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3D MODELING OF SHAFTS FOR WOODWORKING MACHINES

Nelly Staneva

Abstract

Two approaches for creating of parametric 3D models of circular saw shaft with CAD/CAE systems Solid Works Simulation® and Autodesk Inventor Professional® are presented. The specific features of the generation of the 3D models with real saw shaft elements - keyway grooves, wrench, grooves for retaining rings, centre holes, thread for fixing of mounting flanges, etc. are discussed for both approaches. Autodesk Inventor Professional®' approach for creation of 3D shaft model is considerably faster. Modulus "Shaft Generator" of Autodesk Inventor Professional® proposes possibilities for creation of elements according to world standard and implementation of control calculations of support reactions, bending moments, stresses and displacements. 3D shaft models are the basis for further numerical investigations of static strength, frequency and fatigue by FEM with CAD/CAE systems.

Key words: *shaft, circular saw, 3D modeling, CAD/CAE, FEM*

INTRODUCTION

Circular saw woodworking machines are the most commonly used in manufacturing of wood and wood materials. Most often the operating shaft of circular saws is with two bearing supports and console disk and console V-belt pulley. The saw shaft is more non-uniform loaded – great bending and shear stresses which induce different dynamics processes and shaft operation is getting more complicated. That is way of especially importance is not only the proper calculation of the cutter shaft but the improvement and optimization of these calculations. This is coming true with the development of CAD/CAE software in our days. 3D models are the basis for implementation of numerical calculations and analyses by FEM with CAD/CAE systems. Geometrical precise **3D models** allow receiving of more precise results about static and dynamic behavior of cutting mechanisms for woodworking machines saving a lot of efforts and time of engineers. More and more the modern CAD/CAE systems for 3D modeling and engineering calculations and analyses of the operating shafts of woodworking cutting mechanisms have been applied (Chaitanya and Kaladhar, 2013; Marta and Corduta, 2010; Michna and Svoren, 2007; Staneva, 2014; Staneva and Vlasev, 2010).

The aim of research presented in this paper was to compare the possibilities of CAD/CAE systems Solid Works Simulation® and Autodesk Inventor Professional® for 3D modeling of woodworking machine shafts and to discuss the specific features for creating of 3D models.

University of Forestry, 10 Kliment Ohridski blvd, 1797 Sofia, Bulgaria
e-mail: nelly_staneva@yahoo.com

METHODS

Two CAD systems and two approaches are used for generating of 3D models of circular saw shafts with two bearing supports, console disk and console V-belt pulley - Solid Works Simulation® and Autodesk Inventor Professional ®.

RESULTS AND DISCUSSION

3D modeling with SOLID WORKS®

A saw shaft for undercutting of boards with folio or plastic covering with two bearing supports, console drive side disk (D =180 mm) and console V-belt pulley is 3D modeled. The 3D model is created according preliminary calculated saw shaft for following conditions: driven by an asynchronous motor with 1,5 kW power and revolutions of 2860 min^{-1} by a V-belt gear with gear ratio i=1,15. Total cutting force (including feeding force and weight of the circular disk and the flanges) $F =60\ N$ ($\delta_2=28^0$) and force from the V-belt stretching - $Fr=630\ N$ ($\delta_1=60^0$); torque $M_{yc2} = 5,59\ N.m;$

CAD system Solid Works® offers only one aproach for creating 3D models of rotational elements (Станева, 2008, Staneva, 2008) – creation of the basic model by means of rotation on 360^0 of a 2D sketch of the shaft outline. The sketch of the saw shaft outline is presented on Fig.1. The sketch is outlined by preliminary calculated dimensions (diameters and longitudes) of the separate shoulders of the saw shaft.

Further, the basic 3D model of the shaft is upgraded with the real elements - centre holes and keyway grooves in the end-shoulders, wrench and thread for fixing of mounting flanges and saw disk in the final left shoulder, grooves for retaining rings, fillets and chamfers.

