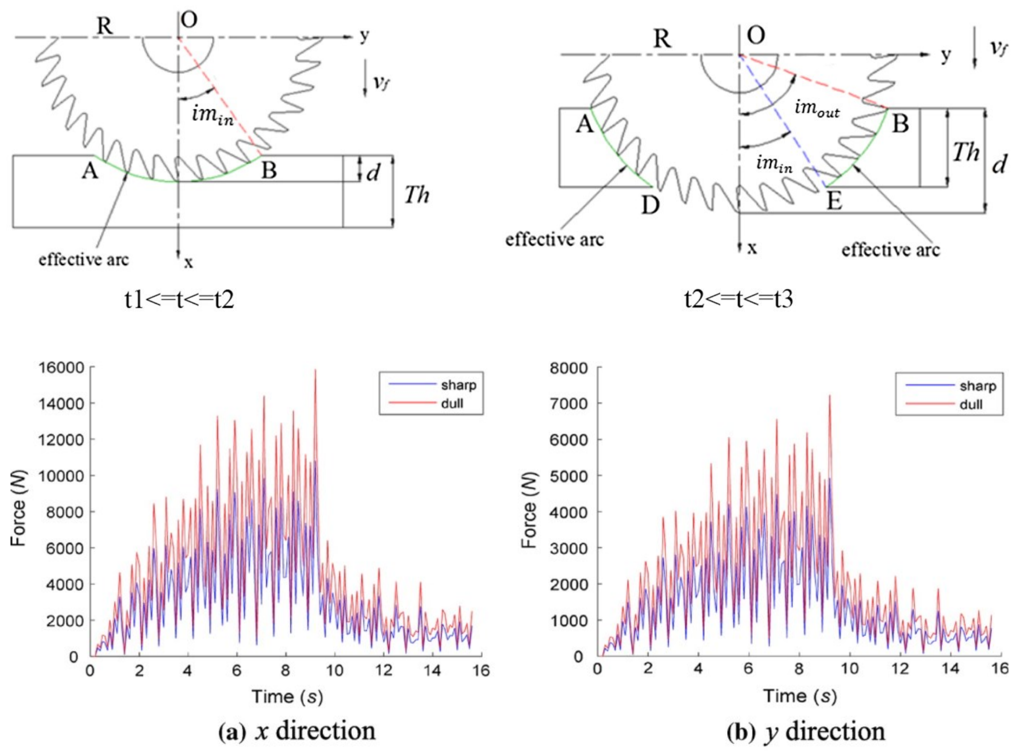

Fig. 2: Analysed saw blades [2]

In most cases, the wood is cut at high speed to achieve better surface quality and efficiency. For that reason, it is necessary to reduce blade vibrations that cause manufacturing inaccuracies, faster tool degradation, noise, higher energy costs. As a result, certain anti-vibration openings have been made, which are cut out in shapes of rounded grooves, which reduce these adverse effects. On the other hand, by cutting such optimization openings, the integrity of the disc will be weakened. Here comes the question of how the maximum stress amplitude caused by the centrifugal forces of such anti - vibration discs will increase. 0-4Chyba! Nenalezen zdroj odkazů.

Submitted paper is focused on measuring the stresses caused by the centrifugal forces on rotating discs using reflective photoelasticimetry, (PhotoStress), which is one of the experimental methods of mechanics. This issue has already been addressed by the authors in articles [5-8], the most important contribution to this work was the analysis of the rotor model, by which the experimental part will be based on. The experimental samples will represent the components of the real use i.e. saw blades, which will be made of PS- 1A photo elastic material, cut by water jet method. The experimental analysis of these samples will be comparing in terms of increase in maximum stress response at the anti-vibration discs caused by centrifugal forces [9-12].

Production of experimental samples. The experiment, which is realized, should correspond as much as possible to the real operating conditions. On this basis, samples respectively models were produced that match the exact dimensions of real saw blades.

