



TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 61, Issue I, March, 2018

CUTTING PARAMETERS AND ANALYSIS BY FEA SIMULATION OF THEIR INFLUENCE ON THE RE-PROFILATION OF THE WHEELS OF THE RAILWAY WHEELSET

Ionuț Gabriel GHIONEA, Adrian GHIONEA, Nicolae PREDINCEA

Abstract: Modern approaches on research projects in the field of lathes' remanufacturing involve various simulation stages, like FEA and CAM, in order to obtain results and solutions with different aspects and data important to consider. These simulations may confirm data obtained through measurement, but also extrapolate values that can't be measured directly on the machine-tool technological system. Usually, a mathematical and simulated models, with a low error percent, are the main key for the remanufacturing team. The newest trend in manufacturing technologies, the acclaimed Industry 4.0, relies on new design concepts and methods, data acquisition and exchange between systems, processing, visualization and automation. Modern simulation methods, system integration between simulated and measured data, augmented reality, etc., are important parts of the actual factories. More and more machine-tools without CNC capabilities are remanufactured in this new vision of Industry 4.0. This paper presents some phases in establishing the turning process parameters in profiling and re-profiling of the trains wheelsets. There are used specific instruments (a mathematical approach and 3D models for FEA simulation) in order to determine which system (tool holder – insert – process parameters) are better to be used on the remanufactured lathe.

Key words: tread profile, wheelset, re-profiling, cutting parameters, FEA analysis.

1. INTRODUCTION

Wheelsets are the most loaded components of railway vehicles and subject of a continuous process of wearing resulted from different and difficult running conditions: non-uniform loads of the freight wagons, alteration of rail and wheel profile, sudden temperature variations, curved segments of rails, breakings, etc. Periodically, the wheelsets are checked and once they reach a critical level of wear, they must be reshaped or even replaced.

The replacement is difficult and occurs only when the material to be removed by cutting processes surpass a certain limit [1].

In figure 1 there are presented three samples of used wheels with different wear grades: normal, medium and very worn. In the last sample, the rolling surface may be reshaped after an analysis. If the wear includes also deep cracks, the reshaping process cannot be achieved and the wheelset will be replaced.

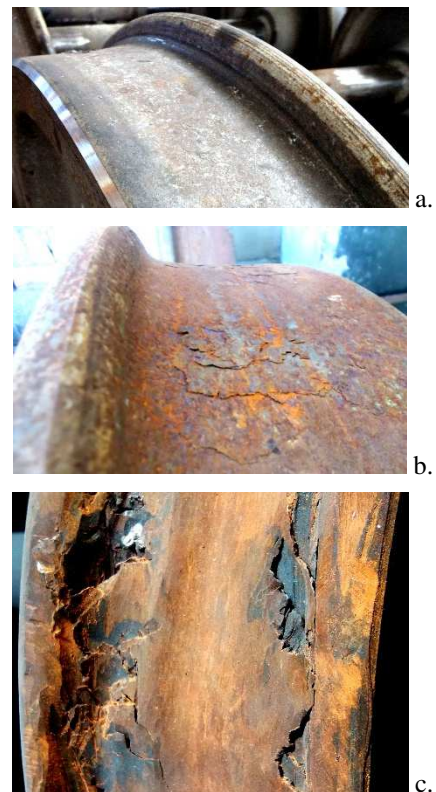


Fig. 1. Samples of worn railway wheels

The specialized lathes for processing the wheels and wheelsets of the railway vehicles are modernized according to the requirements of international standards and norms [2, 3, 4, 5]. The operation/movement of the railway vehicle involves the contact between the rail and wheels surfaces. In time, these surfaces become worn, leading to changes of the wheels profiles and, therefore, to instability in the movement of vehicles, an important problem for traffic safety and passengers comfort.

Due to the very high cost for acquisition of a modern new lathe, the companies often opt for the remanufacturing of an existing machine tool. Thus, they search and invest in the development and implementation of an automated equipment suitable for simulation, manufacturing and measuring of wheels running profile, both static and dynamic.

The remanufactured lathe has new driving, command and measurement systems and the costs are soon recovered by increasing the productivity and profiling/re-profiling accuracy, with the life of the lathe highly increased [6].

Our theoretical and experimental studies of cutting the alloyed steels are important in actual approaches [7, 8]. Such research generates important data on the theory of cutting, development and use of new cutting tools, rigidity increase of the technological system components, reducing processing times and of energy consumption [9].

The knowledge of the phenomena that characterize the chip formation and detachment, the quality and condition of the processed surface and the wear of the cutting tools is ensured by numerous researches.

The machinability of steel alloys differs depending on composing elements, heat treatments and manufacturing processes (cast, forged, etc.) [10, 11, 12].

The evaluation of roughness determined by the quality of the surface is the result of how the surface is generated [13].

The geometry of the cutting edge (constructive and active), the parameters of the cutting process, the vibrations, the elastic failures, the thermal phenomena, chip formation etc. are also important.

The components of the machining system are: the machine-tool subsystem, semi finished parts,

fixture devices, cutting tools, measuring and control devices.

2. SETTING THE PARAMETERS OF THE CUTTING CONDITIONS

The profiling and re-profiling of the wheels are carried out by technological processes of turning on specialized machine tools [1, 14]. Three types of machine tools are used, namely: conventional, portal and underfloor.

The main turning conditions for rolling surfaces are the following: the difference in diameters on the reference circle at the two wheelset's wheels $\Delta D \leq 0.15$ mm, the profile accuracy ≤ 0.15 mm, the roughness of the surface $R_z = 10 \dots 20$ μm , runout of the tread ≤ 0.15 mm [3, 13].

Usually, the wheels have the diameter in certain dimensional domains, which are established and used for international transport vehicles intended for passengers. Diameter values may vary from minimum to maximum, as follows: 330-390 mm, 390-470 mm, 470-550 mm, 550-630 mm, 630-680 mm, 680-760 mm, 760-840 mm, 840-920 mm and 920-1000 mm, according to standards. These dimensions are imposed for both locomotives and wagons. The wheels' geometry and dimensions are indicated in European standards in their annexes [4, 5].