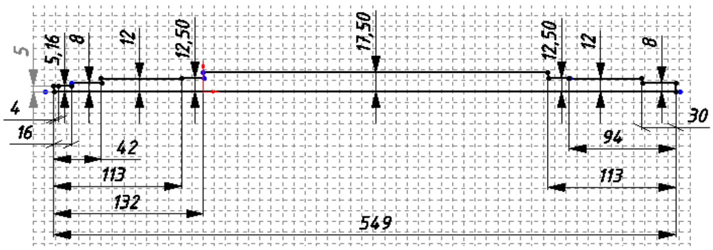

Figure 1: Sketch of the shaft basic model

Generation of the right keyway groove is presented on Fig.2 – from the sketch of the key groove in Plane1 (parralel to the shaft axis and on distance – the depth of the key groove) with the feature “Cut-Extrude” in direction as is pointed on Fig.2. Generation of the wrench in final left shoulder is also presented on Fig.2 – by means of feature “Cut-Extrude” from the wrench sketch outlined in an additional plane.

More complex is generation of the thread for fixing of mounting flanges and saw disk in end left shoulder, presented on Fig.3. The first step is outlining of the sketch of thread profile (Sketch5) in Plane 5. All dimensions of the thread profile are according to standard for Metric thread BDS 10689-78 (M12x1,5 LH) – diameter of this shaft shoulder is preliminary set in the basic model by internal thread diameter. A spiral line “Helix/Spiral” with tread pitch and length is generated in Plane6 trough the centre of medians of the thread triangle profile. The spiral surface of the tread is generated by means of feature "Sweep boss" - the thread triangle profile is swept on assigned spiral line. As it is known this thread is left hand, so the direction of the spiral line is set counter. Additionally the thread is finished as creating of fillets in the base of thread profile and for taking off of the cuting instrument. The history of thread creation is shown on the left on Fig.3.

The creation of the 3D saw shaft model is finished with generating of centre holes, grooves for retaining rings, fillets and chamfers by analogous manner.

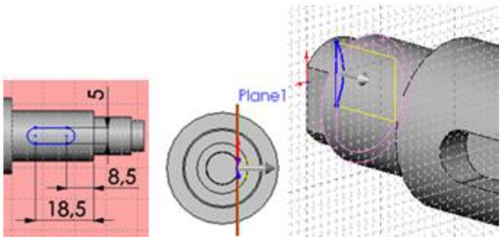

Figure 2: Creation of a keyway groove and wrench

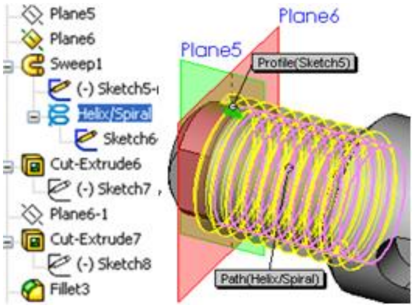

Figure 3: Creation of metric thread

3D modeling with AUTODESK INVENTOR®

A saw shaft for cutting out of solid wood is preliminary calculated for following conditions: driven by an asynchronous motor with 3,4 kW power and revolutions of 2860 min^{-1} by a V-belt gear with gear ratio i=1,32; Total cutting force of 170 N ($\delta_2=35^0$) and force from the V-belt stretching – 963,7 N ($\delta_1=55^0$); torque 14,72 N.m;

CAD system Autodesk Inventor® proposes very express approach for 3D modeling with his modulus "Shaft Generator" – creation of 3D shaft model section by section. The sequence of history creation is shown on the left of Fig. 4.

For every section this modulus gives opportunity for creation of all elements of the real saw shaft - wrench and thread for fixing of mounting flanges and saw disk in the final left shoulder, keyway grooves in the end-shoulders, grooves for retaining rings, fillets and chamfers. On the upper right side of Fig.4 is shown the program window for generation of the left-side keyway groove according to DIN 6885 A. Modulus "Shaft Generator" automatically generate relevant feature according to the standard and dimensions which were set.

The generation of the metric thread is according to the standard ISO – metric profil, but the visualisation is alike for all kinds of the threads, which is a disadvantege of the system Autodesk Inventor Profesional®.

The creation of the both centre holes with its dimensions are presented on Fig. 5.

