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ADVANCED PARAMETERIZATION OF CAD-CAM PROCESS FOR MACHINING RAIL WHEELS ON A LATHES

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Abstract: *In this paper some aspects regarding advanced parameterization of a lathe cutting process for a specialized field – rail wheel machining are presented. A method was developed for obtaining an optimum NC file by taking into account: design, machining technology aspects and machine dynamic behavior in cutting process. Some correction coefficient and parameters for CAD, CAM and postprocessors are defined based on the rail wheel dimension and machine displacement. The next step consists of implementation of this method in machining process for smart cutting.*

Key words: *CAD, CAM, dynamic behavior, machining, rail wheel.*

1. INTRODUCTION

Today the industrial demands are more and more high. In order to be more competitive on the market the requests of factories are for high quality of the products, short execution time togetehr with lower price [1].

Inside of the production system for achieving these goals, the engineers use high quality machines and specialized software.

Among the priorities of manufacturers, in their attempt to be more competitive and better serve their customers, it is necessary to shorten delivery times. Manufacturers strive to do things faster at every stage of the process, attempting to reduce time for design, programming, machining, and inspection. Two machining methods, High Speed Milling (HSM) and High Performance Machining (HPM), have become increasingly popular because of their ability to drastically speed up machining, while achieving better results [2, 3].

The general flow of a part into a manufacturing process consists in machining, (that involve CAD-CAM-Postprocessing-Cutting process on a machine tool), assembling, inspection, and delivering. In Fig. 1 it is presented the general schema for the flow of a part into industrial process.

Milling is the most common form of machining, a material removal process, which can create a variety of features on a part by cutting away the excess material. The milling process requires a milling machine, workpiece, fixture, and cutter. The workpiece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to a platform inside the milling machine. The cutter is a cutting tool with sharp teeth that is also secured in the milling machine and rotates at high

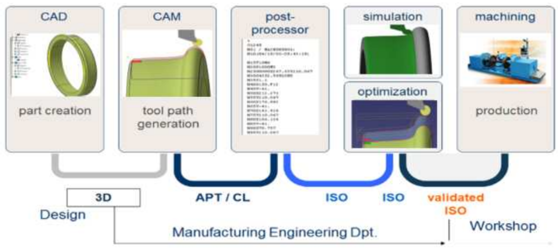

Fig. 1. Part form CAD to machining.

speeds. By feeding the workpiece into the rotating cutter, material is cut away from this workpiece in the form of small chips to create the desired shape.

Turning is typically used to produce parts that are axially symmetric. Parts that are fabricated completely through milling and turning often include components that are used in limited and large quantities (prototypes, such as custom designed fasteners or brackets) [4].

The manufacturing process design is made with specialized software which generates automatically the NC software [5]. The advanced CAM software used 3D models of the pieces to generate complex NC programs for many types of operations: surface milling, turning at high and classical speed on machine tools with up to 5 CN axes.

2. FROM CAM TO NC DATA AND MACHINING

All the information from CAM software must be transferred on a machining center in order to process the part.

This transfer is made by an interface software between the CAM software and Machine called postprocessor.

Normally, for machine and CAM software it must be a postprocessor which is capable to read the information from computer and based on the machine capabilities to

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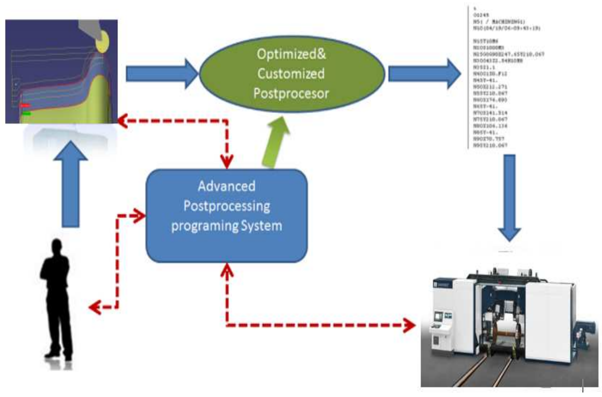


Fig. 2. Optimized and customized postprocessor.

transform them in NC files. For 5x machine this postprocessor should be programmed individually. The classical information flow between engineer knowledge-CAM software and machine is presented in Fig. 4.