2.1 Materials for wheels and turning tools

The steel materials used for wheels and rails across Europe have predominantly pearlitic structures containing hard cementite lamellae for a high wear resistance. A pearlitic microstructure, ensures a better resistance than bainitic or martensitic structures.

Although the standard UIC 812-3 [2] for solid wheels lists seven types of steel, which mainly differ in carbon content, heat treatment state and strength, the actual SR EN 13262 [4] contains only four types.

Because Grade R1 for freight wagon wheels is on the decline in favor of the standard R7 material, and Grades R2/R3 never established themselves in operational practice, this represents the current state of technology in Europe.

The maximum percentages of the various specific elements are presented in the two standards (Table 1).

Table 1: Wheel steel requirements according to UIC 812-3 and SR EN 13262

Steel category		Carbon content (%)	Yield strength (N/mm ²)	Tensile strength (N/mm ²)	Elongation (%)	Notch impact energy (J)	
UIC 812-3	SR EN 13262	UIC/SR EN	SR EN 13262	UIC/EN	UIC/EN	UIC 812-3 U-notch (RT)	SR EN 13262 V-notch (-20°C)
R1 N	-	≤ 0.48	-	600...720	≥ 18	≥ 15	-
R2 N	-	≤ 0.58	-	700...840	≥ 14	≥ 10	-
R3 N	-	≤ 0.70	-	800...940	≥ 10	≥ 10	-
R6 T, E	ER6	≤ 0.48	≥ 500	780...900	≥ 15	≥ 15	≥ 12
R7 T, E	ER7	≤ 0.52	≥ 520	820...940	≥ 14	≥ 15	≥ 10
R8 T, E	ER8	≤ 0.56	≥ 540	860...980	≥ 13	≥ 15	≥ 10
R9 T, E	ER9	≤ 0.60	≥ 580	900...1050	≥ 12	≥ 10	≥ 8

N - normalized, T - rim heat treated, E - whole wheel heat treated

The choice of the cutting tools requires specific conditions, established by theoretical and experimental research, significant being those indicated by the main producing companies (Sandvik Coromant, Widia, Pramet, Iscar, Stellram, Ceratizit, Toprail).

For normal wear of the tread, the profile is processed in a single pass, and in other cases, the machining allowance is removed in two or more passes according to the specified machining conditions (dimensional precision, surface quality, profile and position deviations of the tread) [15]. The cutting tools system for re-profiling the railway wheels consists of turning tools with replaceable supports for tangentially mounted inserts. According to the companies recommendations, these inserts are able to withstand complex stresses at mechanical machining specific to turning, with high cutting depths, at high temperatures [12, 17].

The turning tools and their inserts are chosen according to the type of re-profiled wheel, the steel category (Table 1), the wheels wear condition, technical conditions of machining, the lathe version (e.g. RAFAMET UBC 150, Polish made, presented in figure 2), stability of the technological system, installed power of the machine-tool.



Fig. 2. Front view of the RAFAMET UBC 150 lathe

The machining of the two wheels composing the wheelset is done on the same machine tool in a single grip. There are used cutting tools with identical inserts, one on the left, the other on the right and the same cutting parameters.

The modular construction [17, 18] of the cutting tools indicates the high degree of technical characteristics and performance. For the tool choice it is taken into account the shape of the processed surface, the insert type (square, round or triangular), their number (one or two) and the producing company.

The insert's shape and type are chosen depending on the machining process (roughing, semi finishing, finishing), current status of the surface and the requirements imposed by the fragmentation of the chips, also depending on cutting depths and feeds.

Thus, figure 3, a. shows fragmentary chips obtained in the machining process of the wheel surface of a wheelset (Fig. 2) at UV Aiud (the wagons factory of Aiud, Romania).

The main processing parameters according to figure 3 are: the wheel material is ER7 (242 ... 276 HB), cutting speed $v_c = 38$ m / min, cutting depth $a_p = 7$ mm, the cutting tool has a round insert (diameter $D_c = 20$ mm) without cooling.

The chip type (continuous or segmental) is determined by numerous parameters, including the hardness of the material to be turned for re-profiling.

A segmented chip is also recommended to avoid wrapping it in the working area. Long chips also mean machine-tool idle time and an operator to clear the chips.

Figure 3, a. presents the turning process (turning tool with a round insert) in a normal

wear area, the chips result in segmentation. In figure 3, b. there is observed a spiral and continuous long chip obtained during the same turning process, but in a flattened layer area (fig. 1, a.), with a larger machining allowance, the wheel material in the respective area having a bigger wear and hardness. In figure 3, c. some segmental chips are exemplified.

The cutting process is not stable since the machining addition is uneven in size and hardness. These increase the tool wear, vibrations accompanied by specific noise. All this results from the analysis of the shape and appearance of chips (intense blue color and serrated edges, fig. 3, c. detail).

