STATIC ANALYSIS OF A BAND SAW SHAFT BY FEM

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

ABSTRACT

A static analysis of the main shaft of a universal band saw with two bearing supports, a console drive side wheel and console V-belt pulley is carried out by the method of finite elements (FEM) with Autodesk Inventor Professional®. The 3D model of the band saw shaft is generated with all elements of the real shaft – keyslot, grooves for clip ring, centre holes, chamfers, filets, and etc. Two variants of loading are set: first for vertical V-belt transmission and second for horizontal V-belt transmission. Stresses, strains, displacements and factor of safety distributions are obtained and visualized in the 3D model of the band saw shaft for these variants. The effected differences in the static strength of band saw shaft are analyzed.

Key words: band saw, woodworking, shaft, static analysis, FEM, Autodesk Inventor Professional®

INTRODUCTION

Band saw woodworking machines have large application in different productions – machining of logs, prisms, boards, slabs, furniture details, which has been led to availability of different constructions (Filipov 1967). The driving of the cutting mechanism of the different band saw woodworking machines not differ significantly from one to another. It is known that the main shaft of the woodworking band saws is designed mainly by two bearing schemes (Filipov at al 1983). Most often the main shaft of band saws is with two bearing supports and console drive side wheel and console V-belt pulley (Filipov 1967). In this case the main shaft is more non-uniform loaded – great bending and shear stresses from the bend saw blade stretching are resulted and shaft bending make worse the bend saw blade operation. That is way these loading scheme is more interesting for investigations. Sokolovski and Deliiski (2012, 2013) have been worked out a procedure for 2D verifying calculations of static strength and fatigue of the main band saw shaft with the similar scheme of loading as shown in Fig.1. In the literature there are no data for 3D investigations by the method of finite elements for main band saw shaft.

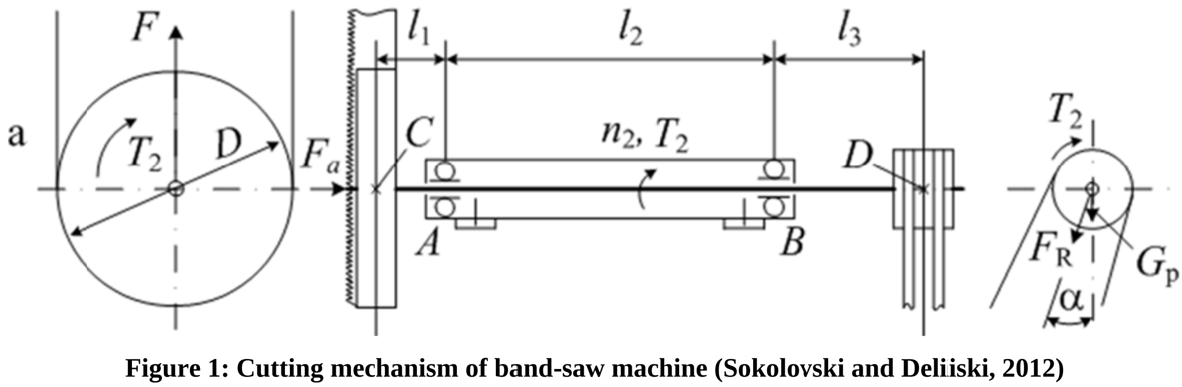

Figure 1: Cutting mechanism of band-saw machine (Sokolovski and Deliiski, 2012)

The object of this study is caring out of a static analysis of the main shaft of a universal band saw with two bearing supports, console drive side wheel and console V-belt pulley by the method of finite elements (FEM). Two limited cases of V-belt transmission layout vertical ($\alpha=0^0$) and horizontal ($\alpha=90^0$) are considered and the effected differences in the loading and static strength of a band saw shaft are analyzed.

The availability of suitable CAD/CAE software allows quickly and precisely calculations and analyses for different variants of loading.