In the advanced CAM system the post processor can be programmed by taking into account many variables. A customized and optimized postprocessor must interact with the CAM engineer, CAM software and also the machining center. The general schema is presented in Fig. 2. In this case the engineers can modify the machine behavior according with the part requirements taking into account also the CAM software and machine limitation.

Usually, the CAM software is focussed on the technological issue for generating part surfaces. The tool is moving over the part surfaces in various trajectories. In reality, the trajectories are generated on the surfaces by physical movement of the machined part.

3. POSTPROCESSOR DEVELOPING

In this paper some aspects of programming complex postprocessor for a specialized machine is presented. It was used a CAD-CAM solution which allows an advanced programming system postprocessors [4].

The post is composed of two separate files interacting each other. The definition file (Fig. 3) allows the user to implement the NC code and machine parameters (such as precision, way of writing circular interpolation, etc.). The programming (Fig. 4) is more complex and allows the programmer to create different scenarios in order to define the machine (travel limits, spindle limits, how to move in a certain situation between 2 points – connect scenario, etc.); to define the machining cycle (e.g the drilling cycle) and to define the human interfaces allowing the engineers to take some decision.

In this study the authors try to input some parameters into CAM software and also in the post in order to optimize the tool path according to the machine particularities [6, 7].

For example, some equation for coordinate system definition in the machine controller can be introduced:

$$
\begin{aligned}
v_1 &= J\_NONROT\_UCS \cdot K_{X}\_NONROT\_UCS - K\_NONROT\_UCS \cdot J_{X}\_NONROT\_UCS; \\
v_2 &= K\_NONROT\_UCS \cdot I_{X}\_NONROT\_UCS - I\_NONROT\_UCS \cdot K_{X}\_NONROT\_UCS; \\
v_3 &= I\_NONROT\_UCS \cdot J_{X}\_NONROT\_UCS - J\_NONROT\_UCS \cdot I_{X}\_NONROT\_UCS; \qquad (1)
\end{aligned}
$$

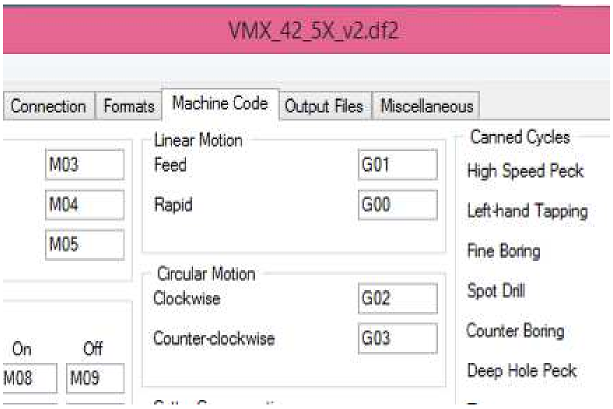


Fig. 3. Machine definition.

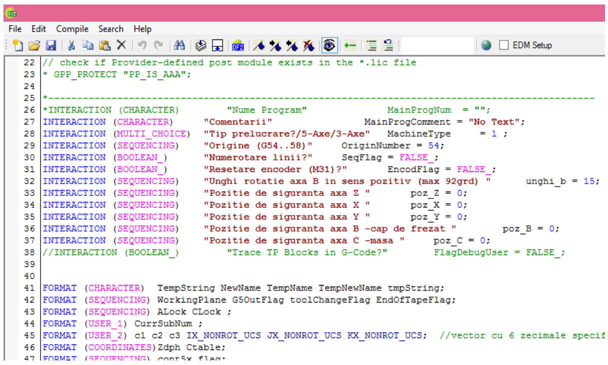


Fig. 4. Programming example.