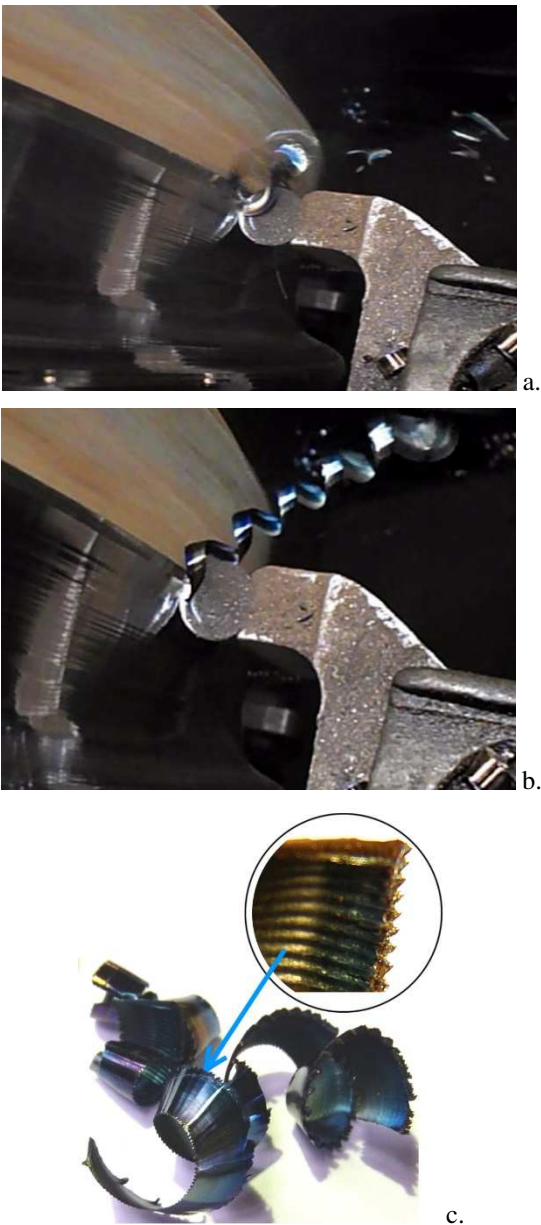


Fig. 3. Sample of chips

One of the common problems in wheels re-shaping is the chip formation during the back turning operation at the rim zone. Most of the inserts have a specialized chip former that has been designed [19] to prevent long/continuous chip formation during the turning process.

The choice of the inserts' material is based on the condition of deterioration/wear of the wheel surfaces, the insert's codification being specific to each tool producing company.

Thus, these grades [17, 18] are classified depending on the tread's state of wear: for wheels with a low wear, it is used the ISO-P: GC3015 grade (high cutting speeds for maximum productivity).

Most wheels have some flattening and/or exfoliation areas, thermal cracks, small breaks, so it is used the ISO-P: GC4215 grade (it is almost universal, recommended as the first choice for all re-profiling processing).

In the case of the wheels with serious damaged areas, it is recommended to use the ISO-P: GC4225 or ISO-P: SH grades and turning at low cutting speeds.

For the analysis of the cutting parameters, two types of turning tools are considered: with square plates and with round plates. The tools bodies differ according to the shapes and dimensions of the inserts, an example being shown in figure 4 (with the main cutting edge on the right). It is also considered whether the processing of the rolling surface (the specific areas of the profile [3]) is done or not with the same tool.



Fig. 4. Sample of a turning tool

In practice, for the analysis of the possible cutting setup, firstly the cutting tools are chosen, characterized by different constructive, dimensional and shape variants of the inserts.

Next, to obtain the tread surface, the following machining variants are indicated, recommended by tools manufacturers [17, 18]:

- semi finishing re-profiling of the excessively worn wheels, using a tool holder support fitted with two tangentially mounted inserts;
- finishing re-profiling of the low worn wheels using a tool holder support with two rhombic inserts;
- roughing re-profiling of wheels with an increased wear using two turning tools with square or triangular inserts;
- roughing re-profiling of the excessive worn wheels using a single turning tool with a round insert.

2.2. Roughness and cutting feed

The surface roughness is determined by the shape, state and dimensions of the main cutting edge of the insert and of the value of the cutting feed. This parameter is determined by the precision and the prescribed quality of the processed surface [20].

Also, in the determination of the feed, there are taken into account the technical conditions for machining [12, 19] of the wheels profiles. The surface roughness R_a , according to the feed

rate [14], is: *Group I*: $R_a = 6.3 \mu\text{m}$; *Group II*: $R_a = 12.5 \mu\text{m}$.

There is a direct link [12] between the R_a and R_t roughnesses and it can be considered a constant ratio $k_R = R_a / R_t = 0.25$.

Therefore, for the two groups mentioned, the theoretical roughness R_t has the value: *Group I*: $R_t = 25 \mu\text{m}$; *Group II*: $R_t = 50 \mu\text{m}$.

Knowing that at turning, the theoretical roughness of the machined surface for turning tools with peak radius r_ϵ is given by the relation:

$$R_t = 10^3 \cdot \frac{f_n^2}{8 \cdot r_\epsilon} [\mu\text{m}], \quad (1)$$

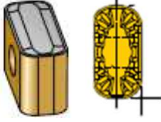
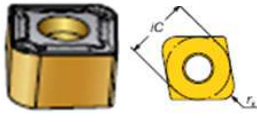
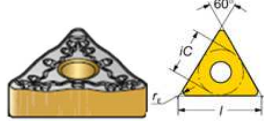
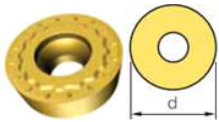
the optimal feed is determined by the condition: $R_t \equiv R_z \leq R_{zadm}$

$$f_{opt} \leq \left(8 \cdot 10^{-3} \cdot r_\epsilon \cdot R_{zadm} \right)^{1/2} [\text{mm / rot}], \quad (2)$$

where R_z is the average roughness, in μm .

The peak radius having different values depending on the shape of the insert and considering the admissible R_z roughness according to the two processing groups, the optimum values for the feed are obtained and indicated in Table 2.

Table 2. Optimal feed rates for different insert shapes depending on the machining group and the peak radius r_ϵ

Insert's shape, according to [17, 18]			
			
Peak radius r_ϵ , mm			
$r_\epsilon = 4$		$r_\epsilon = 1.6$	
$r_\epsilon = d / 2 = 10$			
Group I: admissible R_z roughness: $R_t = R_{zadm} = 25 \mu\text{m}$			
Optimal feed depending on roughness f_{opt} , mm/rev			
0.9		1.41	
Group I: admissible R_z roughness: $R_t = R_{zadm} = 50 \mu\text{m}$			
Optimal feed depending on roughness f_{opt} , mm/rev			
1.26		2.0	
<p><i>Note:</i> The values set for the f_{opt} parameter can be diminished by a certain factor that takes into account the static and dynamic behavior of the technological system. The recommended value is also determined by experimental research.</p>			

Analyzing the values in Table 2 according to the peak radius and admissible R_{zadm} , it is found that these values are in accordance with the values indicated in the catalogs of the companies producing the cutting tools.