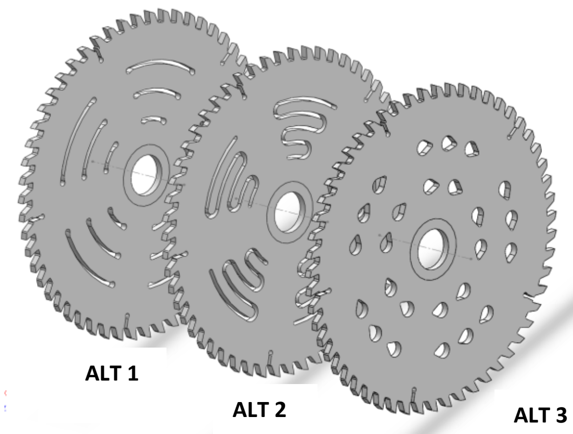

Fig. 3: Analysed saw blades

For the production of samples was used photosensitive material PS - 1A 3 mm thick from Vishay company. The proposed discs shapes were made using the water jet cutting method of Watting, s.r.o. - Prešov. Fig. 1 shows the design of all saw blades alternatives with optimization grooves that will be analysed. It is possible to notice five symmetrically spaced grooves around the periphery in every case, representing the so-called expansion grooves designed to protect teeth, resp. cutting segments against degradation. Mounting hole has a diameter of 20 mm which is commonly used for small circular saws.

The most important part of design are anti-vibration grooves. They are used to reduce the amplitude of the vibration frequency at the desired speed on the rotating discs. Their principle is that by adding a certain number of holes in the body of disc, its integrity is reduced as well as stiffness, so the oscillation will be reduced. These optimization openings, on the other hand, also have the influence of adjacent notches, when appropriately positioned that cause optimal distribution of stress response during cutting process.

Modification of the construction part for mounting rotating discs. The threaded end of the servomotor shaft with an M5 thread and the following 7,5 mm step Fig. 2 had to be adjusted for the possibility of mounting a disc with a 20 mm hole in order to achieve the most realistic results compared to practice, accordingly the mounting device shown in Fig. 2. The protruding shaft of the motor was relatively short and therefore it was necessary to provide the additional fixation - by nut M5 at the threaded end of the shaft. The M20 thread on the flange has been cut in the sense of counter-rotation of the tool for obvious reasons.

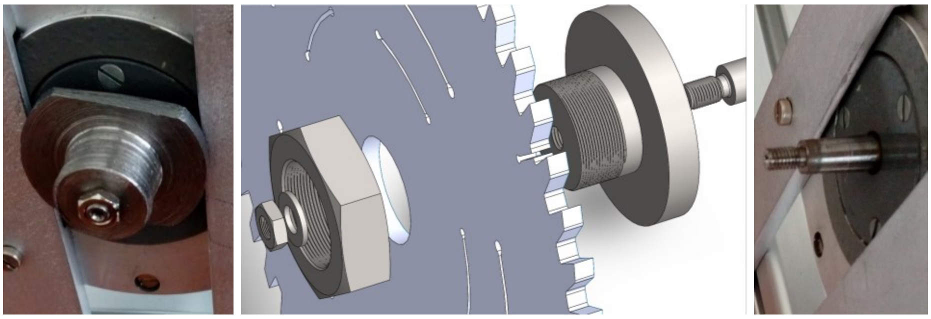

Fig. 4: Modification of the mounting part of structure

On the servomotor shaft was clamped and locked reducing flange to which a disc made of photosensitive material was attached. The speed was adjusted using a phase converter in a sequence of 3000, 3500, 4000, 4500, 5000 RPM, which corresponds to the most commonly used velocities in practice.

Analysis of centrifugal forces on rotating discs using by LF/Z-2 polariscope. To measure the stress response, it was necessary to assemble a photoelasticimetric assembly that can be seen on Fig. 3. A LF / Z-2 polariscope (5) was attached to the stand plate (tripod) and a strobe (4) Strobex Model 135 M-11 was then mounted. Another part of the measuring chain consisted of a frame (1) made of aluminum MB profiles, on which was mounted a servomotor (2) controlled by a phase converter (3) for speed setting.