4. CAM PARAMETRIZATION

Advanced CAD-CAM software allows definition of relation between CAD features and also CAM parameters (suc as tool diameter, depth of cut, etc.)

Oome applications were achievd in DELMIA V5 for milling and turning.

The main idea was to adjust automatically the CAM parameters based on CAD features and machine quality characteristics.

The methodology applied is presented in the fallowing steps:

1. Implementation of complex CAD model in CATIA based on mathematical calculus;
2. Generating 3d model for all necessary elements for CAM: solid model of the part, solid model of the stock, orientation of part and stock according to machining coordinate system.
3. Establish main parameter and generating relation between them.
4. Testing of CAD parametric model for different scenarios.
5. Establish the machining technology: type of operation, type of tools, cutting regime.
6. Establish parameters and relation between CAM technology features and geometrical form and CAD elements.
7. Testing the CAM parametric application for different scenarios.
8. Generating NC file based on CAM and customized postprocessor.

The metrology can be applied on every type of machining application and is suitable for part families in large and mass production system.

By a full parameterization an artificial intelligence for machining processes in some specific fields can be obtained.

5. CAD-CAM PARAMETRIZATION FOR A ROLLING SURFACE OF RAILWAY WHEELS

The authors try to apply the methodology for generating an optimal NC file for a turning of a rolling surface of railway wheels.

Rail wheel is a type of wheel specially designed for use on rail tracks (Fig. 5). A rolling component is typically pressed onto an axle and mounted directly on a rail car or locomotive or indirectly on a bogie. Wheels are cast or forged (wrought) and are heat-treated to have a specific hardness. New wheels are trued, using a lathe, to a specific profile before being pressed onto an axle. All wheel profiles need to be periodically monitored to ensure proper wheel-rail interface [11].

A rail wheel is usually made from steel, and is typically heated, where it remains firmly as it shrinks and cools.

Function of destination (train, tram, metro) and also of different countries there are different type of rail wheel profiles.

These types of rail wheels are established by directive 2008/57/CE. The classification and indication of the geometric parameter limits for the railway vehicle wheels are indicated by EN 15313 standard [12].

Generic profile of the rail wheels is presented in Fig. 6 [13].

Fig. 5. Rail wheel sample [1].

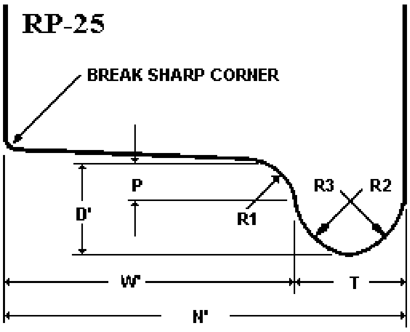


Fig. 6. Rail wheel profile.

Fallowing the method presented before, the first step was to implement the types of rail wheels in advanced CAD-CAM software.

There are a few step:

Implement the point coordinate of the profile based on mathematical calculus. There were 264 points introduced in the CAD software by reading it's from a table of points.

A complex 3d model of the profile was used to generate the wheel. First, a spline was generated based on the deined points (Fig. 7) and then a revolute surface.

Based on this geometry, a certain relation was established between ideal profile and the real one. For each change of the parameters, the rail wheel model will be modified (nominal and real diameters) (Fig. 8).

For machining, the roughing technology from both sides of the profile was defined (Fig. 9).

Based on relations defined in CAD and taking into account the machining conditions, some relations were defined in CAM process (Fig. 10).

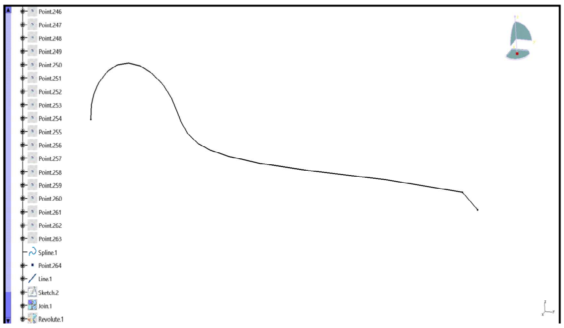


Fig. 7. Rail wheel profile input in CAD.