In these conditions, the minimum feed value is adopted: $f_{min} = 0.3 \text{ mm/rev}$. For the maximum

feed value f_{max} in the roughing process of the wheel profile, the value $f_{max} = 2 \text{ mm/rev}$ is also indicated in the catalogs of cutting tools.

Consequently, the recommended range of variation $D_f = f_{min} \dots f_{max} = 0.3 \dots 2 \text{ mm/rev}$.

2.3. Setting the cutting speed

For the determination of the cutting speed v_c , a calculus relation is presented, taking into account the following parameters: effective durability T , cutting depth a_p and feed f_n [8, 21]. The durability is adopted at the value $T = 120$ min, imposed by the processing of a suitable number of wheels, considering an average productivity of the process. Thus, it is considered:

$$v_c = C \cdot a_p^E \cdot f_n^E \cdot T^G \cdot K_g \text{ [m/min]}, \quad (3)$$

where the constant C and the exponents F , E and G depend on the processing group (Table 1), on the pair of materials cutting tool-wheel; K_g - global correction factor that takes into account the machinability and rigidity of the machine-tool - tool - fixture device - part system.

Thus, for the wheels material, it is considered the group of alloyed steels with chromium, nickel and molybdenum, with the yield strength $R_m = 1000$ N/mm², that is included in the processing Group 7 (Table 1).

The machining is done with a sintered metal carbide turning tool with thin-film coatings (grade GC 4215). This coated carbide grade is used for finishing to roughing in applications with continuous cut to light intermittence of steel and steel castings. It presents a gradient substrate optimized in hardness and toughness with a wear resistant coating.

The GC 4215 grade is able to withstand high temperatures without sacrificing edge line security in wet and dry applications. According to [21] the values are admitted: $C = 168$; $E = 0.45$; $F = -0.12$; $G = -0.16$ for use in relation (3).

The following parameters for the machining conditions are considered: $a_p = 8$ mm; $f_n = 1.2$ mm/rev and a value of the correction coefficient $K_g = 0.75$.

Through replacements and calculations it is obtained the value of $v_c \cong 45$ m/min, which is the main recommendation of the companies producing cutting tools.

For finishing processing, the considered parameters are: $a_p = 3$ mm; $f_n = 0.5$ mm/rev and a correction coefficient $K_g = 0.8$. By replacing in relation (3), it is obtained: $v_c \cong 75$ m/min.

2.4. Range of cutting speed and feed rates

The minimum and maximum values of the wheels diameters subjected to re-profiling are considered to be: $D_{min} = 630$ mm; $D_{max} = 1300$ mm, then results the maximum and minimum spindle speed (n_c) of the main shafts that support and drive the wheelset, namely:

$$n_{cmax} = \frac{1000 \cdot v_{cmax}}{\pi \cdot D_{min}} = \frac{1000 \cdot 75}{\pi \cdot 630} \cong 38 \text{ [rev/min]}; \quad (4)$$

$$n_{cmin} = \frac{1000 \cdot v_{cmin}}{\pi \cdot D_{max}} = \frac{1000 \cdot 45}{\pi \cdot 1300} \cong 11 \text{ [rev/min]}; \quad (5)$$

Thus, the spindle speed variation range is determined $D_{nc} = n_{cmin} \dots n_{cmax} = 11 \dots 38$ rev/min. The remanufactured lathe has: $D_n = n_{min} \dots n_{max} = 9 \dots 35.5$ rev/min. The range is achieved by a combined adjustment mechanism that consists of a two-speed asynchronous electric motor and a four-speed gearbox with the ratio of $\varphi = 1.41$.

The feed speed range D_{vf} is based on the values of the feed parameters (f_{min} and f_{max}) and of the spindle speed (n_{cmin} and n_{cmax}) as follows:

$$v_{fmin} = f_{min} \cdot n_{cmax} = 0,3 \cdot 38 \cong 11 \text{ [mm/min]}; \quad (6)$$

$$v_{fmax} = f_{max} \cdot n_{cmin} = 2,0 \cdot 11 = 22 \text{ [mm/min]}. \quad (7)$$

2.5. The cutting forces

The identification of the cutting forces values is useful both for the design and for the functioning of the lathe. Thus, for the design of the main shaft assembly, data are needed to dimension its structural elements (shaft, bearings, clamping and drive mechanisms). It is necessary to determine the components of total cutting resistance and moment of cutting.

The components of the total cutting resistance F [22], called cutting forces and defined according to the working plane are obtained by projecting the force F on the axes of the $OXYZ$ kinematic reference system. These are:

F_c - the cutting force required for dimensioning of the main shaft;

F_f - the feed force required for dimensioning the components of the kinematic chain of feed/positioning, with the speed v_f ,

F_p - the passive force required to dimensioning the mechanisms from the structure of the kinematic chain of feed/transversal positioning (radial).

In literature [15] there is a multitude of mathematical relations theoretically or experimentally determined, which can lead to results with different values.

$$F_c = b \cdot h \cdot k_c \cdot K_{\gamma_o} \cdot K_v \cdot K_{ms} \cdot K_{uz} \cdot K_{prd} = b \cdot h^{1-m} \cdot k_{c1.1} \cdot K_{\gamma_o} \cdot K_v \cdot K_{ms} \cdot K_{uz} \cdot K_{prd} \text{ [N]}, \quad (8)$$

in which: m - a polytropic exponent; K_{γ_o} - correction factor depending on the orthogonal departure angle γ_o ; K_v - correction factor according to the cutting speed; $K_{ms} = 0,95 \dots 0,9$ - correction factor depending on the material of the cutting tool insert; $K_{uz} = 1,3 \dots 1,5$ - correction factor according to the wear of the cutting tool edge; K_{prd} - correction factor according to the machining process, h - chip thickness.

