



APPROACH TO CREATING MODELS OF BLADE FOR PORTABLE SAWMILLS

Valentin Atanasov¹ – Radoslav Miltchev² – Zhivko Gochev³

Abstract

The present paper considers the opportunities for creation of digital models of band saw blade through which to study the behaviour of mobile sawmills. Development of two- and three- dimensional models is essential part of design and analysis process based on use of numerical methods. Application of numerical methods depends on generated mesh of studied areas and objects. In the particular case the finite element method mesh generation has been applied in order to give an account to behaviour of cutting instruments in different mechanical conditions. The analysis of possible use of different computer application and development of proper procedures of their interaction for creation of quality two-and three- dimensional models has been done.

Key words: CAD, 2D/3D models, portable sawmill, band saw blade

INTRODUCTION

Until now the studies related to design, analysis and optimization of working process of band saw blade for portable sawmills mainly perform classical methods based on use and application of analytical equations derived as a result of experimental work, engineering assumptions and simplification of the examined objects. The rapid development of the information technologies in recent years and improved capabilities of available hardware and software applications allow to apply numerical methods instead of classical methods to solve similar problems. To raise the accuracy of applied analysis we can use methods of three-dimensional modelling for solving field problems in complex areas. Accuracy also can be increased by solving coupled field problems.

The application of numerical methods is possible after creation of suitable digital models that take into account the complexity of geometry of the studied objects and surrounding area, used materials (materials that have been used for construction of cutting instruments are comparatively new with characteristics that derive from chemical composition and treatment and resulting into higher elasticity and hardness for instance), applied forces and boundary conditions. There are three different types of band saw blades used in the cutting process. For the preset research we examine the creation of digital models of band saw blade with ordinary teeth because they are widely used in our enterprises.

¹ Faculty of Forest Industry, UF, 10 “Kliment Ohridski” Blvd., 1756 Sofia, BULGARIA,
e-mail: vatanasov_2000@yahoo.com

² Faculty of Business Management, UF, 10 “Kliment Ohridski” Blvd., 1756 Sofia, BULGARIA,
e-mail: rmilchev@ltu.bg

³ Faculty of Forest Industry, UF, 10 “Kliment Ohridski” Blvd., 1756 Sofia, BULGARIA,
e-mail: zhivkog@yahoo.com

MATERIALS AND METHODS

The forces which arise in the interaction between the wood and incisors are taken into account when applying the analytical method to determine band saw blade's teeth load. This interaction is spatial therefore idealization of teeth's forceful loading is applied. The purpose of this is easier calculations. The determination of the forces is performed by sequential decomposition to radial (Ri) and tangential(Pi) components of the full cutting force(S) (Fig. 1,2). The total radial (R) and tangential (P) force is the sum of forces which act perpendicular and along the cutting speed vector (Grigorov 1992):

$$R = R_c + R_b - R_f, \quad (1)$$

where:

R_c - radial force which acts on the cutting edge, called reaction of the cutter, N;

R_b - radial force which acts on the backside of the tooth's edge, called reaction of the processed surface, N;

R_f - radial force which acts on the front side of the tooth's edge, called reaction of the chip, N.

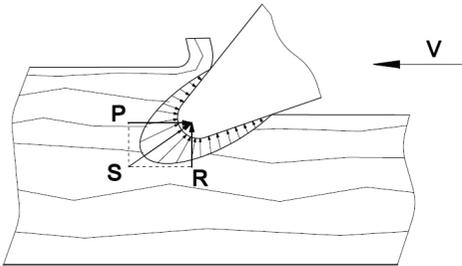


Fig. 1 Distribution of normal pressure on the cutting edge (Grigorov 1992)

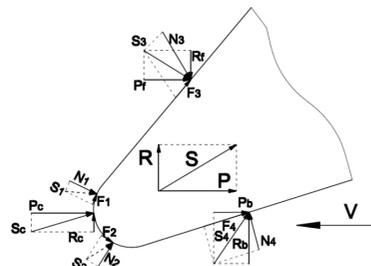


Fig. 2 Diagram of the forces which act on the cutting edge (Grigorov 1992)

$$P = P_c + P_f + P_b \quad (2)$$

where:

P_c - tangential force which acts on the cutting edge, called incision force, N;

P_f - tangential force which acts on the front side of the tooth's edge, called resistance force of the chip's deformation, N;

P_b - tangential force which acts on the backside of the tooth's edge, N.

