Preliminary Considerations Regarding Modernization of the Driving, CNC Control and Measurement Systems of a Lathe Model UBC 150 RAFAMET

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Abstract: In specialized literature are presented results of many researches in the field of remanufacturing of machine tools, some of which are referring to specialized lathes. Lathes for processing the wheels and wheelsets of the railway vehicles were diversified and modernized in accordance with the requirements of railway transport. The paper presents the preliminary stages of theoretical and applied research on modernization of a conventional lathe with two working units. This ensures adaptation of four kinematic chains for CNC advance/positioning and improvements of translation couplings, adaptation of CNC equipment for driving and measuring simultaneous both wheels mounted on axle, reducing of geometric errors of running profile processing. The modernization process also involves restoration of functional requirements and measurement of the lathe geometric precision. The new data referring to speed for advance and positioning range will be established, with higher values than for the conventional version. The final results of steps for modernization of the lathe also allow improvement of the data sheet, called Reshaping Protocol.

Keywords: railway wheel profile, CNC lathe modernization, kinematic structure, turning parameters, railway wheel re-profiling, wheelset

1 INTRODUCTION

The wheels are the most loaded components of railway vehicles [6], [10], being subject to a continuous process of wear due to difficult operating conditions: load, modification of rail and of the wheel profile, temperature variations, curved paths, variations of speed, breakings, etc. When the wheels reach a certain critical level of wear, they must be re-profiled or replaced [19], when the adding removal material exceeds a certain limit. Using wheels with appropriate profile reduce the risk of derailment and minimizes the dynamic interaction between the vehicle and the track, reducing noise, vibration and wear.

The development of rail transport in present focus on increasing the reliability of rolling stock and traffic safety, operating costs reduction, improvement of the manufacturing technologies and control and maintenance possibilities, reduction of noise and wear in operation [22]. Framing the rolling profile of the railway vehicle wheels into the geometric and functional dimensions are ruled by national and international standards [11], [16] [18]; [19].

Re-profiling of the wheels after a certain period of operation is imposed following a control phase which is an important part of the rolling stock maintenance.

Modern approaches required the development and implementation of automated equipment for manufacturing and measuring of wheels running profile, both static and dynamic.

Profiling and re-profiling of wheels are performed by turning technological processes on specialized machine tools [5], [21]. There are used three types of such machine tools, namely: conventional, portal and under-floor. Due to the high cost for acquisition of such a modern machine tool, is required, as appropriate, remanufacturing [4] of existing machine tools by adding driving, command and measurement systems.

The remanufacturing costs are soon recovered by increasing the productivity and profiling/ re-profiling accuracy [3], [14], [15].

This paper presents the main results of Stage I: “Studies and analyses of the technological system for profiling/ re-profiling and measurement of machined surfaces of the train wheels”. There were defined many functional requirements of the lathe construction and of the measurement and command equipment within the project WheelReshaping PN-II-PT-PCCA-2015-4-1681 [21].

2 LATHE STRUCTURE, ELEMENTS, ASSEMBLIES AND COUPLINGS

UBC 150 RAFAMET lathe (Fig. 1) [20] is a machine tool that processes the running surfaces of wheelset in a single clamping, having two working units (2). Each unit has in its structure two radial slogs (3), a longitudinal sledge (4) and a transversal sledge (5).

This last sledge supports the other ones on linear guidance. For processing, slogs (3) and (4) are doing the advance/positioning movement and sledge (5) is doing positioning movement when the wheel diameters range of the axle (10) is changed.

The driving slogs are as follows: in advance movement with an electric motor with variable speed (6) and in positioning movement with a constant speed motor.

Function of the reversal movement is achieved by an inverting mechanism with gear and electromagnetic coupling. The wheelset is driven in rotation with the cutting speed \( n_c \), simultaneously at both ends by a rotating device (12). The faceplate drive mechanisms are located in each assembly (1), hereafter noted HS1, respectively, HS2.

To process the running surfaces, for each radial sledge is used a copying system (9), with electrical contacts [7], port program being type template with open contour.

Figure 2 shows the main view of the lathe in which are represented and noted the basic couplings for translating movement (T) and rotation (R).
The two working units WU₁ and WU₂ have identical structures and driving systems. Their role, from the point of view of generating the running surface of the wheelset (Ws), consist of movement B₁₁, B₁₂, and C₁ for unit WU₁, respectively, B₂₁, B₂₂, and C₂ for unit WU₂.