Between the specific cutting force and the specific cutting resistance, the calculation relation is established:

$$k_c = \frac{k_{c1.1}}{h^m} \text{ [N/mm}^2\text{]}. \quad (9)$$

Figure 5 shows some basic geometric parameters of the insert (a. round insert and b. rectangular insert) and technological parameters of the processing: the feed f_n , the cutting depth a_p , the chip thickness h , the insert radius r_ϵ , the approach angle K_r .

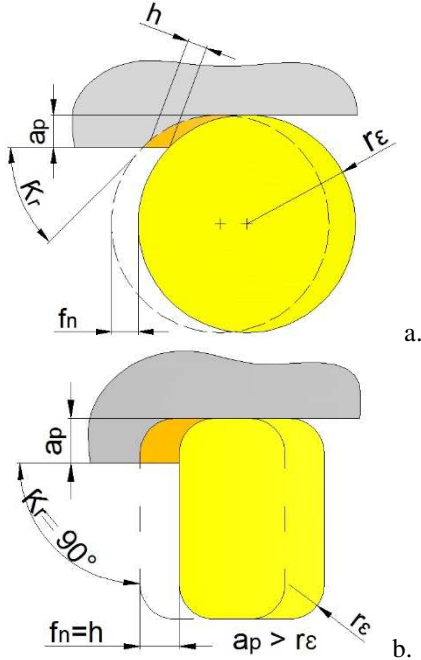


Fig. 5. Parameters notation of two inserts types

The feed force F_f and the passive force F_p are determined with similar relations (10) as that of the cutting force F_c :

Thus, the cutting force is determined by the calculation relation [21]:

$$F_f = b \cdot k_{f1.1} \cdot h^{1-x} \text{ [N]}; F_p = b \cdot k_{p1.1} \cdot h^{1-y} \text{ [N]}. \quad (10)$$

The values for the polytropic constants and exponents [8, 21] were considered for the 30CrNiMo8 wheel material: $m = 0,2$, $k_{c1.1} = 2600 \text{ [N/mm}^2\text{]}$, $1-x = 0,38$, $k_{f1.1} = 355 \text{ [N/mm}^2\text{]}$, $1-y = 0,57$, $k_{p1.1} = 255 \text{ [N/mm}^2\text{]}$. The material has characteristics close to those of the wheel (ER7).

The chip thickness h is determined by the relations established between the geometrical and technological parameters (Fig. 5). Also, using these chip parameters, there are determined the cross section area A , the chip rate Q and the machining productivity.

$$A = a_p \cdot f_n = b \cdot h \text{ [mm}^2\text{]}. \quad (11)$$

The detached chips rate Q is determined depending on the machining process. When turning, the calculation relation (12) is used:

$$Q = a_p \cdot f_n \cdot v_c = A \cdot v_c = \pi \cdot d_m \cdot a_p \cdot v_f \text{ [cm}^3\text{/min]}. \quad (12)$$

The corresponding time for a pass is determined using the calculus relation:

$$t_c = \frac{l_z}{f_n \cdot n_c} \text{ [min]} \quad (13)$$

where: l_z (mm) is the length of the machining stroke.

3. ANALYSIS BY FEM SIMULATION OF THE MACHINING PROCESSES

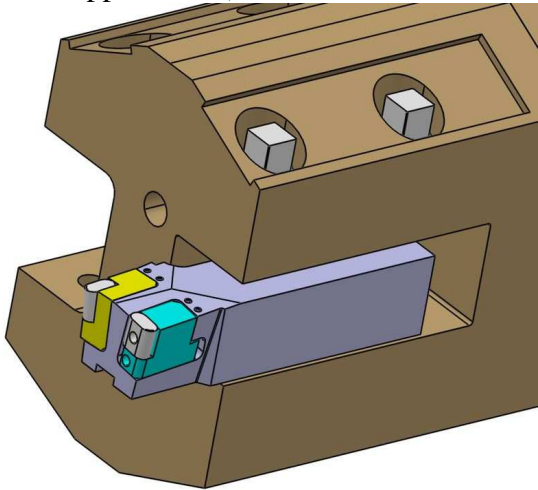
In order to study the static and dynamic behavior [23, 24] of the assembly insert - tool holder - radial sledge in the case of using certain tools recommended by the producing companies, the finite element method is used.

This is one of the best methods to achieve various engineering calculations/simulations.

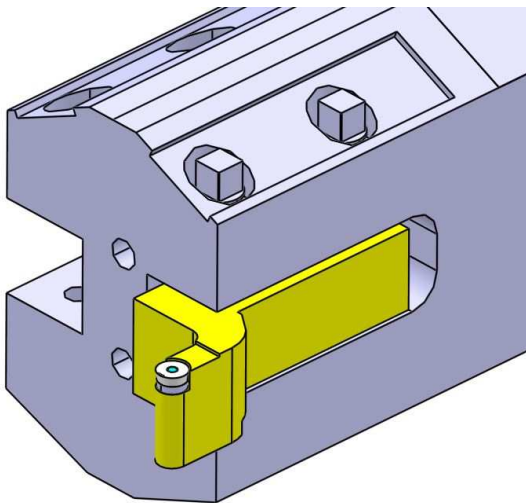
The 3D modeling of the assemblies (radial sledge, tool holder, supports, insert) was performed in CATIA v5 considering two manufacturing variants: with square plate and

with round plate (fig. 6). The components were assembled geometrically by applying specific constraints of coincidence, contact, parallelism, linear distance, etc.

The dimensions required for the modeling were taken from tools, tool holders and inserts catalogs, but also through direct measurements of other components (radial sledge, clamping screws, supports, etc.).



a.



b.

