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

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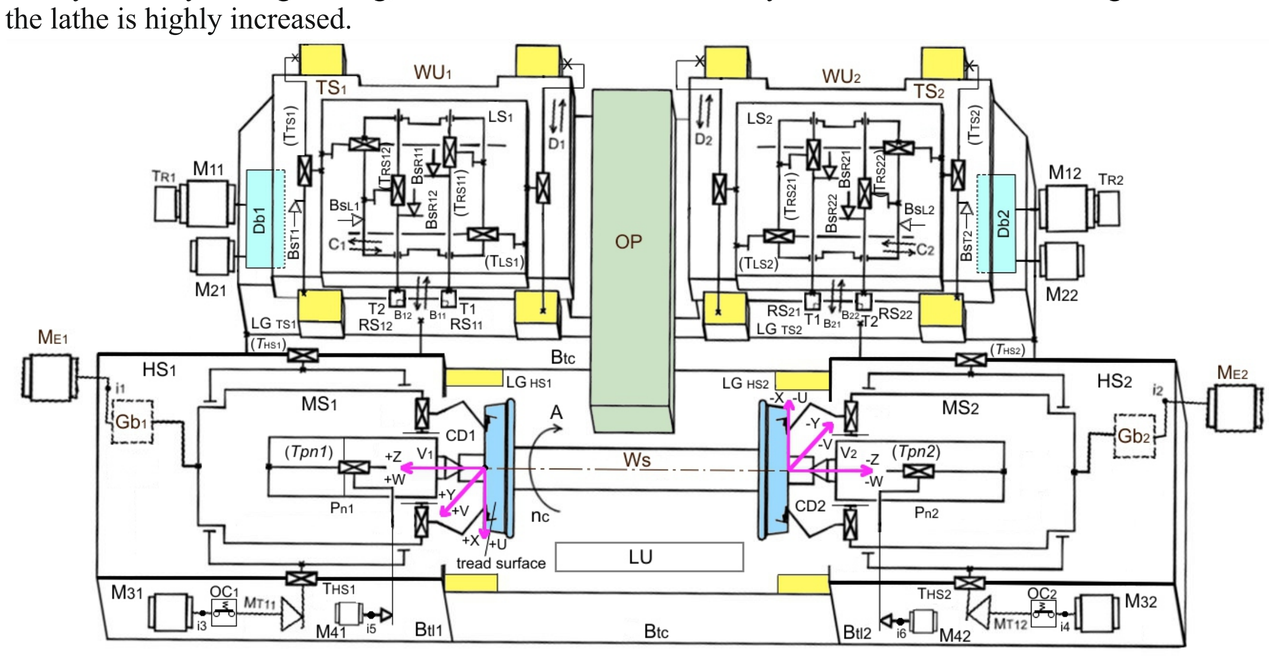
Abstract. Many projects and researches in the field of remanufacturing of specialized lathes are presented in the specialized literature. In the process of design for remanufacturing, a great number of solutions contain different aspects and data important to consider. The paper presents important stages of theoretical and applied research regarding the modernization of a conventional lathe with two working units by adaptation of four driving chains for CNC advance/positioning movements and improvements of translation couplings, adaptation of CNC equipment for driving and measuring simultaneous both wheels mounted on axle. The reducing of geometrical errors of the running profile is very important in reshaping the worn wheelsets. The lathe remanufacturing process involves the restoration of functional requirements and measurement of the geometric precision. The CNC capabilities of the remanufactured lathe require a database of parametric representation of profiles and rolling surfaces using CAD techniques according to international standards.

Keywords: Railway wheel profile, CNC lathe remanufacturing, Rolling surface reshaping, Wheelset.

The lathes for processing the wheels and wheelsets of the railway vehicles are diversified and modernized in accordance with the requirements of railway transport standards and norms in the field. During the operation of the railway vehicle, the contact surfaces between the wheels and rail become worn. This wear lead to changes in wheel and rail profile, contact surface and, consequently, to instability in the movement of vehicles. Therefore, the maintenance and repair of the rolling stock are important for traffic safety and passenger comfort