METHODS

1. 3D MODELING OF A BEND SAW SHAFT

The main shaft of a universal band saw UB-800 with two bearing supports, console drive side wheel and console V-belt pulley is 3D modeled with CAD/CAE system Autodesk Inventor Professional®. The shaft is preliminary calculated for following conditions [3]: driven by an asynchronous motor with 4,0 kW power and revolutions of 1430 min^{-1} by a V-belt gear with gear ratio i=2; revolutions of the shaft are 715 min^{-1}; characteristic longitudes of the shaft are: l_1=150 mm, l_2=560 mm and l_3=180 mm; the drive side wheel is with diameter D=800 mm; the sizes of bend saw blade are: width B=30 mm and thickness s=1,2 mm.

The 3D model of the bend saw shaft is created with the modulus “Shaft Generator“ of the program Autodesk Inventor® section by section. For every section “Shaft Generator” gives opportunities for creation of all elements of the real shaft – grooves for clip ring, center holes, chamfers, filets, etc. The sequence of creation of the 3D model of the band saw shaft is shown on Fig. 2. The creation of a circular shaft 3D model with modulus “Shaft Generator” has been described more detailed in Vasilev at al. (2012).

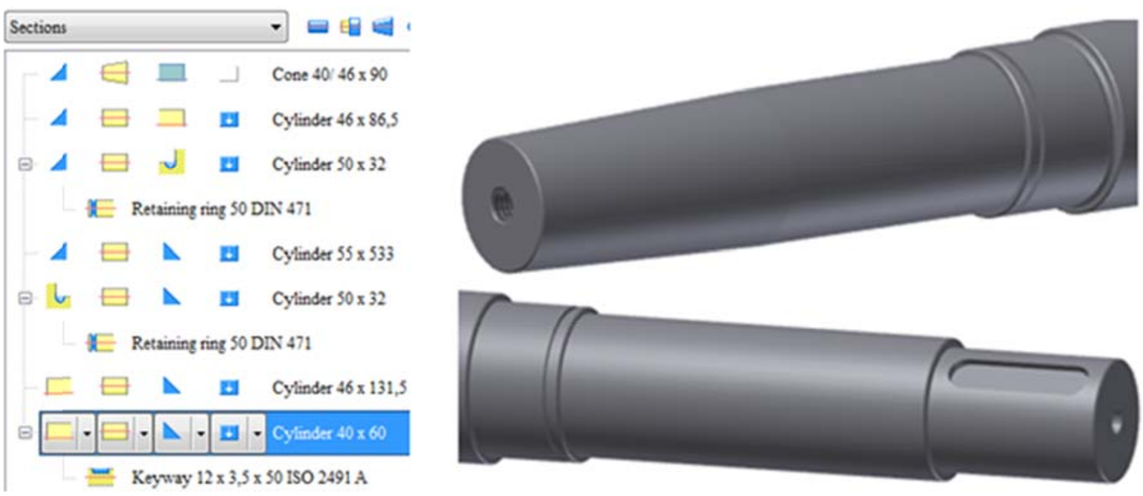

Figure 2: Sequence of creation of the bend saw shaft 3D model

2. CALCULATION SHEME OF THE BEND SAW SHAFT

The bend saw shaft is horizontal and is loaded with a torque and forces according to Filipov (1967) and Sokolovski and Deliiski (2012) as pointed on Fig.1. The authors have been determined the forces exercising an effort on the bend saw shaft (Fig.1):

Torque, T_2 =54,0 N.m;

Cutting force from the bend saw blade: resultant radial force acting in point *C,* plane *xOz*: *F*= (F_0+F_t-G_w) = 2900 N, where F_0=2*B.s.*σ is saw blade stretching force; F_t =2T_2/D is peripheral force; G_w is mass force of band saw wheel.

Force from feeding mechanism: axial force, acting in plane *xOy*: F_a = 0,5. F_f = 50 N, where F_f is the feeding force for manual feeding;

Force from the V-belt stretching: $F_R = 2\left(c_1.\dfrac{2.T_2}{d_2} + z.c_2.\upsilon^2 \right) sin\dfrac{\alpha_1}{2}$; This force was calculated: F_R = 1658 N for c_1 = 1,5 (middle loading); belt section "*A*" – c_2 = 0,637; number of V-belts – *z* = 3; d_2 = 0,200 m; *v* = 7,48 m/s; α_1 =156^0.

Mass force of the V-belt pulley: G_p = 46,7 N.