Fig. 6. Tool holders: with square and round inserts

In each case, the meshing of the studied assembly was made by establishing conditions specific to the FEM analysis to obtain a finite structure.

The loads and deformations at a certain number of points within the assembly are sufficient to accurately characterize its mechanical behavior.

The finite element method calculates the displacements and tensions only at these points of the created mesh, and the meshing process must provide a sufficient number of points in the

areas of interest in order to obtain a satisfactory approximation of the structure's geometry and loading conditions [24].

To the components of each assembly have been applied specific materials, according to the catalogs and standards, the most important parameters and a determinant role in the FEM simulation being Young's module, yield strength and density.

Thus, the component materials are considered as follows (in N/mm^2): Tool holder 4.2×10^8 , Inserts seats 3.8×10^8 , Inserts 5.2×10^9 , Radial sledge 2.8×10^8 , Clamping screws 2.5×10^8 , Insert's guide rail 2.2×10^8 .

Based on the work parameters previously determined by the calculations results the cutting forces occurred during the machining process. These forces were applied to the cutting edges of the inserts and load the whole assembly.

In the FEM analysis performed for its validation, several different situations are considered, varying the cutting depth and feed rate, but there are also considered the machining material, the angle of the insert and the required cutting power of the machine tool [25].

Thus, the values of the cutting forces are obtained for roughing, semi finishing and finishing. The four cases considered are presented in Table 3.

The application of force is done in each case on the insert's edge, in a precise, but small area, experimentally determined.

To perform the specific calculations of the FEM analysis, it was used a computer with Windows 8.1 64 bit, 16 Gb RAM and i7 processor, the average time of each of the four iterations being about 5 hours.

The relatively high duration of each FEM simulation was due to the complex conditions imposed on the components, but also to their high discretization, resulting in relatively low error rates (between 13.48% and 18.44%). These values are lower than 20% and are considered acceptable for this assembly.

Upon completion of each calculation/simulation iteration, the components exhibit a stress distribution and certain displacements.

Figure 7 shows the FEM models of the assembly for the two tool holders. The increased rigidity of the radial sledge, as well as the

components with higher displacements (insert, seat, tool holder, etc.) are observed.

The displacements values are small and do not affect the manufacturing precision and measurement. It is noted that the maximum

displacement appears on the insert's cutting edge [23].

For example, in the case of roughing with a cutting force of 17744.64 N, the displacement value for the round plate is 0.12 mm.

Table 3. Values of the cutting forces for different machining processes

No.	Processing	Cutting depth, a_p , mm	Feed, f_n , mm/rev	Cutting force, F_c , N	
				Square insert	Round insert
1	Finishing	3	0.3	3132.62	3358.74
2	Semi finishing	4.5	0.6	7375.91	8482.56
3	Roughing 1	6	0.65	11970.62	11853.33
4	Roughing 2	7	0.9	17229.4	17744.64

Table 4. Stresses values of the main components of the two assemblies radial sledge – tool holder - insert

Part	Stress, N/m ²			Displacement, mm		Machining process
	Yield strength	Square insert	Round insert	Square insert	Round insert	
Tool holder	4.2×10^8	1.49×10^8	7.49×10^7	0.0182	0.0164	Finishing
Insert seat	3.8×10^8	6.1×10^7	7.92×10^7	0.0189	0.0182	
Insert	5.2×10^9	4.52×10^8	4.7×10^8	0.0239	0.0243	
Radial sledge	2.8×10^8	2.01×10^7	2.6×10^7	0.0043	0.0037	
Tool holder	4.2×10^8	3.51×10^8	1.8×10^8	0.0429	0.0413	Semi finishing
Insert seat	3.8×10^8	1.44×10^8	2×10^8	0.0445	0.0461	
Insert	5.2×10^9	1.06×10^9	1.19×10^9	0.0562	0.0613	
Radial sledge	2.8×10^8	4.74×10^7	6.57×10^7	0.0101	0.0095	
Tool holder	4.2×10^8	3.86×10^8	2.63×10^8	0.0692	0.0577	Roughing 1
Insert seat	3.8×10^8	2.23×10^8	2.8×10^8	0.0717	0.0644	
Insert	5.2×10^9	1.66×10^9	1.66×10^9	0.0897	0.0857	
Radial sledge	2.8×10^8	9.08×10^7	9.19×10^7	0.0166	0.0134	
Tool holder	4.2×10^8	4.11×10^8	3.94×10^8	0.0852	0.0864	Roughing 2
Insert seat	3.8×10^8	3.36×10^8	3.4×10^8	0.0861	0.0964	
Insert	5.2×10^9	2.48×10^9	3.26×10^9	0.0925	0.1282	
Radial sledge	2.8×10^8	1.11×10^8	1.38×10^8	0.0236	0.0214	

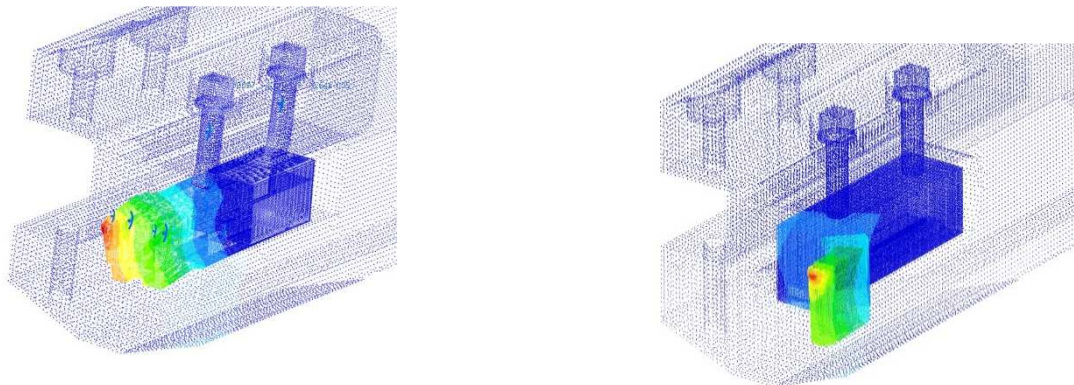


Fig. 7. Highlighting areas with displacements and their distribution in assemblies

The stresses values of the two assemblies' main components are also shown in Table 4.