The wheelsets are the most loaded components of railway vehicles. They are subject of a continuous process of wearing according to difficult running conditions: non-uniform loads, alteration of rail and wheel profile, temperature variations, curved paths, sudden changes of speed, breakings, etc. In the moment that the wheels reach a critical level of wear, they must be reshaped or replaced, when the material to be removed by cutting 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 main requirement of this approach is the profile processing and maintaining the contact surfaces of wheels and rails within geometric and functional parameters. Profiling and re-profiling of wheels are performed by technological processes on specialized lathes. Due to the high cost for acquisition of such a modern new machine tool, the manufacturers often have an option for the remanufacturing of an existing machine tool. Thus, there is a need for development and implementation of an automated equipment for simulation, manufacturing and measuring of wheels running profile, both static and dynamic by adding driving, command and measurement systems. The remanufacturing costs are soon recovered by increasing the productivity and profiling/ re-profiling accuracy. Also, the life of the lathe is highly increased.

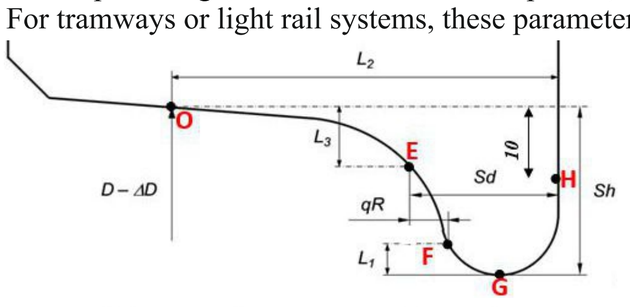


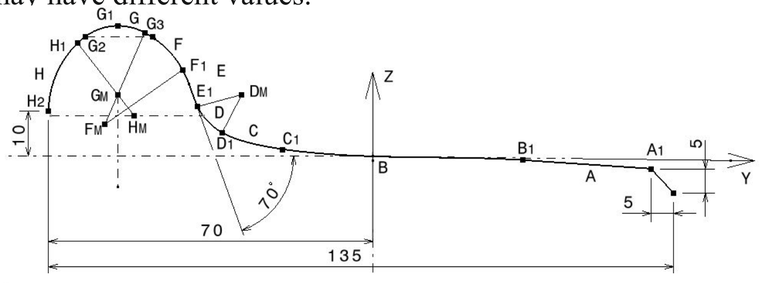
The analyzed technological system is composed of: a Polish machine tool UBC 150 RAFAMET lathe, modern measurement equipment, certain turning tools for this type of machine tool, CNC equipment, clamping devices, etc. A representation of the remanufactured lathe as it will be in the end of the project is done using a scheme of rotational and translational couplings that ensure the generation and auxiliary trajectories. The lathe processes the rolling surfaces of the wheelset in a single clamping, having two working units. Each one of these units has in its structure two radial sledges, a longitudinal sledge and a transversal sledge.

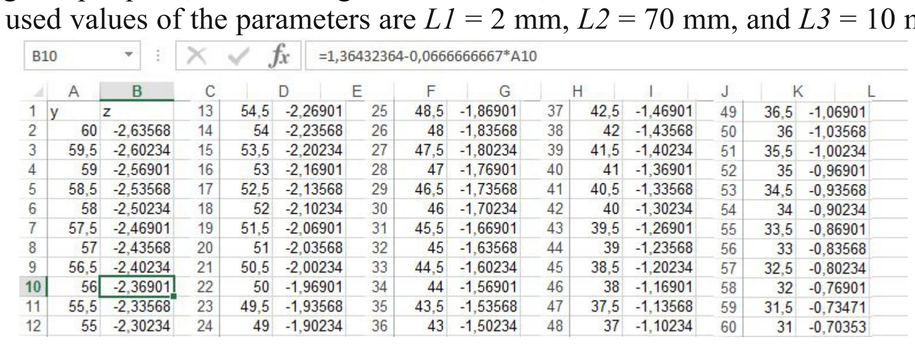
Structure of the UB 150 RAFAMET lathe: A – main cutting motion, B1, B2 – advance radial motions and positioning, Bg – bearing, Bs – ball screws (L-longitudinal, T-transversal, R-radial), Btc – central bed, Btl – lateral beds, C1, C2 – advance longitudinal motions and positioning, CD – clamping devices, D1, D2 - transversal positioning, Db - distribution box, Gb – gearboxes, HS – headstocks, i - transmission ratios, LG – linear guides, LS1, LS2 – longitudinal sledges, LU - loading and unloading system of the wheelset, M11, M12 – advance and positioning electric drives with continuous adjustment, M21, M22 – synchronous servomotors (longitudinal L and radial R), M31, M32 – headstocks positioning electric drives, M41, M42 – pinolas positioning electric drives, ME11, ME12 – main electric drives, MS - main spindle, MT11, MT21 – nut screw mechanisms, OC – overload coupling, OP – operating platform, Pn – pinolas, RS11, RS12, RS21, RS22 – radial sledges, T1, T2 – tools, (TLS1), (TLS2) – translational couplings, TS1, TS2 – transversal sledges, (T), (R) – motion joints, Ws – wheelset, WU – working units.