The acted on the saw shaft forces are pointed on the scheme of loading – Fig.3.

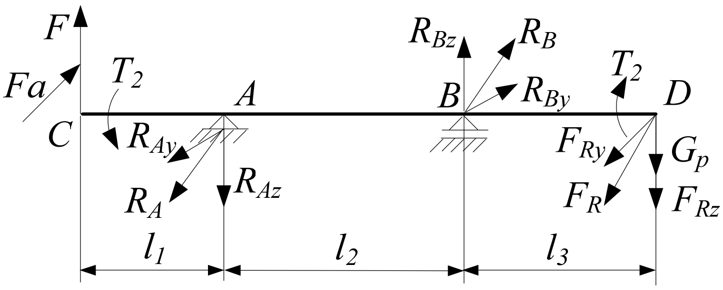

Figure 3: Scheme of loading

3. STATIC ANALYSIS

The static analysis of the bend saw shaft 3D model is performed by the method of finite elements (FEM) with the CAD/CAE system Autodesk Inventor Professional®.

First, from the Inventor® library, the material "Steel" is chosen with the following characteristics: yield strength 207.10^6 N.m^{-2}; ultimate tensile strength 345.10^6 N.m^{-2}; elastic modulus 2,10.10^{11} N.m^{-2}, shear modulus 8,0810^{10} N.m^{-2}; Poisson's ratio 0,3; density 7850 kg/m^3. These characteristics are closest to the Bulgarian carbon steel brand 45 according BDS 2592:1971 usually used for production of shafts for band saws.

The fixing of the shaft in the 3D model is set according to the loading scheme (Fig. 3): fixed, without translations.

Two variants of loading are analyzed: first is for **vertical V-belt transmission** and the second for **horizontal V-belt transmission**. In dependence of the V-belt transmission layout (from vertical α=0^0 to horizontal α=90^0 – Fig. 1) the directions and values of the V-belt transmission forces are different in the different planes. The following loads according to the scheme of loads (Fig. 3) are set for the relevant variants:

Ist - Vertical belt transmission – α=0^0: F_{Ry}=0; F_{Rz}=F_R=1658 N (Fig.1 and Fig.3):

T_2 =54,0 N.m - *torque,*; *F*= 2900 N – *force, initiating at cutting process*, directed along the *z*-axis; F_a = 50 N**,** *axial force* directed along the *x*-axis, acted on the distance 0,5.*D*; F_{Rz}+ G_p =1658 + 47 = 1705 N - *resultant radial force from V-belt transmission*, directed along the *z*-axis in plane *xOz*;

IInd - Horizontal belt transmission α=90^0: F_{Ry}=F_R; F_{Rz} =0 (Fig.1 and Fig.3):

T_2 =54,0 N.m – *torque,*; F= 2900 N – *force, initiating at cutting process*, directed along the z-axis; F_a = 50 N**,** *axial force* directed along the x-axis, acted on the distance 0,5.D (D=800 mm); F_{Ry} =1658 N - *radial force from V-belt transmission*, directed along the y-axis in plane xOy; G_{p} = 47 N – *radial force (mass of the belt puley)*, directed along the z-axis in plane xOz;

Specified forces and torque are shown on Fig.4 for both variants – vertical and horizontal in such a way as they are visualized by the program Inventor®. For differentiation of the two variants of loading, they are indicated as follow: "vertical" (α=0^0) and „horizontal" (α=90^0).

The loading variant for V-belt transmission at α=45^0 (F_{Ry}=F_{Rz} =1173 N) was preliminary analyzed: the loading are almost similar as this for horizontal V-belt transmission – except the resultant radial force, directed along the z-axis (F_{Rz}+ G_{p} =1220 N) there is a radial component, directed along the y-axis (F_{Ry} =1173 N). The performed static anlysis for this variant showed very close to the "horizontal" loading results, that is way this variant will not been discussed.

The following characteristics of the finite elements mesh are set: average element size 0,1; minimum element size 0,2; grading factor 1,5; maximum turn angle 60 deg; curved mesh elements; The created mesh for the model has 23917 numbers of nodes and 14973 numbers of finite elements. For the solver the following are set: maximum number of h refinements 3; stop criteria 10 %; h refinements threshold 1.