Modulus "Shaft Generator" of Autodesk Inventor® offers oportunity for carring out of control calculations of shafts and for optimization of shaft dimensions.

Material "Steel" with characteristics pointed on Fig.6 and coresponding loads and supports were set. Results about real shaft mass, bending , shear and reduced stress, support reactions and deflections are shown on the right side of Fig.6. Graphs of bending moments,

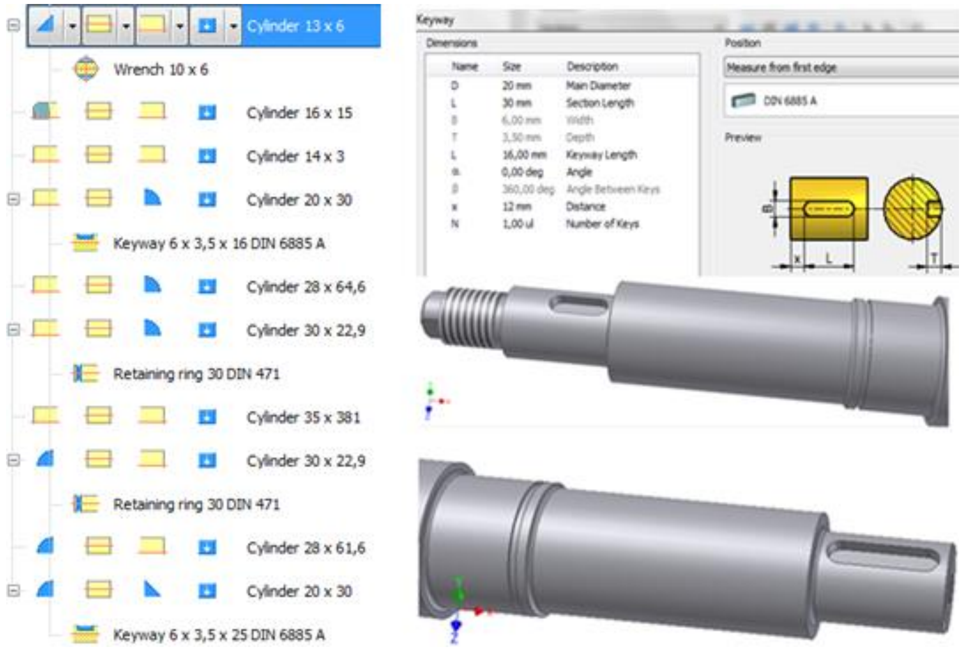

Figure 4: Sequence of creation of the shaft 3D model with "Shaft Generator"

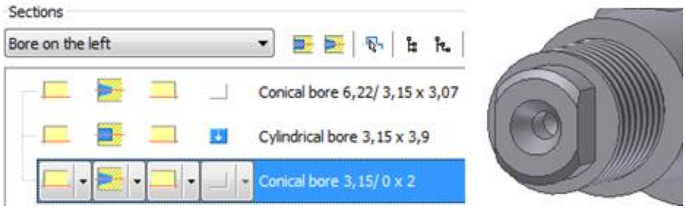

Figure 5: Sequence of creation of the centre holes

bending stress, shear stress and equivalent stress, displacements in every plane (YZ and XZ) and rezultant were available. The distribution of the bending stress and "ideal" diameter of saw shaft along the shaft length are prezented on Fig. 7. It is evident that in the most loading point near to suppport 2 the bending moment is maximal. The "ideal diameter" of 25,95 mm is less then real one -28 mm, i.e. the shaft is corectly calculated for given loading.

Both systems Solid Work Simulation® and Autodesk Inventor Professional® give posibility for simulating of loading of the shafts and carring out of static analysis, frequence analyses, fatigue analysis by FEM.

On Fig. 8 the distribution of von Mises stress and factor of safety (FOS) received with Solid Works Simulation® are presented for plain carbon steel.

