DIRECT CALCULUS FORMULAS FOR THE LATHE TOOL EQUIVALENT STRESS VALUES DURING THE MANUFACTURING OF STEEL SHAFTS

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Abstract. *In this paper, starting from the stress values presented in Roşu (2015) [1], a method for determining direct calculus formulas for the lathe tool equivalent stress values during the manufacturing of steel shafts is established. There is used the regression analysis for the formulas determination. The equivalent stress will be dependant on the cutting depth. The obtained formulas will be verified by using an analytical model from Strength of Materials. The results and the calculus formulas are presented from an original point of view.*

Keywords: regression analysis, equivalent stress, bending, turning.

1. INTRODUCTION

In this paper, starting from the researches presented in Roşu (2015) [1] regarding the stress determination from the lathe cutters that manufacture steel products through turning, I will establish a method to determine direct calculus formulas for the equivalent stress by using the regression analysis. I will also take into account the researches from Miriţoiu (2014) [2] and Miriţoiu (2014) [3]: there will be searched for linear, logarithmic, power and exponential functions to approximate the experimental results in order to obtain a correlation factor close to 1 value. The polynomial functions were avoided because their obtained factors insert errors if the experimental results are repeated (see Miriţoiu (2014) [2] and Miriţoiu (2014) [3] for these aspects). Also, some researches regarding the regression analysis applied in the manufacturing process can be found in Zamfirache (2009) [4] (titan alloys manufactured by turning) and Zamfirache (2009) [5] (stainless steels manufactured by grinding).

The stress results from Roşu (2015) [1] are presented in table 1.

Table 1. Stress values versus the cutting depth (Roşu (2015) [1])

a_p [mm]	0,5	0,7	0,9	1,1	1,3	1,5
σ_{echexp} [MPa] (varianta 1)	6,6895	9,3591	12,118	14,826	16,43	19,677
σ_{echexp} [MPa] (varianta 2)	38,785	56,143	73,365	90,629	108,37	123,67

I have used the next chipping parameters: *the feeding* f= 0,2 mm/rot; *the cutting depth* a_p= 0,5; 0,7; 0,9; 1,1; 1,3; 1,5 mm; the *speciffic pressure* p_m= 310 MPa (according to Cârstea (2007) [6]). There will be used two different lathe cutters with the next transversal sections: 25x25 mm (first lathe cutter) and 25x10 mm (second late cutter) (see Roşu (2015) [1] for details). The dependence of the stress and cutting depth, for both considered variants, are presented in fig. 1 and 2.

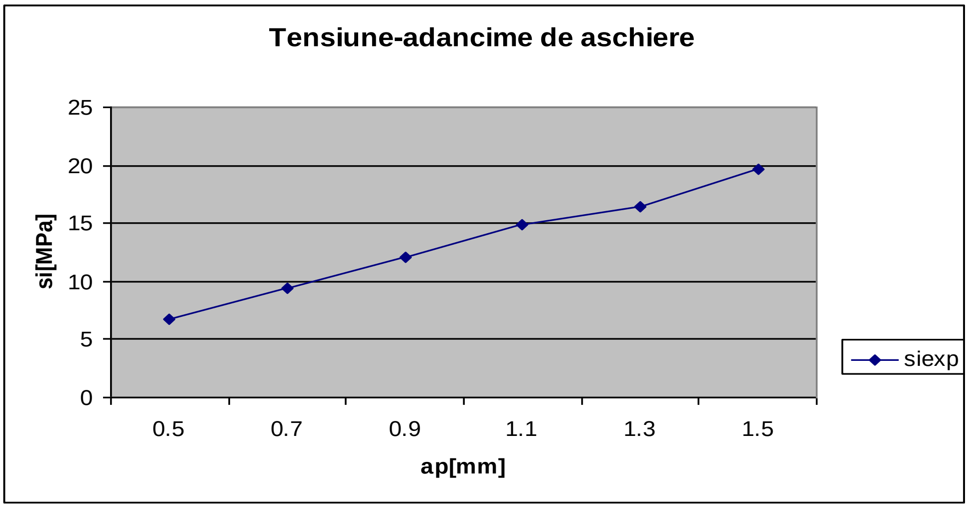

Fig. 1. Stress vs. cutting depth (variant 1)