Involving of wheelset in cutting movement A (n₁) at both ends of the axle is ensured by the electric motors ME₁ respectively ME₂. The main spindle MS₁ and MS₂ contain each one a driving kinematic chain for driving tailstocks PN₁, respectively PN₂. Each one is equipped with a center spindle V₁ and V₂ and in combination with the clamping and fixing devices CD₁, respectively CD₂, provides driving rotational movement of the axle.

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**Fig. 1. UBC 150 RAFAMET lathe main view:**
1 – headstocks, 2 - working units, 3 - radial sledges, 4 - longitudinal sledges, 5 - transversal sledges, 6 – feed and positioning drives, 7 – belt drive, 8 – control panels, 9 – electromechanical copying system, 10 – wheelset, 11 – operating platform, 12 – driving faceplate

**Fig. 2. The couplings structure of the UB 150 RAFAMET lathe:**
For moving the HS₁ and HS₂ assemblies on the longitudinal guides of lateral bases B₁₁ and B₁₂ is used for each a kinematic chain driven by an electric motor M₁₁, respectively M₃₂.

The control for these motors must be simultaneous and controlled so that the assembly consisting of HS₁, Wₛ and HS₂ move synchronized on guides Tₛ₁ for working units W₁ respectively Tₛ₂.

It is proposed that this movement to be for positioning and controlled by CNC equipment on +Z and -Z directions, to determine the reference position depending on which will perform the movements for simultaneous processing of running profiles.

In figure 3 it is a simplified representation of flow of the radial sledges RS, longitudinal sledges LS and transversal sledges TS movements. There are indicated the electric motors M₁₁, M₂₁ for working units W₁ and motors M₁₂, M₂₂ for working units W₂ (see Fig. 2). Those movements (B₁₁, B₁₂, and C₁) are performed with the feed rate vₘ for processing for positioning and with speed v₁ for positioning. These movements are received from the motors M₁₂, respectively M₂₂. The D₁ movement is achieved by motor M₂₁ at the speed v₁.

3 REQUIREMENTS FOR MEASURING THE RUNNING PROFILE

Worldwide there are a variety of profiles for train wheels ruled by national and international standards.

The Technical Specification for Interoperability relating to the subsystem "rolling stock" [23], developed in accordance with Directive 2008/57/EC and its annexes define the parameters of wheel profiles compliance and stated that the assessment of conformity must be documented.

Therefore, a modernization of control and computerized data processing is a major goal for companies that manufacture or recondition the rolling stocks.

Running profile of the wheels is given by the shape of its periphery in a meridian plane of the wheelset. This profile is achieved by assembling several conical and toroidal surfaces, with fillet radius between them, forming a continuous curve with well-defined geometry [12]. Both rail and wheel profiles are regulated by UIC (International Union of Railways) recommendations. From wheel profile there are variants derived from the wheel profile recommended by the UIC, depending on the characteristics of the railway network determined by each railway administration.

Wheel and rail profiles can be divided according to three functional contact regions, as shown in figure 4 [11].

Zone A is the contact region between the central region of the rail head and wheel tread is made most often in this region. This region is important for vehicle stability. Geometric parameters of interest for this area are taper and rolling diameter.

Zone B is the contact region between the rail corner and wheel flange root. This region is of interest to ensure guidance of the wheelset on rail.

Parameters of interest in this area are:
- Radius and lengths of the profile arcs;
- Flange angle;
- Height of the flange.

Zone C is the region in which contact between rail and wheel ends. In this region may be contact between the field sides of both wheel and rail.

In this region can arise important tensions and so important and considerable wear can occur.

Fig. 3. The flow of the machining and positioning motions for the UBC 150 RAFAMET lathe

Fig. 4. Functional regions of wheel/rail contact
The main geometrical parameters of wheel and wheelset profile are given in figure 5 and figure 6 [19].

Running profiles of wheels and rail influence sustainability of rolling couple that consist of wheel and rail, traffic safety, reduce noise and vibration level. For this purpose it is necessary to create a computerized database with used profiles.