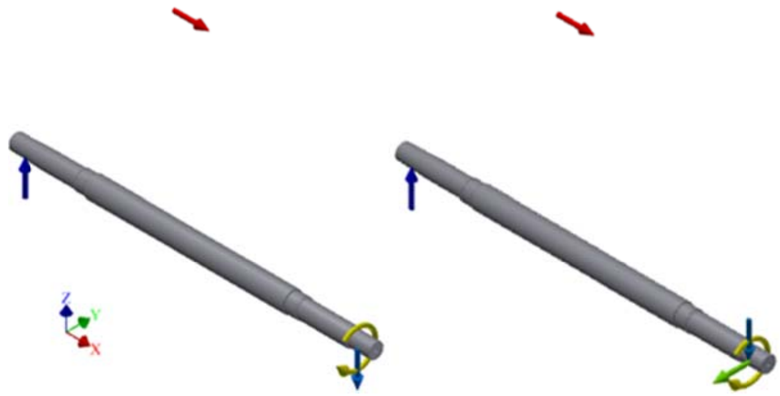

Figure 4: Loads for "vertical"/"horizontal" belt transmission

REZULTS AND DISCUSSION

Some of the results from the static analysis are represented on Fig. 5 to Fig. 10 for both variants of loading – "vertical" and "horizontal". In order to understand where deformation is occurring an exaggeration effect is provided with "Adjust Displacement Display" – Adjusted x 0,5 [7].

The distribution of equivalent von-Mises stresses in the band saw shaft 3D model is represented on Fig.5. The maximum value of $69{,}43.10^6$ N.m^{-2} is received for „vertical" and $77{,}37.10^6$ N.m^{-2} for „horizontal" loading near to the bearing shoulder "A".

On the Fig.6 the distribution of equivalent strains is represented. Maximum strain 0,0003088 for „vertical" and 0,0003393 for „horizontal" loading are received in the same places where the stresses are maximum – near to the shaft bearing shoulder "A" – Fig. 6.

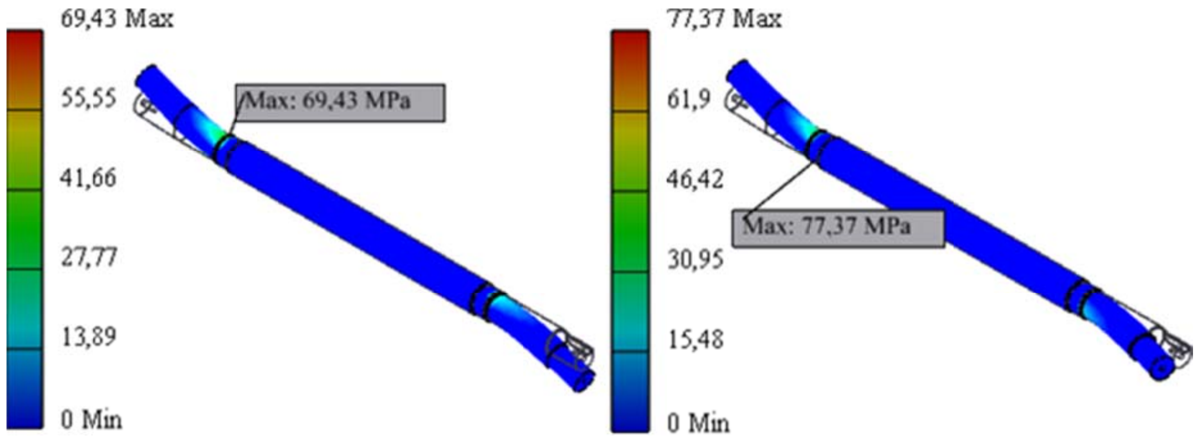

Figure 5: Distribution of von-Mises stresses for "vertical" and "horizontal"