In addition to the tangential and radial cutting force some scientific works include the power ΔQ without giving specific values (Genchev 1978). This force is the difference between the lateral components Q_1 and Q_2 (Fig. 3).

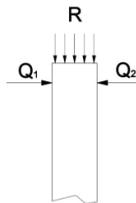


Fig.3 Spatial loading of band saw blade's tooth (Genchev 1978)

The calculation of the tangential cutting force is given by (Gochev 2005):

$$P = \frac{K_p b h u}{v}, \quad (3)$$

where:

K_p – specific cutting work, Nm⁻²;

b - cutting width, m;

h - cutting height, m;

u - feed speed, ms⁻¹;

v - cutting speed, ms⁻¹.

The calculation of the radial cutting force is given by (Genchev 1978):

$$R = mP, \quad (4)$$

where:

m - coefficient which depends on the teeth's wear (0,2 – 1).

The lower values of the coefficient are used for sharp teeth and higher values for blunted teeth. Currently there aren't any methods for determination of this coefficient.

The development of computational procedures to calculate stress in band saw blade also includes implementation of principle of minimum potential energy (Borchelt 1983) or theory of an elastic Cosserat surface (Rubin 2006).

Recently many researchers applied numerical methods to solve different problems in the area of woodworking. As it shown in (Deliiski 2010, Deliiski 2011) application of analysis accomplished by use of Finite Difference Method is extremely suitable for examination of thermal field problems connected with wood processing for example.

As it shown in (Zienkewich 1998), recently the Finite Element Method (FEM) is also used to solve a variety of different field problems in different scientific areas. FEM is a method for numerical solution of partial different equations. Solution of differential equations with analytical methods is limited and it is possible for a small group of trivial cases. From the other side solution achieved by numerical methods is universal and can be adopted as a part of variety of computational and applied software. These factors transform FEM into powerful instrument for design, analysis and optimisation.

Except its universal features the FEM possess and some other benefits including: application in medium with homogeneous and heterogeneous, linear and nonlinear, isotropic and anisotropic characteristics; application in planar, axisymmetric and three-dimensional problems. Application of method in the case of stress analysis studies of different object and in particular examining band saw blade is a new approach which cans significant increase opportunities to design complete devices or to improve their working capabilities.

The organizations of pre-processor activities required by FEM for analysis of band saw blade model are based on previously developed approach (Miltchev 2004). We use the environment of a general purpose CAD software system to prepare model and to apply material properties, forces and boundary conditions. The two-dimensional model of band saw blade has been created by use of complex geometrical object such as polyline. The main benefit of polyline is ability to create a logical sequence from arcs and lines that are suitable for extraction of complex geometry data and integration with different computational procedures or software products. On Fig. 4 are shown three sections of the band saw blade model with base set of dimensions measured on the real object. The developed model reveals the level of accuracy used to describe the real band saw blade in FEM analysis. Three- dimensional model with lower level of accuracy could be achieved after application of extrude procedure over preliminary transformed to region shape initial

contour of the blade. In this case we use the height as a parameter of extrusion corresponding to the thickness of the real band saw blade which is 1.4 mm.

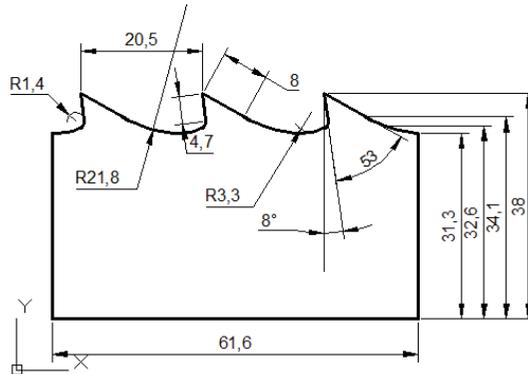


Fig. 4. Two-dimensional model composed from three uniform sections.

The three-dimensional model created by extrusion procedure could not fully take into account the presence of teeth bend under 9 degrees toward vertical plane of the blade. These bends are situated on 2.2 mm from the top of the teeth. In the real object teeth with numbers 1, 4, 7 and etc. are bended in left direction and teeth with numbers 3, 6, 9 are bended in right direction. For the rest of the teeth there is no bending toward vertical plane. Creation of model with such a level of accuracy meets some difficulties in the environment of general purpose CAD software. These difficulties can be overcome after application of higher class CAD software like Autodesk Inventor 10 Professional which is more suitable to solve problems of complex geometry of the studied object. In this particular case we can use procedures for bending sheet metal or standard set of procedures for modelling volume structures. The newer versions of the product contain built-in procedure for bending which can significantly facilitate creation of a high quality three-dimensional model. Results from geometry modelling are shown on Fig. 5.