In the repair and maintenance workshops, the measurement of the wheels is still widely performed using simple tools (special callipers, templates and other) (figure 7). Many modernized lathes equipped with CNC have not integrated measuring systems. This adjustment of the starting point of cutting tools path is made with blocks or other mechanical means, this resulting in decreasing of productivity and processing accuracy.

There is a pronounced need to integrate in the manufacturing CNC machines and systems for complex profiles measurement.

To streamline the process of shaping/reshaping the wheels of railway vehicles on CNC lathes, measuring systems must be integrated in the machine tool structure.

These measurement systems must provide the following functions: measurement before reshaping profile to determine wear and choosing the optimal profile to be processed; determination of the starting points of the cutting tools paths; measurement the wheel profiles after the processing is completed.

A measurement system should have a proper coordinate system, defined in relation to the coordinate system of the machine tool.

This measurement system must allow probing of the radial and frontal surfaces of both wheels mounted on the axle, simultaneously (Fig. 8).

We propose that the two units of measurement system to be positioned on radial sledges SR_{11} and SR_{21} of the two working units numerically controlled (Fig. 2). In this way, the longitudinal displacement and radial positioning of the measurement probes are numerically controlled. The scheme of integration the measuring system in machine tool structure is shown in figure 9.
4 MANUFACTURING PARAMETERS

During the processing on CNC machine tools machining errors have many causes, including: guides and actuators inaccuracy, low stiffness of couplings or driving mechanisms [9] or of structure elements [13], guides and bearings clearance, etc.

The main processing conditions for machined surfaces are: differences between diameters of both wheels on an axle, on reference circle, \( \Delta D \leq 0.15 \text{ mm} \), reproducibility of the profiles \( \leq 0.15 \text{ mm} \), processed surface roughness \( R_z = 10 \ldots 20 \text{ \mu m} \).

To reduce the processing inaccuracy is done a step correction of the moving screw along the direction of advance movements, on the screw axis.

The method for determining the shape of the guides by construction and adjustment chart shows that the current measurement mode characterized not enough the sledges movements or the displacement errors.

Due to the type of mixed friction in guides of the longitudinal and radial sledges and their form, it is necessary to improve the precision of the sledges movements using numerically controlled axes.

Also, it is necessary to improve the measurement of the machine accuracy and to set the geometric correction required in the part program [9] for simultaneous processing of the wheels’ running surfaces. In this manner, it can be accurately determined the size of deviations and methods of making corrections for two CNC axes of the lathe.

The existing NC commands enable corrections in the movement direction, but also the optimization of the processing programs: trajectories, cutting parameters [1]. Thus, the generation of wheels surface is performed with smaller deviations. This is favored also by the new generation of cutting tools, with 2 inserts (Fig. 10), recommended for profiling/ re-profiling of the wheels of railway vehicles [14], [15], which allows processing the entire profile in a single pass.
5 KINEMATIC CHAINS NUMERICAL CONTROLLED

Figure 11 shows the components of a kinematic chain for advance/positioning in rectilinear trajectory movement.

Such a structure is proposed to be adapted to drive the longitudinal slide LS₁ (Fig. 2) on the guides (LG₁₃₅₁) which are positioned on the transversal sledge TS₁.

For the modernized version of the lathe there is a need to replace the drive screw – nut mechanism with mixed friction with the version proposed in figure 10. It is also necessary to select and adapt a transducer (Lt or Rt) for each numerically controlled axis to accurate measurement of displacement and position. The solution with Lt proved to be more accurate. FM and Gb will be fixed on the transversal sledge TS₁ in marked place. However, it is proposed the removal of the electric motor M₃₁ (see also Fig. 2), its function being taken by the existing M₃ motor existing on the lathe.

For mounting of the two bearings Bg will be used the existing holes in the housing of sledge TS₁, in its upper part. The nut Nₜ is adapted to the longitudinal sledge LS₁, in the lower part, using a support.

Figure 12 shows the following elements: 1 – the housing of the longitudinal sledge LS₁, 2 and 3 - guides of the sledge LS₁, fixed on the transversal sledge TS₁, 4 – asynchronous electric motor M₃₁, 5 - variable speed asynchronous electric motor M₃, 6 - the area where is proposed to be located the Gb and FM according to the proposed solution (see Fig. 11), 7 and 8 – radial sledges guided in the housing of the longitudinal sledge LS₁, 9 - distribution box Db₁ (see also Fig. 2 and Fig. 3) and 10 – transversal sledge TS₁.

