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THE SHAPES OF TEETH OF CIRCULAR SAW BLADE AND THEIR INFLUENCE ON ITS CRITICAL ROTATIONAL SPEED

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Abstract

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The main problems during cutting with circular saw blade are inaccurate cut, low quality of surface, high level of noise. These adverse effects are related to oscillation of circular saw blade. This oscillation cause adverse effects not only on workpiece but also on tool. In some case the circular saw blade reaches the value of critical rotational speed which leads to its instability and cause the oscillation of blade which may leads to destruction of tool. So the reduction of the amplitude of oscillation is essential for removing the adverse effects. This paper deals about influence of shapes of teeth as a type of modification that has positive effect oncritical rotational speed of circular saw blade. The parameters of studied models of circular saw blade were 42 number of teeth and the height of teeth with slice from sintered carbide was 14 mm. The variable parameter was the ratio between surface of teeth and surface of teeth gap. In this study was used computer software Creo Parametric 1.0 for obtaining natural frequencies of studied models. This software uses in analysis finite element method (FEM). There were done some steps to idealize the models. For calculating static and dynamics natural frequencies of modelswere used modal analysis. The critical rotational speed was calculated from obtained results by Creo Parametric 1.0 and compared on 5 models of tool.

Keywords: circular saw blade, modal analysis, natural frequency, critical rotational speed, FEM

INTRODUCTION

The main problems during cutting with circular saw blade are inaccurate cut, low quality of surface, high level of noise. These adverse effects are related to oscillation of circular saw blade. This oscillation cause adverse effects not only on workpiece but also on tool. In some case the circular saw blade reaches the value of critical rotational speed which leads to its instability and cause the oscillation of blade. which may leads to destruction of tool. So the reduction of the amplitude of oscillation is essential for removing the adverse effects (Svoreň, 2011). In the present circular saw blades are constructed with variable modifications of body – variable types of slots. These modifications are aimed to reducing or eliminating adverse effects. So this paper deals about influence of shapes of teeth as a type of slot that have positive effect on critical rotational speed of circular saw blade.

The phenomenon of oscillation was subject in many scientific publications and for its reduction were used any types of modifications of tool. It could be excepted that teeth gap could be considered as a type of slot and has an influence on natural frequencies either statics or dynamics. In the past the research based on different types of slots, natural frequencies and critical rotational speed was subject in many scientific papers (HolØyen, 1987; Mote, 1965; Nishio and Mauri, 1996; Schajer and Mote, 1983; Yu and Mote, 1987; Svoreň, 2011; Stachiev, 1970; Veselý *et al.*, 2012)

In the paper is used the finite element method. Its applicationon oscillation and determination of the natural frequencies of circular saw blade was research area of many authors (Gogu, 1988; Leopold and Münz, 1992; Michna and Svoreň, 2007; Ekevad *et al.*, 2009; Droba, Paulíny and Svoreň, 2013).

The aim of this paper is to demonstrate the influence of shapes of teeth on critical rotational speed and design the model of circular saw blade with the highest critical rotational speed with respect of given parameters.

MATERIALS AND METHODS

The subjects of research were models of circular saw blades with 42 teeth and the height of teeth with slice from sintered carbide was 14 mm. Additional static parameters of models are shown in Tab. I. The variable parameter was the ratio between surface of teeth and surface of tooth gap that is shown in Tab. II. There were created 5 models of blades with these parameters.

I: *Static parameters of model*

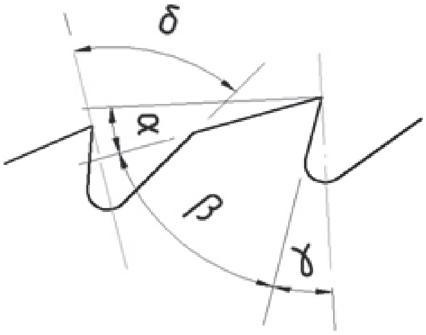
Outer diameter [mm]	350
Inner diameter [mm]	30
Outer diameter of collars [mm]	110
Number of teeth [-]	42
Thickness [mm]	2.4
Height of teeth [mm]	14
Pitch of teeth	Unbalanced