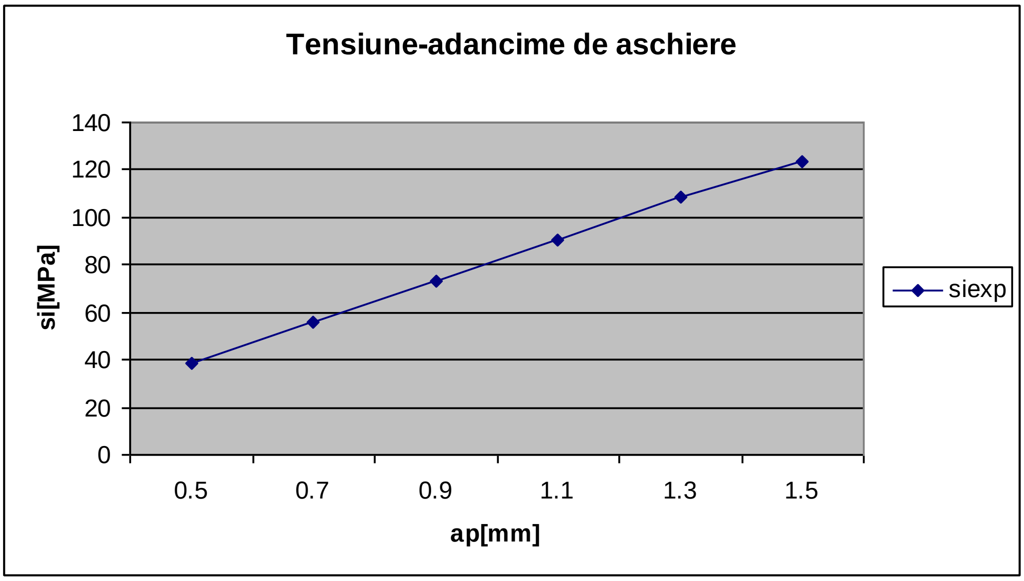

Fig. 2. Stress vs. cutting depth (variant 2)

2. REGRESSION ANALYSIS USED TO DETERMINE DIRECT CALCULUS FORMULAS

In this paprt of the paper I will use the regression analysis to determine a direct calculus formula for the equivalent stress experimentally obtained. I have searched for the next correlation functions:

- linear: $\nu(v)=\alpha_1 \cdot v+\alpha_2$
- logarithmic: $\nu(v)=\beta_1 \cdot \ln(v)+\beta_2$
- power: $\nu(v)=\eta_1 \cdot v^{\eta_2}$
- exponential: $\nu(v)=\lambda_1 \cdot e^{\lambda_2 \cdot v}$

By using the regression analysis and the experimental data, I have obtained the values for α, β, η, λ, ξ, ζ parameters. For every set, I have written the results in tables 2 (variant 1) and 3 (variant 2).

Important remark: the free length of the lathe cutter is 50 mm.

Table 2. The parameters α, β, η, λ, ξ, ζ values – variant 1

Function type	Linear	Logarithmic	Power	Exponential
Parameters	α_1= 2,5388 α_2= 4,2974	β_1= 6,9766 β_2= 5,5332	η_1= 6,4547 η_2= 0,5955	λ_1= 5,9853 λ_2= 0,2081
Correlation factor R^2 [%]	99,52	94,29	99,18	96,58

Table 3. The parameters α, β, η, λ, ξ, ζ values – variant 2

Function type	Linear	Logarithmic	Power	Exponential
Parameters	α_1= 17,096 α_2= 21,99	β_1= 46,821 β_2= 30,486	η_1= 37,228 η_2= 0,6519	λ_1= 34,249 λ_2= 0,2281
Correlation factor R^2 [%]	99,97	94,406	99,32	96,89

From the tables 2 and 3 it is seen that the linear function approximate the best the experimental results. So, for the variant 1 I propose the formula (1) and for the variant (2) I propose the formula (2).

$$\sigma_{ech\exp}(a_p) = 2{,}5388 \cdot a_p + 4{,}2974 \tag{1}$$

$$\sigma_{ech\exp}(a_p) = 17{,}096 \cdot a_p + 21{,}99 \tag{2}$$

Important remark: because there was no distributed force to act upon the lathe cutter, it was expected to obtain, for the stress, a first degree function.