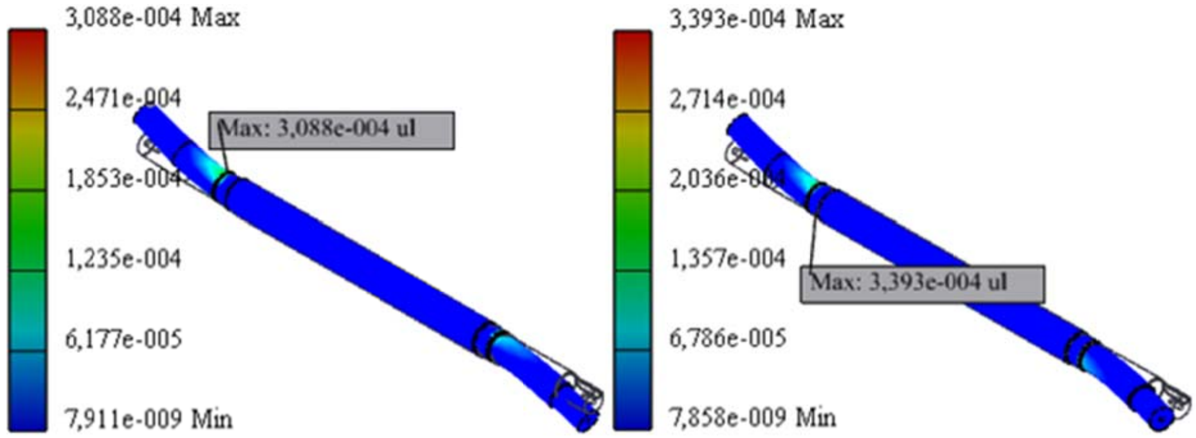

Figure 6: Distribution of equivalent strain for "vertical" and "horizontal"

The distribution of Safety Factor is shown on Fig.7. The program calculates the factor of safety as the ratio of the maximum allowable stress to the maximum von-Mises stress when using Yield Strength as a Yield Limit. A minimum Safety Factor of 2,98 is received for "vertical" and 2,68 for "horizontal" loading, both localized near to the bearing support "*A*" – Fig. 7. The factor of safety is not under the 1 for no one finite element, i.e. there is no danger of shaft failure in both cases.

The distribution of resultant displacements in the shaft 3D models is represented in Fig. 8. Maximum resultant displacement 0,09155 mm for "vertical" и 0,09163 mm for "horizontal" is received in the left end of the band saw shaft. The distribution of Z- and Y-displacements is shown on the Fig. 9 and Fig. 10 – the maximum Z-displacements are almost equal for both loading (0,0902 mm) and are received in the left end of the band saw shaft. The maximum Y-displacement is 0.0092 mm for "vertical" loading and is received in the left end of the shaft, while for "horizontal" loading the maximum Y-displacement is 0.08451 mm and is received in the right end of the shaft on the side of the V-belt pulley. The last has not been reflected on the value and localization of the maximum resultant displacement for "horizontal" loading.

From the obtained results (Fig. 5 to Fig. 10) it is obviously that for vertical V-belt transmission the maximum values of stresses, resultant displacements and equivalent strains are smaller than for horizontal V-belt transmission. The stress condition is more favorable for vertical loading variant because in this case the force, initiating at cutting process is counterbalanced with the z-component force from V-belt transmission.