Similarly, it is proposed to be adapted a kinematic chain with the structure from figure 11 for driving each radial sledge RS₁₁ and RS₁₂ (see also Fig. 2).

The screw-nut mechanism from figure 11 is noted in figure 2 by BSR₁₁, respectively, BSR₁₂ for the two sledges. Thus, in figure 13, the two driving structures will be placed on the frontal surface of the housing 8 of the longitudinal sledge LS₁. On this surface shall be adapted the assembly FM - Gb. The bearing Bg is adapted in the cavity 4 or 5 and the other bearing is created in the other frontal wall of the housing.

Also in this case, the nut Nₜ is adapted to the radial slide 1 (or 2, as appropriate) through a support type part. The ends of the shafts 6 and 7 are used for manual operation of the radial sledges. Position 3 marks the lower guides of the two sledges.

6. CONCLUSIONS

The researches conducted in first stage of the project [21] contributed to establish of some requirements useful in the next research steps,
- The control, adjustment of the sledges’ guides and elimination of the causes that can generate vibration in the translating couples of the radial and longitudinal sledges which provide movements for the running profile generation;
- The establishment of the constructive solutions of the elements and of the driving screw-nut mechanism, with intermediate elements of the kinematic chains for advance/positioning CNC controlled and adjusting them on the lathe;
To evaluate the dimensional, form and position deviations, there are determined by measuring the deformations of the radial sledge, translation couple of the longitudinal sledge as well as of clamping device and wheelset driving systems. The elastic deformations of the lathe structural elements have a small influence on processing inaccuracy:
- Establishing by calculation of the cutting forces, masses of the mobile assemblies and their importance in sizing the mechanism lead screw - nut and bearings;
- Calculus that impose the choice of the servo-motors for driving the numerically controlled axes;
- Establishing the solution for integration the measurement system in structure of the numerical controlled machine tool with two working units.

By using these measurement systems, the wheel profile measurement is faster, more accurate and gives a complete profile instead of discrete measured points. Wide range of programming possibilities guarantee easy adapting of the turning process to dimensions and profile of the wheelsets.

The measurement system allows the measuring of the geometrical parameters simultaneously for both wheels mounted on an axle.

Measured parameters are (see Fig. 5 and Fig. 6):
- Wheels rolling diameter (D);
- Profile specific parameters:
  - flange height (Sf);
  - flange width (Sd);
  - flange gradient (q);
  - total profile width (Lp);
- profile wear on rolling diameter (A).
- back to back distance L;
- Wheel full profile;
- Out of roundness on base circle and frontal surfaces runout.

The authors mention that the structure of the kinematic chains for advance/ positioning which are numerically controlled will be much easier and will lead to a grow of the kinematic precision and a significant improvement in surface roughness and wheel rolling profile. The speeds of the positioning movements will be higher (2500 mm/min) than those of the actual lathe. The maximum feed rate can reach the value of 18 mm/min. The recommended feed for roughing processing is about 1.5 mm/rev.

For the positioning movements of the two transversal sledges, there is retained the existing lathe kinematic structure (see Fig. 2). The speeds of these movements are provided by the electric motors M11, respectively, M12.

There will be analyzed in an experimental manner the values of that motors speeds. It will also be considered the speed adjustment feature (power and torque) of electric motors M11 and M12.

Regarding the control system, the CNC equipment must allow the reduction of geometric deviation and compensation of the geometric precision error which can be measured on the machine tool in static and dynamic mode.

Fig. 13. Partial frontal view of the sledge body LS1

ACKNOWLEDGEMENTS

This technological system is developed under Partnerships in Priority Areas Programme - PNII supported by MEN-UEFISCDI, in the 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” (21).

The work of Ghionea Ionuț has been supported by the Sectorial Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/138963.

REFERENCES


[20] *** RAFAMET 150, Cartea maşinii


[22] *** (2014), Romanian railway transport according to the urgent requirements that impose a broad strategic perspective. AGIR, *Univers ingeresc*, XXV, nr. 15 (565).


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