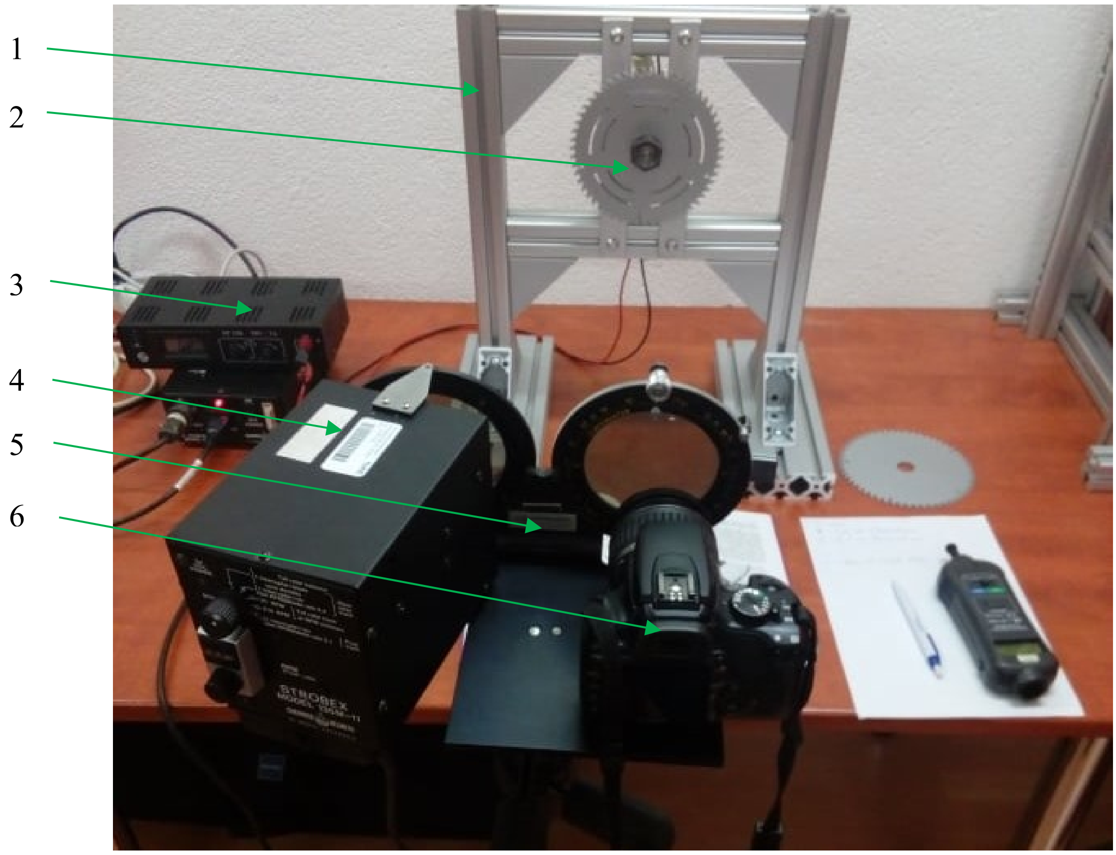

Fig. 5: LF/Z-2 polariscope measuring chain

Further there was a camera (6) to document the results of the experiment and a speedometer to set the desired speed.

The distribution of the stress fields due to centrifugal forces was measured for 3000, 3500, 4000, 4500, 5000 RPM on 3 altenative saw blades designs.