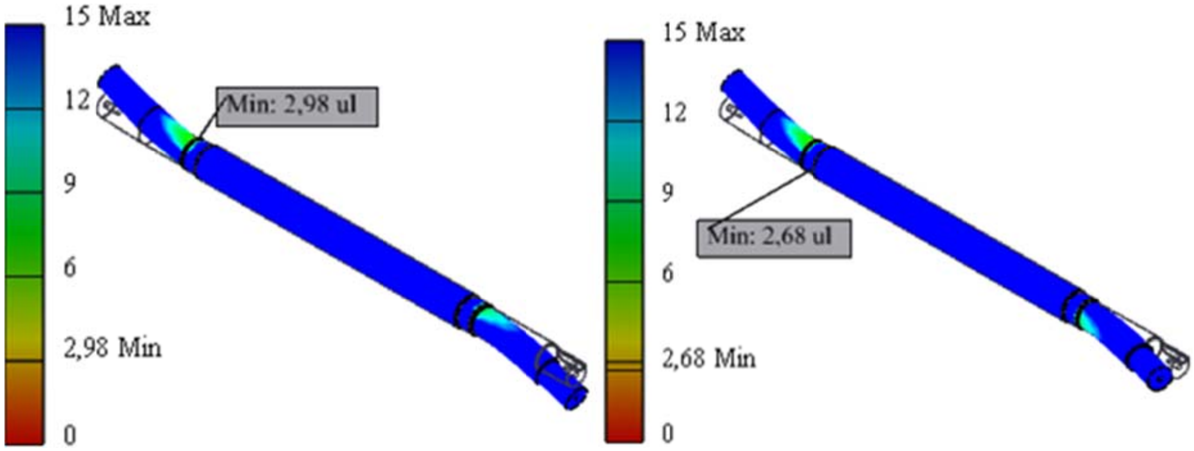

Figure 7: Distribution of factor of safety for “vertical” and “horizontal”

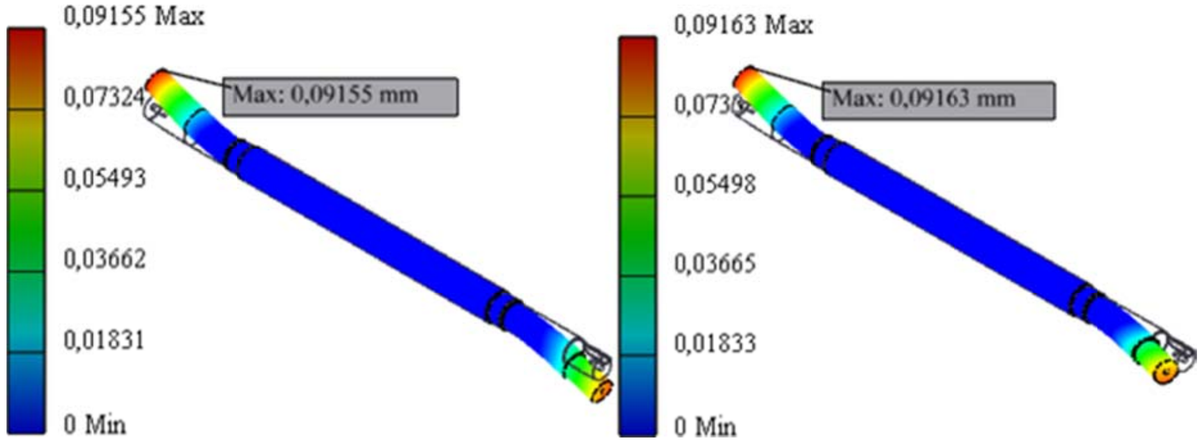

Figure 8: Distribution of resultant displacement for “vertical” and “horizontal”