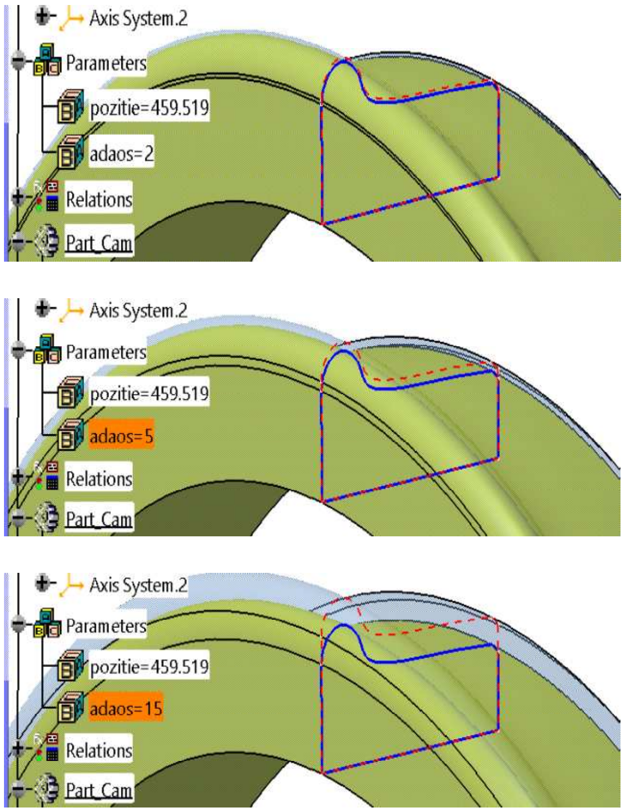


Fig. 8. Rail wheel profile parameterization.

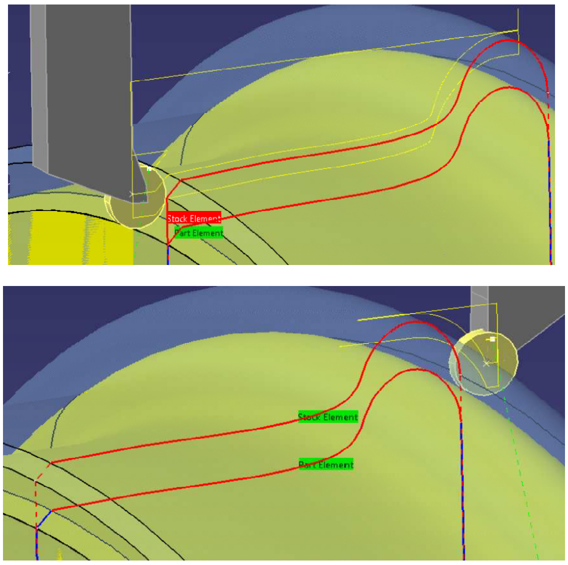


Fig. 9. Rail wheel profile CAM technology;

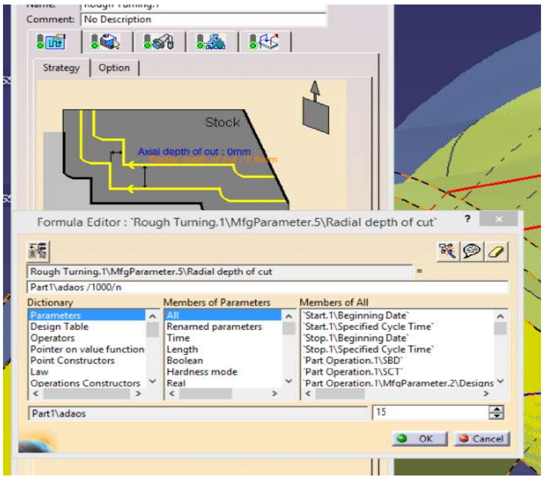


Fig.10. Sample of CAM parameterization.