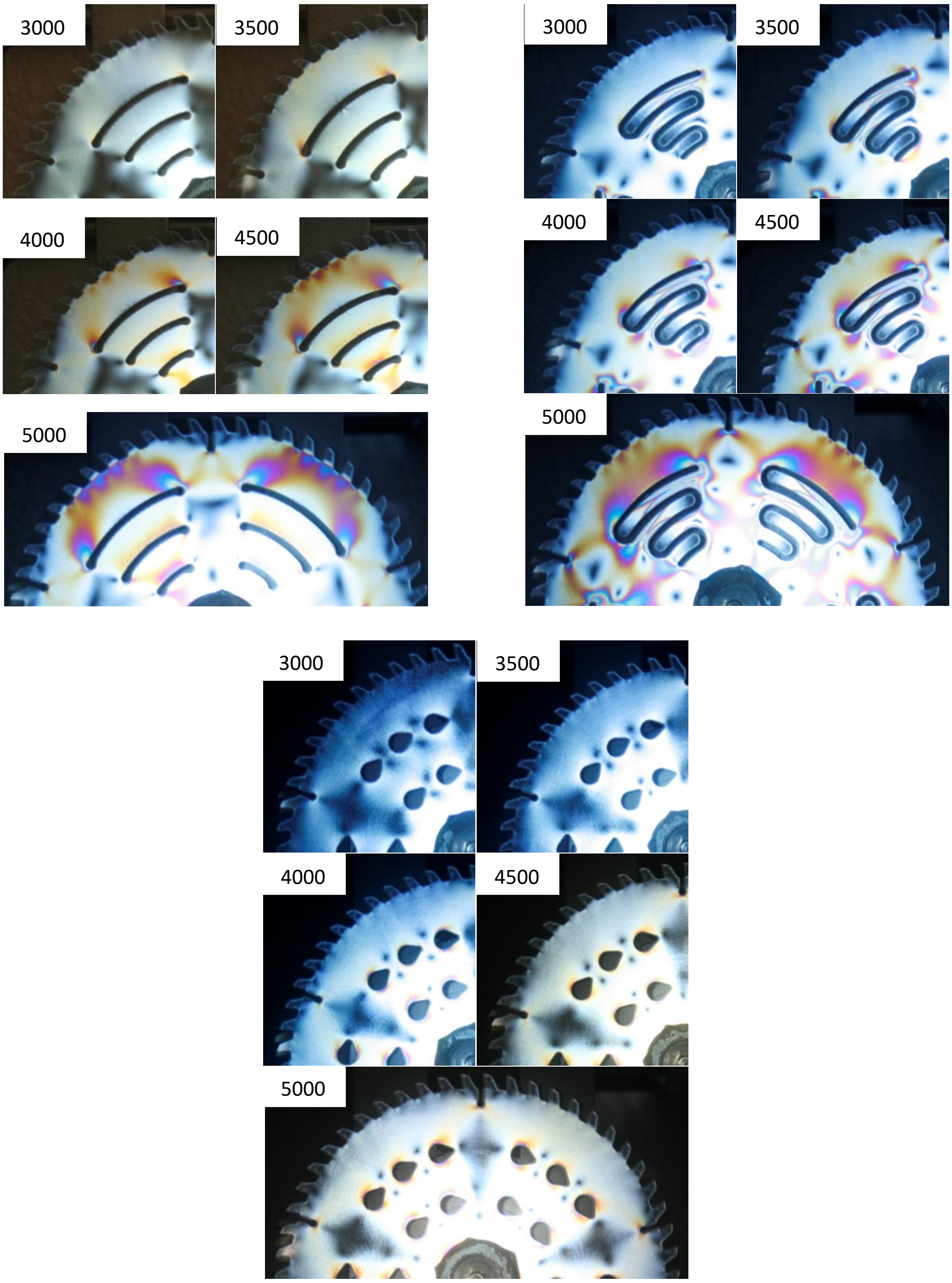

Fig 6: Series of stress responses from CF

By the using of compensator the following main stress responses were found Table 1. Data up to 5000 RPM were measured by experiment, and further values up to 10000 RPM from the safety point of view were determined numerically.

The stress values in the table are given in units of MPa and represent the intensity of the stress, i.e. difference of principal normal stresses.

Table 1: Results of experimental measurements

RPM	Alt 1 [MPa] (PS1-A)	Alt 2 [MPa] (PS1-A)	Alt 3 [MPa] (PS1-A)
3000	1,85	4,89	1,46
3500	2,52	6,65	1,99
4000	3,29	8,69	2,6
4500	4,16	11	3,29
5000	5,14	13,58	4,06
6000	7,4	19,55	5,85
7000	10,01	26,61	7,96
8000	13,15	34,75	10,4
9000	16,65	43,98	13,16
10000	20,55	54,3	16,25

The graph on Fig. 5 represents the dependence of the number of revolutions on the stress response on the measured samples. According to the graph, it is clear that at the same speed, the alt 3 disc produces the lowest stress response and the alt 2 disc produces the greatest stress response due to centrifugal forces.