In the Interoperability Technical Specifications relating to the "rolling stock" subsystem, developed according to the Directive 2008/57/CE, there are established the parameters of the wheel profiles. Running tread of the railway vehicles wheels is regulated by the normative covered by national and international rules. The currently used profile of train wheels is composed of several spline segments, with fillet regions having well-defined geometry, forming a continuous curve at any point.

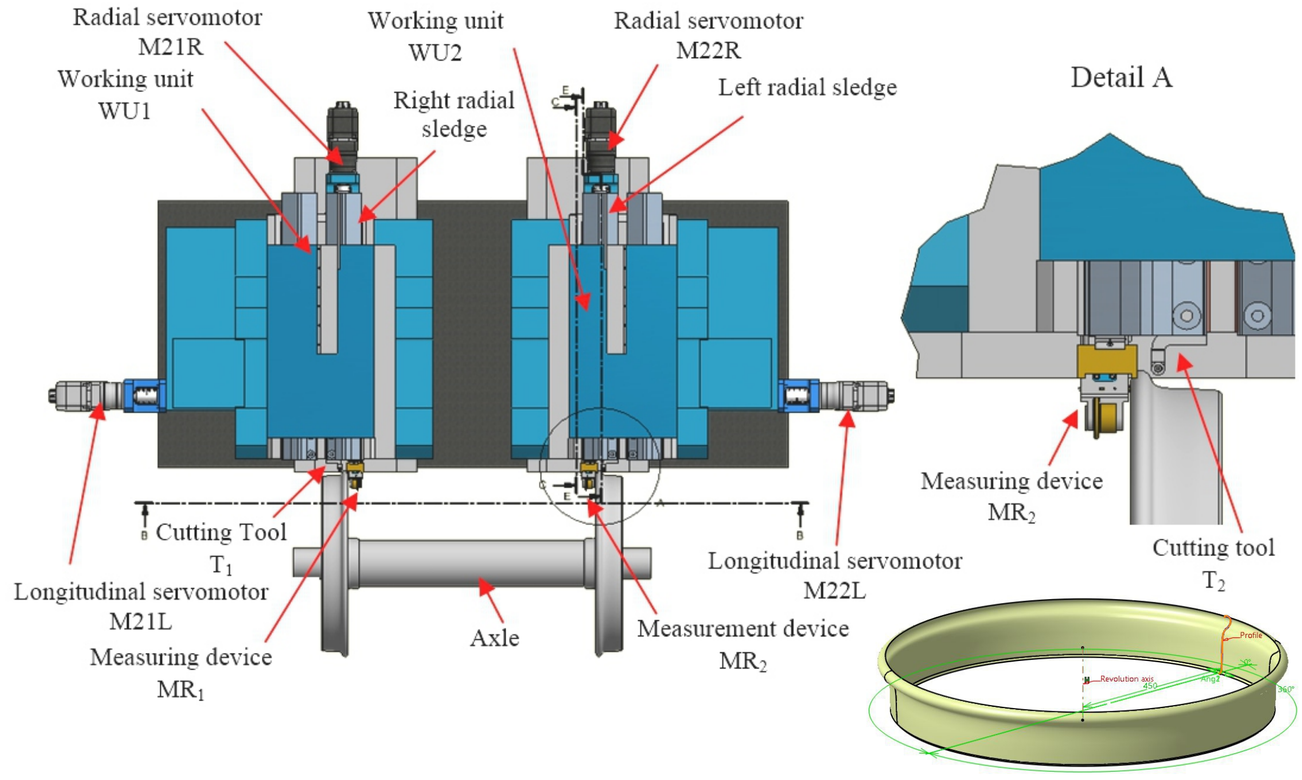
In Romania was created the profile S-78, standardized for passenger and freight wagons fitted with UIC normalized flange. Whatever form they have, profiles of the train wheels are defined by nine constructive areas. The UIC 510-2 standard presents the main parameters that are defining the wheel profile: flange height, flange thickness, width of rim-tire, diameter of running tread, angle of external surface of flange. The designed shape of a wheel is represented by wheel profile drawing. The requirements to draw the wheel profile are described below and they are based on several parameters *Sd*, *Sh* and *qR*, which are represented in figure, where: *Sd* - flange thickness, *Sh* - flange height, *qR* - flange slope quota, *D* - running tread diameter, *ΔD* - deviation of this diameter, *L1* – top of flange, *L2* – total width of the profile, *L3* – running profile height. Usually, for the railway wheels, the most used values of the parameters are *L1* = 2 mm, *L2* = 70 mm, and *L3* = 10 mm. For tramways or light rail systems, these parameters may have different values.