For example, for the depth of cut it was established the fallowing relation:

$$a_p = T \cdot c1 + c2, \qquad (2)$$

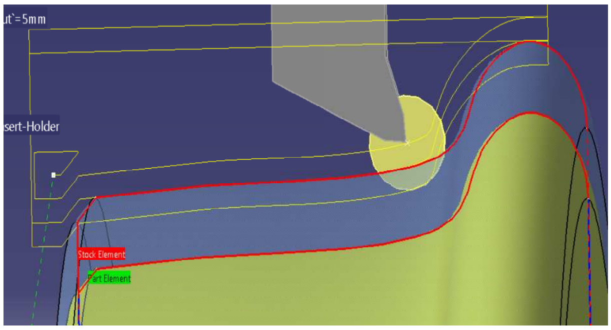
where: T – total cutting depth – is parameter "*adaos*" from the CAD model,

$c1$ – coefficient for depth of each cut. It is established as function of tool geometry, and difference between stock and part. In Table 1 is presented some coefficient c1 which we used for testing,

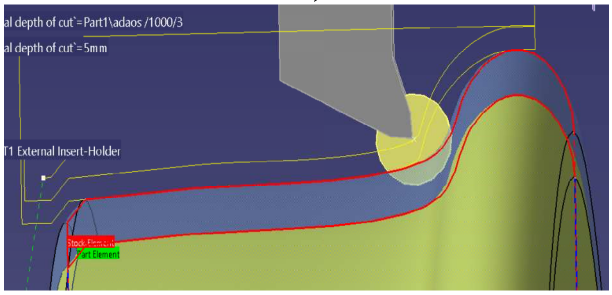
Table 1

Coefficient selection

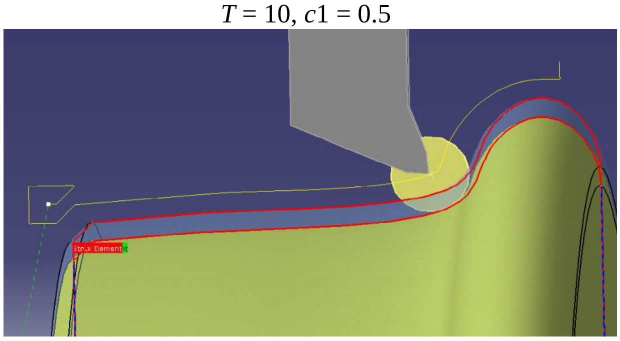
no	Tool insert type	T [mm]	$C1$
1		11−15	0.3
2		6−10	0.5
3		<=5	1
4		11−15	0.2
5		6−10	0.3
6		2−5	0.5
7		<=2	1



T = 15 mm, $c1$ = 0.3



T = 10, $c1$ = 0.5



T = 5mm, $c1$ = 1

Fig. 11. Machining simulation results for various situation.

$c2$ – coefficient for depth of cut established by machine state. Some dynamic measurements were made in order to define the machine behavior.

Some results based on this parameterization can be seen in Fig. 11.

6. EXPERIMENTAL MEASUREMENT

For our study, a Rafamet lathe machine for rail wheel turning was dynamically evaluated.

For machine behavior, an experimental procedure was used for measuring in cutting condition for a wheel with 459 mm radius [5].

The experimental tests were made by using the fallowing equipments and sensors: multichannel system CRIO9076 national instruments with 24 byte resolution and frequency sample rate of 100 kS/s/ch; velometer sensors with 4mv/mm/s senzivity; accelerometer sensors 500 mv/g; displacement sensor – eddy probe with 4 mV/µm sensitivity; the speed monitoring was obtained by laser sensor.

All the signals were acquired and processed in real time and the vibration signal was synchronized in continuous mode with speed signal.

From the analysis of data, it can be observed that the machine has a very good dynamic stability as fallowing: for working without cutting a displacement of 3−7 µm in Z and X direction.