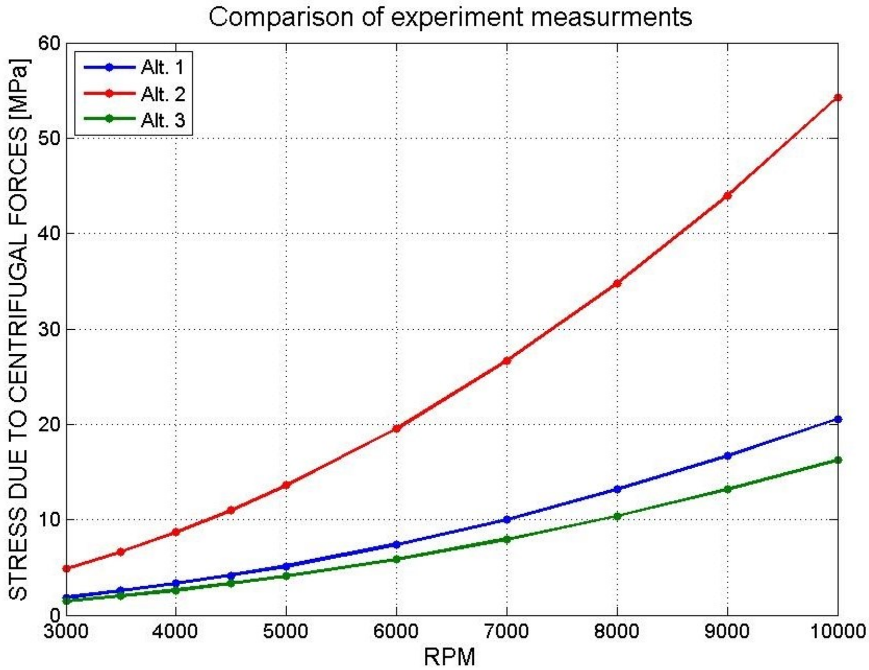

Fig 7: Interpretation of measured data

However, since these samples do not correspond to real material, it is necessary to recalculate the given experimental results for a real steel disc based on equilibrium of the finite element of rotating disk.

In accordance with the similarity criterion that takes into account the ratio of the actual part to the model, we can write relationship

$$\frac{F_{os}}{F_{om}} = \frac{m_s \omega_s^2 r_s}{m_m \omega_m^2 r_m}, \tag{1}$$

where index s denotes the real part and index m denotes the model.
Obviously, the angular velocity ω and the dimension of the disc radius r will be the same when comparing the photo elastic and steel components and therefore it is possible to write

$$\frac{F_{os}}{F_{om}} = \frac{m_s \omega^2 r}{m_m \omega^2 r} = \frac{m_s}{m_m}, \tag{2}$$

The difference between the magnitude of the centrifugal forces, respectively the stresses exerted by these forces will be linearly dependent. On this basis, it is sufficient to derive the ratio between individual materials for only one sample, in this case for the alternative 1. Mass of the photo elastic model of conventional disc m_m = 77,05 g and the real steel disc m_s = 469,54 g were measured. Consequently, it is possible to derive

$$\frac{F_{os}}{F_{om}} = \frac{m_s}{m_m} = \frac{469{,}54g}{77{,}05g} = 6{,}1, \tag{3}$$

The results of the sample experiments can be easily transformed to the maximum stress values for a real steel discs multiplying by this constant.
Thus, the results of the maximum stress differences for 10000 RPM scenario will be 20,55 MPa for the 1st alternative, 54,3 MPa for second one and 16,25 MPa for the last variation of the samples. By multiplying the results of the experiments on photosensitive samples by the ratio according to (10), one obtain the stress values for real steel samples, i.e. from material 75Cr1 (DIN 1.2003), (STN 19418) for which yield strength is 415 MPa. Thus, the maximum stress from the centripetal forces on each steel disc at 10000 RPM will be as follows: Alt.1 = 125,36 MPa, Alt.2 = 331,23 MPa and Alt.3 = 99,16 MPa. Since none of these values exceeded the yield strength, all 3 alternatives are suitable.

Conclusion

Experimental comparison of 3 alternating saw blades with anti-vibration grooves applied showed an increase in the stress response caused by centrifugal forces compared to commonly used blades. Since none of these discs was exceeded by the yield strength, it is possible to proceed with another experimental measurement, namely the measurement of oscillation during rotation by means of digital image correlation and subsequently the measurement of temperature field propagation.

Funding

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