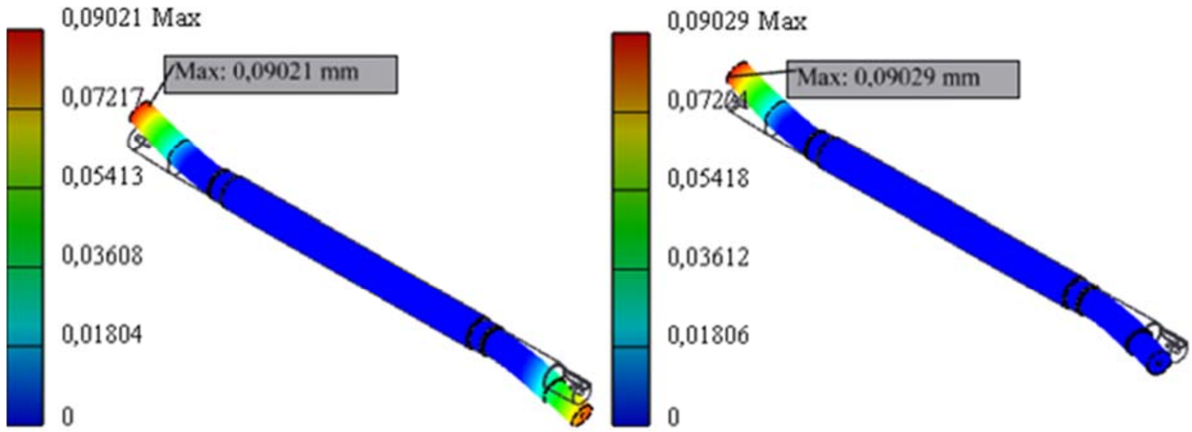

Figure 9: Distribution of Z-displacement for „vertical“ and „horizontal“

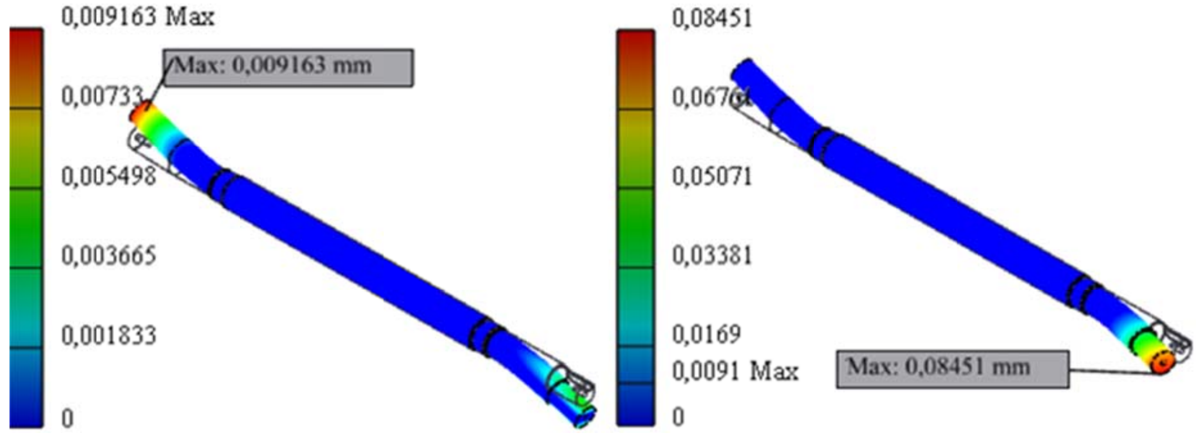

Figure 10: Distribution of Y-displacement for “vertical” and “horizontal”

CONCLUSIONS

3D results of von Misses stresses and equivalent strains distribution in the main band saw shaft 3D model for two variants of loading - vertical and horizontal V-belt transmission are received by FEM. For both variants of loading the maximum values of these parameters are localized near to the bearing support “*A*”. In these places the minimum factors of safety are received. The maximum resultant displacements are localized in the end of the shaft where the drive side wheel is fixed.

The static analysis results show that the maximum values of von Mises stresses, equivalent strains and resultant displacements have smaller values for vertical than for horizontal V-belt transmission, i.e. more favourable stress condition is resulted for vertical V-belt transmission which must be taken into account in designing of new machines.

REFERENCES

1. Filipov, G. (1967). Woodworking machines, Zemizdat, Sofia (in Bulgarian)
2. Filipov, G., Genchev, G., Savov, P. (1983). Manual for course designing of woodworking machines, Technika, Sofia (in Bulgarian)
3. Sokolovski, Sl., Deliiski, N. (2012). Analysis of the driving of the cutting mechanism for band saw, „Innovation in woodworking industry and engineering design”, 1/2012 (1): 174–180. (in Bulgarian)
4. Sokolovski, Sl., Deliiski, N. (2013). Reduction of the load on the main drive shaft of band saws, Innovation in woodworking industry and engineering design, 1/2013 (3): 59–65.
5. Staneva, N., (2008). Parametrical modeling of circular saw shaft with SolidWorks®, Proceedings of Ist science-technical conference „Innovations in Woodworking Industry and Engineering Design“: 173–177. (in Bulgarian)
6. Staneva, N., Vasilev, P., Karev, K. (2012). Controlling calculations of a circular saw shaft with Autodesk Inventor®, Scientific Works of XXIst International conference „Young Scientists’2012“: 209–216 (in Bulgarian)
7. User’s Guide & Help Files, Autodesk Inventor Professional (2012).
8. Vasilev, P., Staneva, N., Karev, K. (2012). 3D modelling of a circular saw shaft with Autodesk Inventor®, IV-th National Students Science Conference “Management and Sustainable Development of Biological Resources“, 20–22 April 2012, Undola: in print (in Bulgarian)