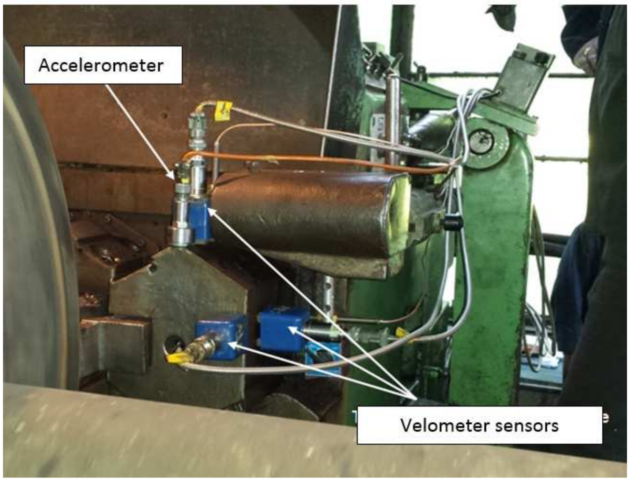


Fig. 12. Experimental set-up.

In cutting process with a round insert with 10 mm diameter and constant depth cut, the displacements obtained were 5−17 µm.

The absolute vibrations measured with transducers sensors in stabile cutting condition is between 0.3 and 0.8 mm/s RMS.

The displacement and speed of vibration show that the amplitude is influenced by the cutting depth variation and also by the chip section variation [8, 9 and 10]. The value obtained is up to 55 µm. when the cutting process is in instability dynamic condition.

The *C*2 correction coefficient is based on the dynamic evaluation taking into account the displacement value of *X* direction.

For this study of cutting with a round insert, *C*2 was established as average function.

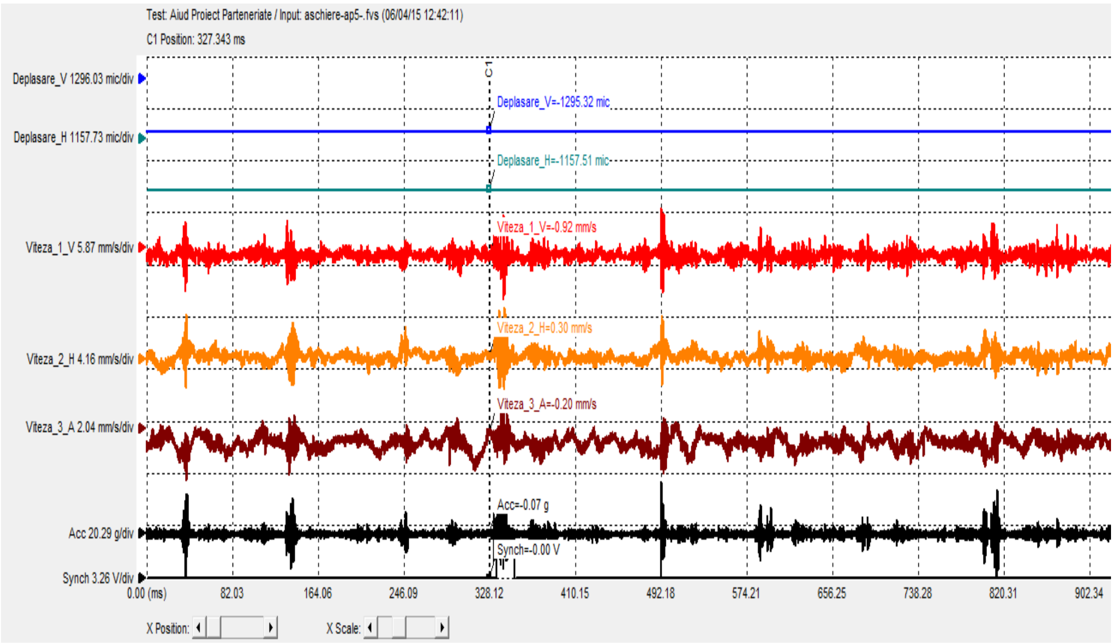


Fig. 13. Wave form signal.