	A	B	C	D	E	F	G	H	I	J	K	L
1	y	z	13	54,5	-2,26901	25	48,5	-1,86901	37	42,5	-1,46901	49	36,5	-1,06901
2	60	-2,63568	14	54	-2,23568	26	48	-1,83568	38	42	-1,43568	50	36	-1,03568
3	59,5	-2,60234	15	53,5	-2,20234	27	47,5	-1,80234	39	41,5	-1,40234	51	35,5	-1,00234
4	59	-2,56901	16	53	-2,16901	28	47	-1,76901	40	41	-1,36901	52	35	-0,96901
5	58,5	-2,53568	17	52,5	-2,13568	29	46,5	-1,73568	41	40,5	-1,33568	53	34,5	-0,93568
6	58	-2,50234	18	52	-2,10234	30	46	-1,70234	42	40	-1,30234	54	34	-0,90234
7	57,5	-2,46901	19	51,5	-2,06901	31	45,5	-1,66901	43	39,5	-1,26901	55	33,5	-0,86901
8	57	-2,43568	20	51	-2,03568	32	45	-1,63568	44	39	-1,23568	56	33	-0,83568
9	56,5	-2,40234	21	50,5	-2,00234	33	44,5	-1,60234	45	38,5	-1,20234	57	32,5	-0,80234
10	56	-2,36901	22	50	-1,96901	34	44	-1,56901	46	38	-1,16901	58	32	-0,76901
11	55,5	-2,33568	23	49,5	-1,93568	35	43,5	-1,53568	47	37,5	-1,13568	59	31,5	-0,73471
12	55	-2,30234	24	49	-1,90234	36	43	-1,50234	48	37	-1,10234	60	31	-0,70353



The flange thickness *Sd* is very important as it limits the lateral clearance of wheelset with respect to the track, which influences the vehicle stability and prevents it from derailment. The flange slope quota *qR* is also an important parameter because if it is too small, the wheel flange will be almost vertical, which implies that the transitions and the flange contacts will occur abruptly causing high contact forces that damage both wheel and rail. All these parameters can be measured and controlled using mechanical and optical instruments. The modern measurement instruments are adapted to be mounted on the lathe with two tools posts integrated with CNC controller, each tool post comprising longitudinal sledge movable in Z-axes direction and radial sledge movable in X-axes direction. Probing of the wheel profile is done with two measuringsystems, positioned on the radial sledges numerically controlled of the two working units.

For the CNC programming and machining of the wheels profiles it is necessary to create a digital database of templates with different profiles versions for the majority of the railway vehicles in traffic. The UIC/ERRI profiles of the wheels are ruled by SR EN 13715 + A1-2011. The most used profiles are: the profile UIC/ERRI for wheels with diameter D = 1000 mm and d = 760 mm, having the flange height h = 28 mm, UIC/ERRI D = 760 mm, d = 630 mm, h = 30 mm and UIC/ERRI D = 630 mm, d = 330 mm, h = 32 mm. These profiles have many points in common in certain zones, being drawn by the same equations.

On the generated profile and on the obtained rolling surface, it is possible to apply different techniques to verify the precision of the drawing. There are 263 pair of points, enough for an accurate resolution of the profile and surface. With this parametric surface (for each profile in the database) it is possible to perform the turning process simulation and develop the CNC program.

The creation of this database contributes to the modernization of RAFAMET UBC 150 lathe in accordance with the terms of the research contract and represents an important stage which will lead to an increased number of orders received by the beneficiary partner, but also as a working model for other users with manufacturing activities in the field.

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