3. THE RESULTS VALIDATION

In the next part of the paper I will validate the experimental results obtained in Roşu (2015) [1], used in this study to obtain the direct calculus formula. If I consider that the lathe cutter is loaded only to bending in the vertical plane (according to the theory from Cârstea (2007) [6]), the relation (3) can be used for stress calculus.

$$\sigma_{ss} = \frac{M_{\max}}{W_y} = \frac{F_z \cdot l}{\frac{b \cdot h^2}{6}} = \frac{60 \cdot p_m \cdot f \cdot a_p}{b \cdot h^2} \tag{3}$$

If I take into account all the loadings (from axial force, shear force and bending moments in vertical and horizontal planes), then I will use the direct calculus formulas from Roşu (2013) [7].

$$\sigma_{echB_2} = \frac{F_x}{A} + \frac{F_z \cdot l}{W_y} + \frac{F_y \cdot l}{W_z} = +3 \cdot p_m \cdot f \cdot a_p \cdot \frac{b \cdot h + 20 \cdot l \cdot b + 8 \cdot l \cdot h}{(b \cdot h)^2} \quad (4)$$

$$\sigma_{echB_1} = \frac{6 \cdot p_m \cdot f \cdot a_p}{b \cdot h^2} \cdot \sqrt{19 \cdot h^2 + 20 \cdot l \cdot h + 100 \cdot l^2} \quad (5)$$

$$\sigma_{echB_3} = \frac{3 \cdot p_m \cdot f \cdot a_p}{h \cdot b^2} \cdot \sqrt{13 \cdot b^2 + 16 \cdot l \cdot b + 64 \cdot l^2} \quad (6)$$

The B_i points (i=1,2,3) are determined accordhing to the scheme from fig. 3 (presented in Roşu (2013) [7]).

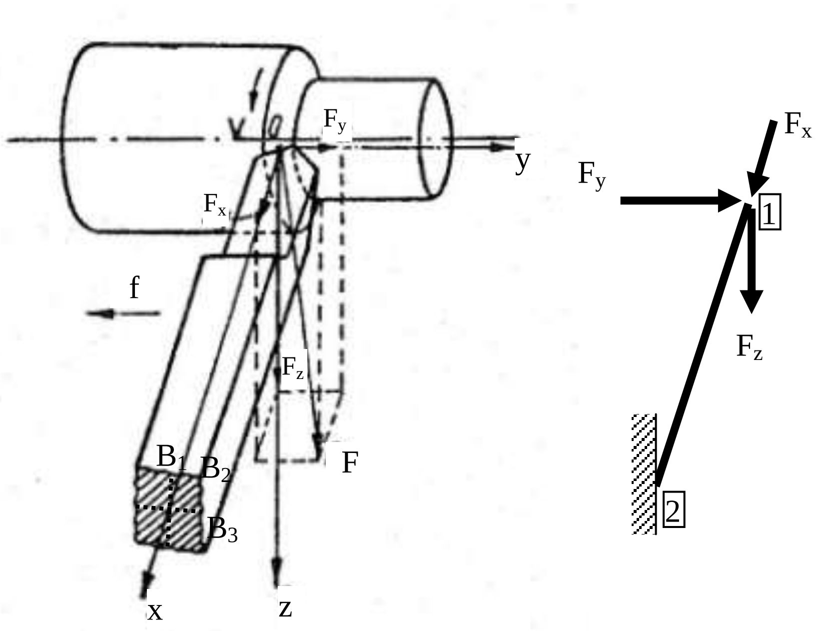

Fig. 3. The loading of a lathe tool Roşu (2013) [7]

In (3), (4), (5) and (6) I have marked with:

- *f* the feeding;
- a_p the cutting depth;
- p_m the specific pressure;
- *b,h* the base and the height of the lathe tool;
- *l* the free length of the lathe tool.

The obtained results for the variant 1 and 2 are written in tables 4 and 5.

Table 4. Stress values (variant 1)

a_p [mm]	0,5	0,7	0,9	1,1	1,3	1,5
σ_{echB1} [MPa]	6,235	8,73	11,224	13,718	16,212	18,706
σ_{echB2} [MPa]	8,482	11,874	15,267	18,66	22,052	25,445
σ_{echB3} [MPa]	2,582	3,614	4,647	5,679	6,712	7,745
σ_{ss} [MPa]	5,952	8,333	10,714	13,094	15,475	17,856

Table 5. Stress values (variant 2)

a_p [mm]	0,5	0,7	0,9	1,1	1,3	1,5
σ_{echB1} [MPa]	37,71	52,794	67,878	82,962	98,046	113,13
σ_{echB2} [MPa]	43,524	60,934	78,343	95,753	113,162	130,572
σ_{echB3} [MPa]	6,454	9,036	11,617	14,199	16,78	19,362
σ_{ss} [MPa]	37,2	52,08	66,96	81,84	96,72	111,6

The stress values versus the cutting depth, for both variants are presented in fig. 4 and fig. 5