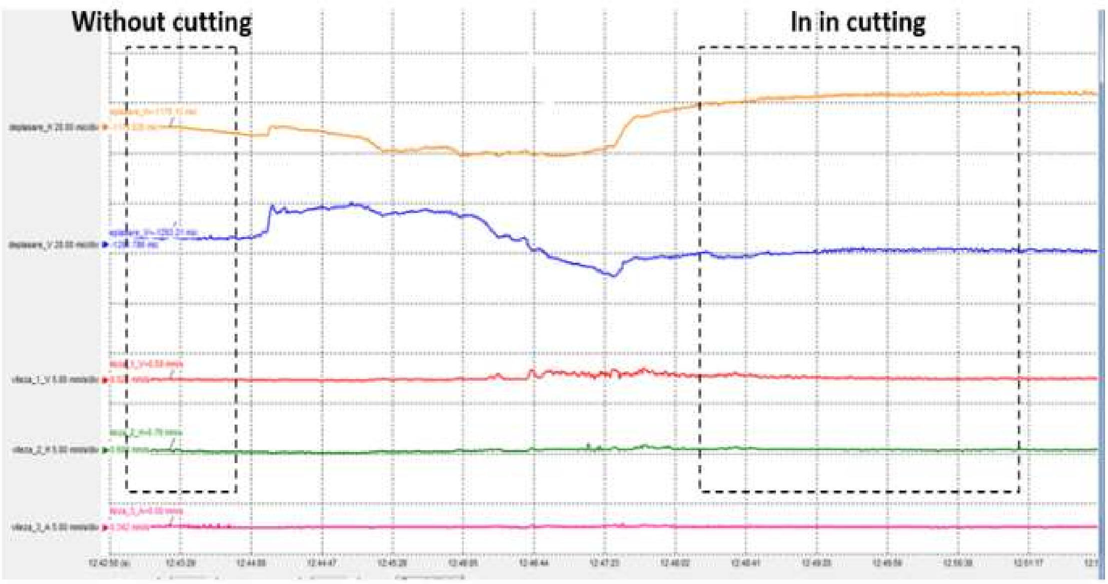


Fig. 14. Dynamic parameters evolution.

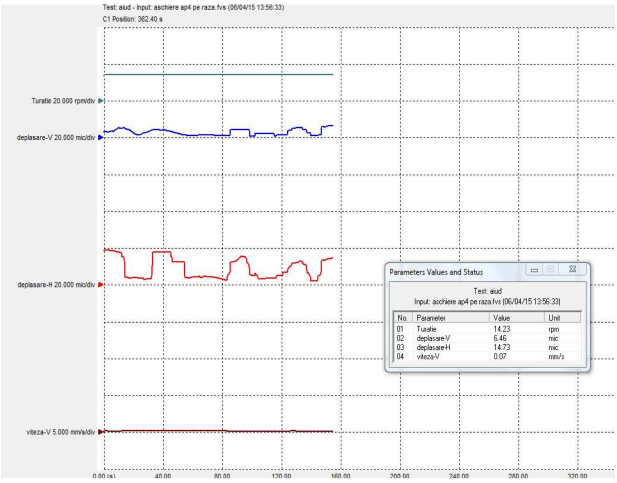


Fig. 15. Displacement parameters evolution.

7. CONCLUSIONS

The metal cutting by turning is one of the most used machining processes in heavy industry.

The manufacturing process design is made with specialized software which generates automatically the CN software.

Today, the CAD-CAM software is advanced and can deal with complex model 2D and 3D. More some integrated software CAD and CAM like Delmia V5 allow complex parameterization between different features.

The modeling of the rail wheel profile 293 points was achieved based on mathematical equation. It was automatically generated a spline profile and 3D model of the wheel and stock.

Optimum NC file were generated based on Delmia application.

Rafamet lathe machine for rail wheel turning was dynamically evaluated. The tests were carried out up to dynamic stability condition limit.

The displacement and speed of vibration show that the amplitude is influenced by the cutting depth variation and also by the chip section variation.

A correction coefficient was established based on the dynamic evaluation taking into account the displacement value X direction.

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