As seen in the table, in the case of the roughing operations, the stresses values in the inserts and tool holders are relatively high, close to the yield strength of their respective materials.

It is recommended to use cutting conditions and machining regimes resulting in forces below 17000 N, the lathe having the capability (speed, installed power) to process the wheelset.

4. CONCLUSIONS

Taking into account the theoretical and experimental researches done in the frame of the project for the remanufacturing and NC equipment of the RAFAMET UBC 150 lathe, some recommendations resulted for its optimal use. These are necessary in the startup and then in the running phases of this lathe.

Thus, on the improvement of the cutting parameters, there are defined range values of feed, feed rate, cutting depth and cutting speed. Optimal machining parameters can be chosen, depending on the different wear conditions of the wheels' tread surfaces.

First, the wheelset is examined by a visual analysis and by measurement of the chip layer hardness and then by measurements of the dimensions of the worn surfaces.

The data obtained are stored in certain databases, analyzed and interpreted, based on them being determined: the tread surface wear condition, the number of processing passes required for re-profiling, the cutting parameters and the CNC program.

It also takes into account the degree of wear of the turning tool, its compensation and the elastic deformations due to the cutting forces and possible vibrations accompanying the cutting process.

It is proven the importance of choosing and supervising the cutting process, since it is performed simultaneously for both wheels of the wheelset.

Regarding the durability of the tools and their simultaneous change in the two work units, it is also necessary to consider the need to adapt the working parameters for each wheelset.

Acknowledgement:

The paper presents researches in the frame of Partnerships in Priority Areas Programme – PNII supported by MEN-UEFISCDI, in project PN II-PT-PCCA-2013-4-1681, *Mechatronic system for measuring the wheel profile of the rail transport vehicles, in order to optimize the reshaping on CNC machine tools and increase the traffic safety*, 2014 - 2017.

5. REFERENCES

- [1] Ghionea, I., Ghionea, A., Cioboată, D., Čuković, S., *Lathe machining in the era of Industry 4.0: Remanufactured lathe with integrated measurement system for CNC generation of the rolling surfaces for railway wheels*, 13th IFIP WG 5.1 International Conference on Product Lifecycle Management PLM16 – In Book Product Lifecycle Management for Digital Transformation of Industries, R. Harik, L. Rivest, A. Bernard (Ed.), Chapter 27, pp. 296-308, doi: 10.1007/978-3-319-54660-5_27, Springer International Publishing, IFIP Advances in Information and Communication Technology, Vol. 492, print ISBN 978-3-319-54659-9, Online ISBN 978-3-319-54660-5, print ISSN: 1868-4238, University of South Carolina, Columbia, USA, 2016.
- [2] UIC 812-3 *Technical specification for the supply of rolled solid wheels of non alloy steel for traction and rolling stock*. 5th edition, 1984.
- [3] UIC 510-2 *Trailing stock: wheels and wheelsets. Condition concerning the use of wheels of various diameters*, 4th edition, 2004.
- [4] SR EN 13262: 2007 - SR EN 13262+A2:2011, *Romanian standard, Railway applications - Wheelsets and bogies – wheels, Product Requirements*, 2007.
- [5] SR EN 13715+A1:2011, *Romanian standard, Railway applications - Wheelsets and bogies - wheels – Tread profile*, 2011.
- [6] Chao L., Xun X., *Cyber-physical machine tool – the era of machine tool 4.0*, The 50th CIRP Conference on Manufacturing Systems, Procedia CIRP, Vol. 63, Elsevier,