II: *Variable parameter of shape of teeth*

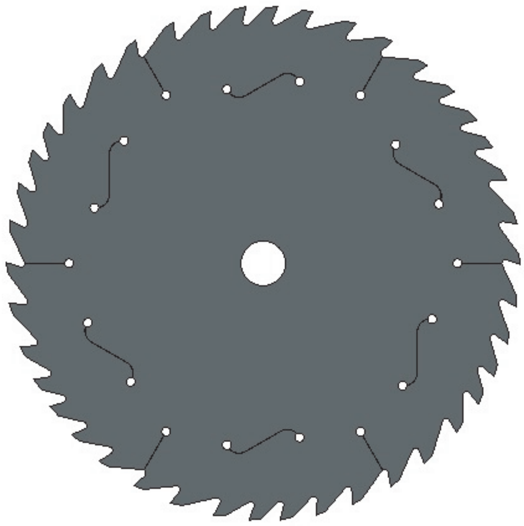
	Surface of teeth	Surface of teeth gap	
CSB1	50	50	**Ratio [%]**
CSB2	55	45	
CSB3	52.5	47.5	
CSB4	47.5	52.5	
CSB5	45	55	

The geometry of tooth (angles – α, β, γ) was in all cases the same, ratio between gap and teeth was achieved by variable angle δ as shows Fig. 1.

The models of circular saw blade have unbalanced pitch, repeating after 1/6 of circle. In the body of circular saw blade were created two types of slots for increasing the natural frequencies (Svoreň, 2011).



1: *Geometry of the tooth*



2: *Model of CSB5 used in modal analyses*

In this study was used computer software Creo Parametric 1.0 for obtaining natural frequencies of studied models. This software uses in analysis finite element method (FEM). There were done some steps to idealize the models.

Idealization

- Material;
- Mass definition;
- Constrain;
- Density of mesh;
- Type of elements.

For calculating static and dynamics natural frequencies of models were used modal analysis. The rotational speed in dynamic modal analyse was n = 3600 min^{-1}.The critical rotational speed was calculated from results calculated by Creo Parametric 1.0 on 5 models of tool.

For calculating centrifugal coefficient was used equation (1) and the critical rotational speed was calculated from equation (2). Both equations were defined by (Mote, 1965; Nishio and Mauri, 1996):

$$f_{dyn}^2 = f_{stat}^2 + \lambda \times \left(\frac{n}{60}\right)^2, \text{[Hz]} \qquad (1)$$

$$n_k = \frac{60 \times f_{stat}}{\sqrt{k^2 - \lambda}}, \text{[min}^{-1}\text{]} \qquad (2)$$

f_{dyn}..... natural frequency of rotating circular saw blade [Hz],
f_{sta} ..... natural frequency of non-rotating circular saw blade [Hz],
n .... rotational speed [min^{-1}],
k .... number of nodal diameters,
λ .... centrifugal coefficient,
n_k...... critical rotational speed [min^{-1}].

III: *Values of the static natural frequencies of models for k = 1, 2, 3, 4*

	k				
	1	2	3	4	
CSB1	135.6	157	219.2	342.5	
CSB2	134.3	155.6	217.3	338.74	
CSB3	134.7	156	218	340	f_{stat} [Hz]
CSB4	136.4	158	220.7	344.9	
CSB5	137.3	159	222.4	347.44	

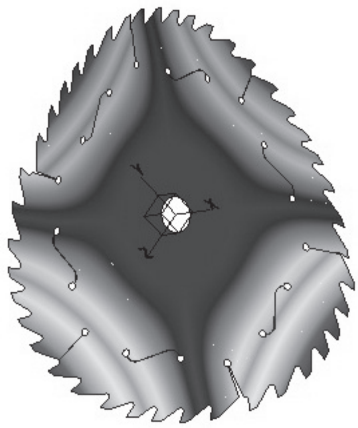
IV: *Values of the dynamic natural frequencies of models for k = 1, 2, 3, 4*

	k				
	1	2	3	4	
CSB1	156	180	241.45	361.94	
CSB2	154.9	178.6	239.68	358.4	
CSB3	155.32	179.1	240.26	359.4	f_{dyn} [Hz]
CSB4	156.78	180.88	242.8	364.3	
CSB5	157.58	181.84	244.4	366.78	

RESULTS AND DISCUSSION

The critical rotational speed was calculated for 5 models of circular saw blade. As a results from modal analysis were obtained values of static and dynamic natural frequencies of 5 models of circular saw blades for k = 1, 2, 3, 4 which are shown in Tabs. III and IV and graphical results of displacement of models (for CSB1 is shown on Fig. 3).