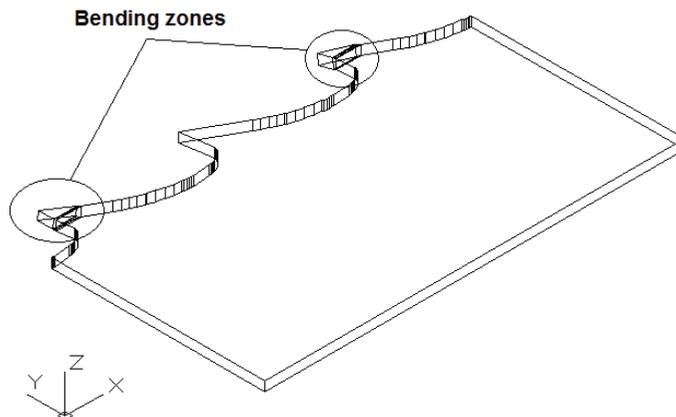


Fig. 5. Three-dimensional model composed from three uniform sections with bendings.

RESULTS

Based on proposed approach and after taking into account the all complexity of the geometry of the modelled object the series of two- and three-dimensional models have been created. Developed models also take into account the thickness of the processed material. Dependencies between thickness of the processed material, the number of teeth taking part in the cutting process and the length of the model are shown on Fig. 6.

Height of cut, mm	Number of teeth	Model length, mm
5	3	61.6
10	5	102.6
15	8	164.2
20	10	205.3
25	13	266.8
30	15	307.9
35	18	369.5
40	20	410.5

Fig. 6. Main features of developed set of models.

The proposed set of two- and three-dimensional models have been tested by modified procedure based on (Miltchev 2004). Pre-processor activities include generation of unstructured triangular mesh for two-dimensional case and unstructured tetrahedral mesh for three-dimensional case. Results from two-dimensional triangulation are shown on Fig. 7. To show in a better way all complexity of the model we implemented the method of geometry visualization proposed in (Meeker 2001). On Fig. 8 are shown three-dimensional mesh and results of stress analysis of the band saw blade created by use of built-in procedures in Autodesk Inventor 10 Professional environment.

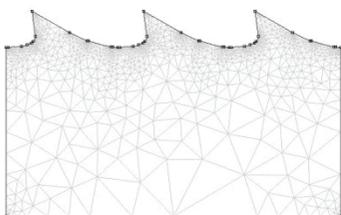


Fig. 7. Sample two-dimensional unstructured mesh of the model.

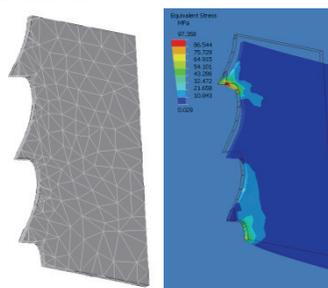


Fig. 8. Sample three-dimensional unstructured mesh and FEM analysis of the model.

CONCLUSIONS

Application of numerical methods for research of different processes and phenomena is based on preliminary preparatory work that include creation of high quality model of the studied objects, taking into account the physical characteristics of the materials, forces and

boundary conditions. There are a variety of computer applications developed recently that can be used to automate different steps of the procedures of numerical methods analyses. That creates more opportunities for application of these methods at the same level with widely used analytical methods. The main problems of their implementation are connected with geometrical modelling and mesh generation especially in the cases of complex two- or three-dimensional geometry. The application of general purpose CAD software allow to use accumulated engineering experience in the field of model creation and edition by well-known environment and intuitive GUI. Unfortunately modelling of three-dimensional complex geometry may need the using of higher class CAD software in some cases. The main benefits of these systems are the presence of more flexible modelling procedures and built-in numerical methods analyses for instance stress or thermal. The solution of pre-processor task can create a suitable base for development of specific software applications which can solve problems on different stages of design or optimisation process of technical devices.

Achieved results show good resemblance with the practical use of band saw blades. The areas of maximal stress coincide with areas when we saw teeth damages of the blade. Developed models can be implemented to solve the time dependent or coupled problems which are a base for better understanding of working process of the studied device. The models could also be exported in standard intermediate formats and to form a common base for analyses performed by different commercial or free and open source computer applications.

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