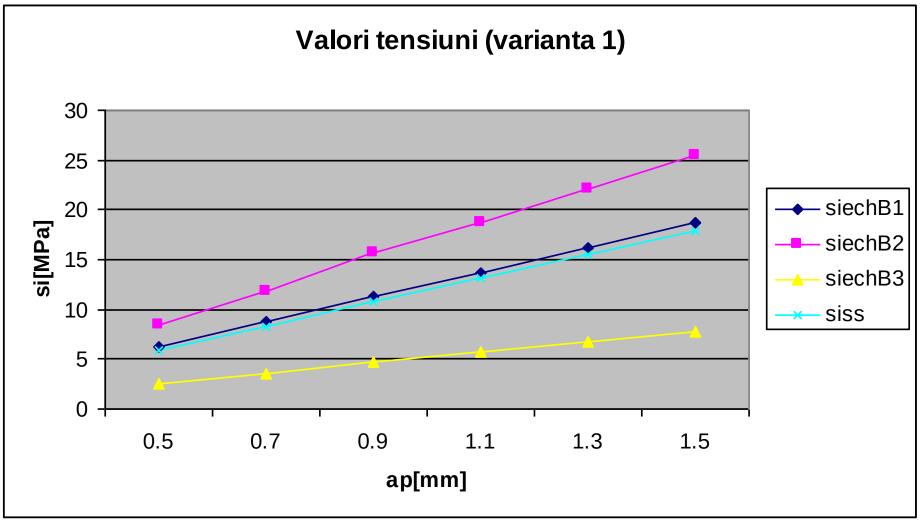

Fig. 4. Stress versus the cutting depth (variant 1) – analytical values

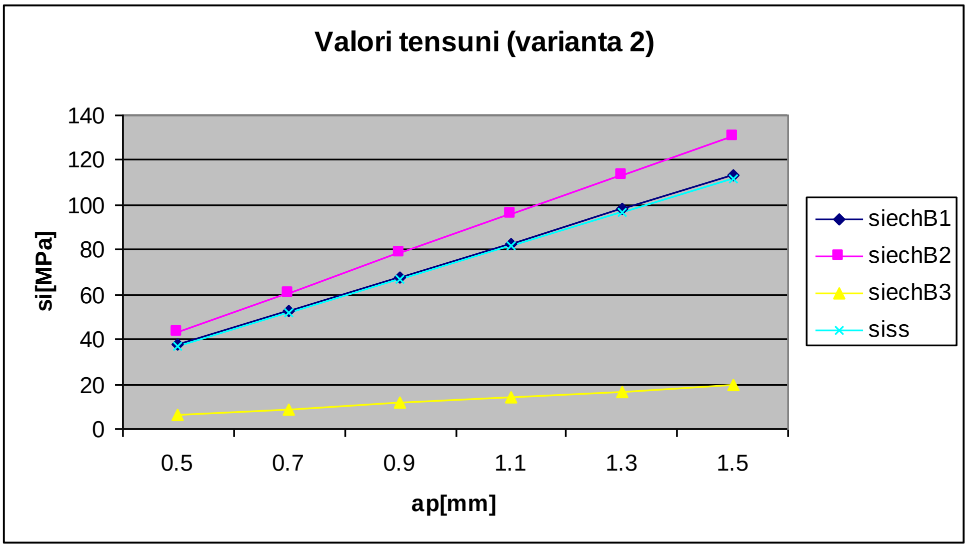

Fig. 5. Stress values versus the cutting depth (variant 2) – analytical values

4. CONCLUSIONS

From the fig. 1,2,4 and 5 and tables 1,4 and 5 we can see the next tendencies:

- the stress increases with the cutting depth;
- the stresses are higher if the second lathe tool is used;
- the graphics variation is almost linear;
- the maximum stress is in point B_2 and minimum in point B_3;
- the stress determined from the simple bending in the vertical plane is almost equal with the equivalent stress in point B_1 (this shows that the shear stress given by shear force F_z has small influence over the equivalent stress);
- the σ_{ss} values and the experimental stress values have small errors, under 12% (the errors may appear because of the vibration from the manufacturing process);
- the σ_{echB1} values and the experimental stress values have small errors, under 8% (the errors may appear because of the vibration from the manufacturing process);
- the σ_{echB2} values and the experimental stress values have high errors (maximum is around 35%) because the influence of the horizontal plane moment is high, and its value has not been determined in the experimental part;

One of the added values of this paper is also the determination of some direct calculus formulas for the equivalent stress, depending on the lathe tool type and on the cutting depth value.

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