CONCLUSIONS

The described approaches for 3D modeling of saw shafts allow creation of a geometrical precise and complete 3-dimensional model of woodworking machine shafts. 3D

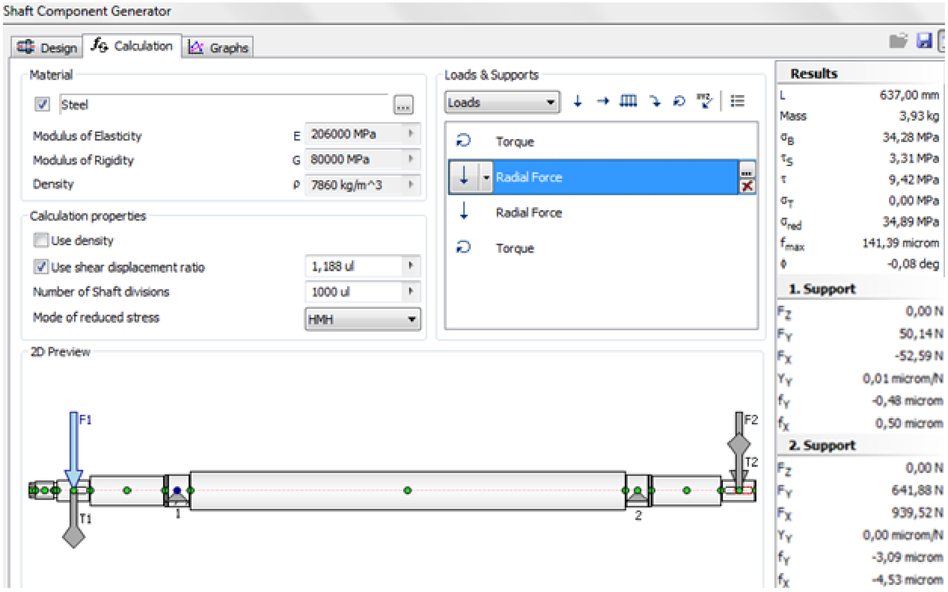

Figure 6: Calculations of the saw shaft

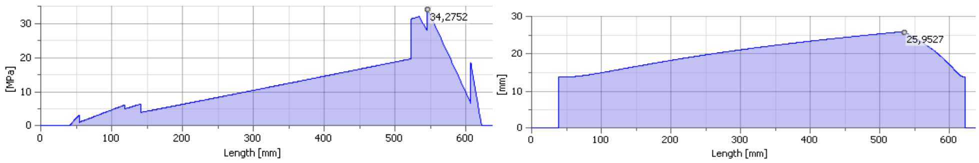

Figure 7: Bending stress and "ideal diameter" of the saw shaft

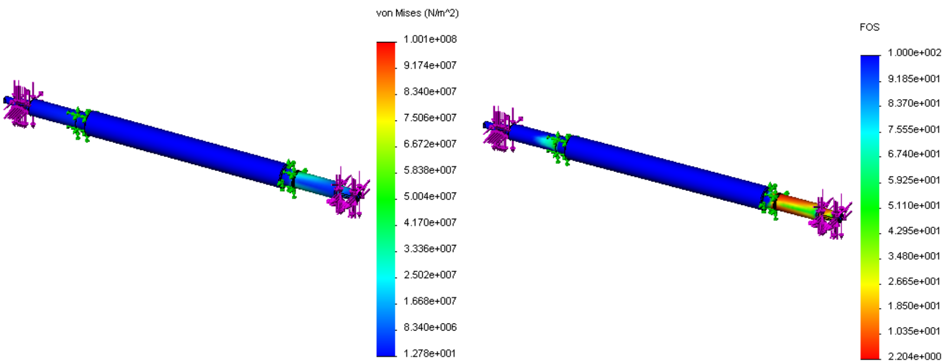

Figure 8. Distribution of von Misses stress and factor of safety for plain carbon steel

shaft models are the basis for further numerical investigations of static strength, frequency and fatigue by FEM with CAD/CAE systems.

The approach of Autodesk Inventor Professional®' for creation of 3D shaft model is considerably faster and appropriate than Solid Works Simulation® one. All the more modulus "Shaft Generator" of Autodesk Inventor Professional® proposes possibilities for creation of elements according to world standard and implementation of control calculations of support reactions, bending moments, stresses and displacements.

Acknowledgments

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