- pp. 70 – 75, doi: 10.1016/j.procir.2017.03.078, 2017.
- [7] Elbah, M., Yallese, M. A., Aouici, H., Mabrouki, T., Rigal, J. F., *Comparative assessment of wiper and conventional ceramic tools on surface roughness in hard turning AISI 4140 steel*, Journal of Measurement, Elsevier, doi: 10.1016/j.measurement.2013.06.018, 2013.
- [8] Degner, W., Lutze, H., Smejkal, E., *Spanende Formung. Theorie, Berechnung, Richtwerte*. Carl Hanser Verlag, München, Wien, ISBN-13: 978-3446417137, 2009.
- [9] Ivanov, K., Gechevski, S., *Empirical models for specific energy consumption and optimization of cutting parameters for minimizing energy consumption during turning*, Journal of Cleaner Production, Elsevier, ISSN 0959-6526, doi: 10.1016/j.jclepro.2014.05.099, 2014.
- [10] Klocke, F., *Manufacturing Processes*, Springer, 522 pp., ISBN 978-3-642-11978-1, doi: 10.1007/978-3-642-11979-8, Berlin Heidelberg, 2011.
- [11] Davim, J. P., *Machining. Fundamentals and recent advances*, Springer, 362 pp., ISBN 978-1-84800-212-8, doi: 10.1007/978-1-84800-213-5, London, 2008.
- [12] Arrazola, P. J., Özel, T., Umbrello, D., Davies, M., Jawahir, I. S., *Recent advances in modelling of metal machining processes*, CIRP Annals Manufacturing Technology, Vol. 62, Issue 2, Elsevier, pp. 695-718, doi: 10.1016/j.cirp.2013.05.006, 2013.
- [13] Čuš, F., Župerl, U., *Surface roughness control simulation of turning processes*, Strojniški vestnik - Journal of Mechanical Engineering, Vol. 61-4, pp. 245-253, doi: 10.5545/sv-jme.2014.2345, 2015.
- [14] Altintas, Y., *Manufacturing automation metal cutting mechanics, machine tool vibrations and CNC design*, Cambridge University Press, ISBN 978-0-51-184372-3, doi: 10.1017/CBO9780511843723, 2012.
- [15] Predincea, N., Croitoru, S. M., *Generating surfaces on machine tools (Bazele generării suprafețelor pe masini-unelte)*, Ed. Printech, ISBN 978-606-521-888-8, Bucharest, 2012.
- [16] Thakare, A., Nordgren, A., *Experimental study and modelling of steady state temperature distributions in coated cemented carbide tools in turning*, 15th CIRP Conference on Modelling of Machining Operations, Elsevier, pp. 234-239, doi: 10.1016/j.procir.2015.03.024, CIRP, 2015.
- [17] ***, *Railway turning, Re-turning and new wheel turning, Application Guide*, Sandvik Coromant, 2014.
- [18] ***, *Machining solutions for railroad car wheels re-turning*. Catalogue ISCAR, 2016.
- [19] Ventura, C. E. H., Breidenstein, B., Denkena, B., *Influence of customized cutting edge geometries on the workpiece residual stress in hard turning*, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, Vol. 231, Issue 9, Maropoulos, P. G. (Ed), ISSN: 0954-4054, doi: 10.1177/0954405416685388 2017.
- [20] Shevtsov, I. Y., *Wheel/rail interface optimisation*, Phd. Thesis, Delft University of Technology, Faculty of Civil Engineering and Geosciences, ISBN 978-90-8570-303-7, Netherland, 2008.
- [21] Perovic, B., *Handbook Werkzeugmaschinen. Berechnung, Auslegung und Konstruktion (Machine tools guide. Calculation and Construction)*, Carl Hanser Verlag, Munchen Wien, 2006.
- [22] Liang, Q., Zhang, D., Wanneng, W., Zou, K., *Methods and research for multi-component cutting force sensing devices and approaches in machining*, Sensors, Vol. 16(11), ISSN 1424-8220, MDPI Basel, Passaro V. (Ed.), doi: 10.3390/s16111926, 2016.
- [23] Constantin, G., Ghionea, I., Ghionea, A., Cioboată, D., Bîșu, C.F., *Integration of CAD-RBS-FEM techniques in refabrication of a lathe used for profiling wheelset*, Proceedings of the 9th International Working Conference Total Quality Management - Advanced and Intelligent Approaches, UDC 004:005, Publisher Mechanical Engineering Faculty, ISBN 978-86-7083-934-2, Majstorovic, V.D. (Ed.), pp. 225-233, selected paper in International Journal of Advanced Quality, vol. 45, no. 2, Publisher United Association of Serbia for Quality, doi: 10.25137/IJAQ.n2.

- v45.y2017.p27-35, pp. 27-35, ISSN 2217-8155, Belgrade, Serbia, 2017.
- [24] Mackerle, J., *Finite-element analysis and simulation of machining: a bibliography*, Journal of Materials Processing Technology, Vol. 86, Elsevier, pp. 17-44, 1999.
- [25] Amaral, N., Rencis, J. J., Rong, Y. M., *Development of a finite element analysis tool for fixture design integrity verification and optimization*, International Journal of Advanced Manufacturing Technology, Vol. 25, Issue 5-6, ISSN: 0268-3768, Springer, pp. 409-419, 2005.

Parametrii de aşchiere și analiza prin simulare FEA a influenței acestora la reprofilarea roților osiei montate

Rezumat: Abordările moderne privind proiectele de cercetare în domeniul refabricării strungurilor implică diferite etape de simulare, cum ar fi FEA și CAM, pentru a obține rezultate și soluții cu diferite aspecte și date importante. Aceste simulări pot confirma datele obținute prin măsurare, dar și extrapolează valori care nu pot fi măsurate direct pe sistemul tehnologic al mașinii-unelte. Modelele matematice și cele simulate, cu un procent scăzut de eroare, sunt cheia principală pentru echipa proiectului de refabricare. Tendința modernă în tehnologiile de fabricație, Industry 4.0, se bazează pe concepte noi și metode de analiză și proiectare, achiziția și schimbul de date între sisteme, procesare, vizualizare și automatizare. Metodele moderne de simulare, integrarea sistemelor între datele simulate și cele măsurate, realitatea augmentată etc. reprezintă preocupări importante ale fabricației actuale. Tot mai multe mașini-unelte de fabricație mai vechi, fără capabilități CNC, sunt refabricate în noua viziune a Industry 4.0. Această lucrare prezintă câteva etape în stabilirea parametrilor procesului de prelucrare prin strunjire pentru profilarea și reprofilarea roților osiilor montate de tren. În lucrare sunt folosite instrumente specifice (o abordare matematică de calcul și modele 3D pentru simularea FEA) pentru a determina ce sistem (portscule - plăcuțe - parametri de proces) este optim a fi utilizat pentru prelucrările prin aşchiere pe strungul refabricat.

Ionuț Gabriel GHIONEA, Phd. Eng., Lecturer, University Politehnica of Bucharest, Faculty of Engineering and Management of Technological Systems, Department of Machine Manufacturing Technology, E-mail: ionut76@hotmail.com, Office Phone: +40722 926 249, Address: Bucharest, Romania, Spl. Independenței nr. 313, district 6.

Adrian GHIONEA, Phd. Eng., Dr.H.C., Professor, University Politehnica of Bucharest, Faculty of Engineering and Management of Technological Systems, Department of Machines and Manufacturing Systems, E-mail: adrianghionea@yahoo.com, Office Phone: +40744 110 472, Address: Bucharest, Romania, Spl. Independenței nr. 313, district 6.

Nicolae PREDINCEA, Phd. Eng., Professor, University Politehnica of Bucharest, Faculty of Engineering and Management of Technological Systems, Department of Machine Manufacturing Systems, E-mail: nicolaepredincea@yahoo.com, Address: Bucharest, Romania, Spl. Independenței nr. 313, district 6.