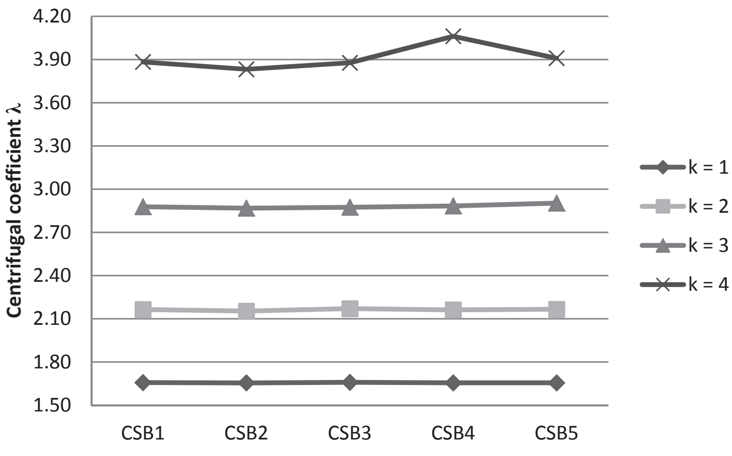
The obtained values of natural frequencies were used for calculating centrifugal coefficients λ from equation (1) and these results are shown in Fig. 4.



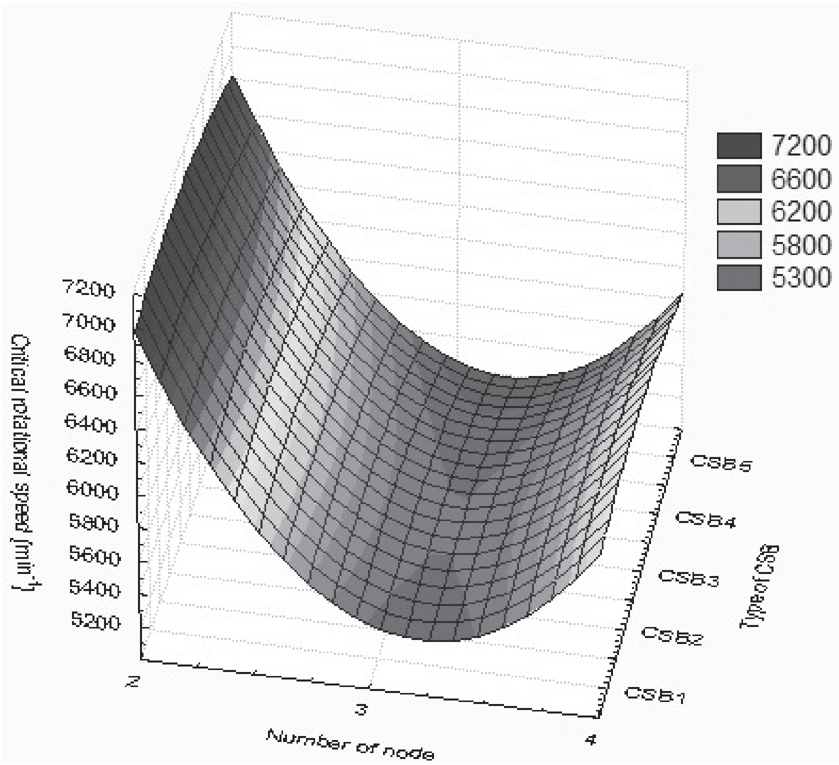
3: *The results of deformed model CSB5 from modal analyse for k = 2*

There were calculated values of critical rotational speed for nodes k = 2, 3, 4 for each studied model from equation (2). As the results show it was decreasing dependence of critical rotational speed from model with largest teeth gap to model with smallest teeth gap. So the model with largest teeth gap (CSB5) had the highest values of critical rotational speed for all nodes. The lowest values of critical rotational speed for all nodes had model with the smallest surface of teeth gap (CSB2). So it has been demonstrated that teeth gap could be considered as a kind of slots and the tool with higher proportionof teeth gap achieved higher critical rotational speed than tool with lower(larger surface of teeth than teeth gap). The influence of shapes of teeth on critical rotational speed is shown in Fig. 5.

In the paper were used special types of slots because of additional reduction of adverse effects during sawing which was demonstrated by (Svoreň, 2011).



4: *Calculated centrifugal coefficient λ of 5 models*



5: *Comparison of calculated values of critical rotational speed of all models*

CONCLUSION

The influence of shapes of teeth of circular saw blade on critical rotational speed was analysed using pc software and equations defined by (Mote, 1965; Nishio and Mauri, 1996; Svoreň, 2011). Five models of circular saw blades with variable ratio between teeth gap and surface of teeth were analysed on which was demonstrated this influence.It has been shown that for achieving higher values of critical rotational speed is better design the tool with larger teeth gap than surface of teeth. Using pc software is in present very helpful in research while the properties of real tool are correctly defined on model. It is necessary to do some idealizations on models. It has been shown that is better to created circular saw blades with larger teeth gap than surface of teeth for obtaining higher critical rotational speed of tool.

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