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EXPERIMENTAL RESEARCH REGARDING THE SPROCKET TOOTHING ON MILLING MACHINE "ISEL MSP 4329"

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Abstract

In the present paper are analyzed the research results of possibilities which aims verification of processing the sprocket with double toothing, on the milling machine "ISEL MSP 4329", to determine the precision of the profile execution by splintering with an end-mill cutter. Obtained profile is measured, using "PC-DMIS" software on the "CNC" measuring machine "3D Sheffield" and an automatic analyzing of roughness with the Taly Profile Gold 5.1.1.5374 software on the Surtronic device . The results of experiment point out the possibilities of toothing at the machine "ISEL MSP 4329"; with an simple technology, accessible and relative reduce as duration of time; the processed surface has an small roughness but with an machining errors at the diameters and profile dimensions.

Keywords: toothing, sprocket, profile, eng-mill cutter, CNC

1. Introduction

The processing sprockets teeth by splintering, currently it can be done by several methods: with profiled disc milling cutter on universal milling machines, on hobbing machines with sprocket hob, through mortising with special knives of toothing having wheel profile or comb and processing with end-mill cutter on "CNC" machines. In the present paper are presented the results of a research which has proposed verification possibilities for sprocket toothing processing, on the milling machine "ISEL MSP 4329" [16] , in order to determine the cut-out of mentioned profile through end-mill cutting.

The article consist of two main parts, first consisting of details on processing by milling in 2,5D coordinate system aforementioned profile teeth and second means measuring realized toothing profile. Measurements consist in scanning by using "PC-DMIS" software [20], on the coordinate measuring machine "3D Sheffield" [22], determining the size of diameter over the rolls and of roughness in the machined zone of toothing profile with the Taly Profile Gold 5.1.1.5374 software on the Surtronic device.

References to geometry, processing technology of sprocket toothing and to measuring them can be found in the works [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11].

2. Working methodology

The following describes briefly how to perform a search for related details to machine tool used, and end-mill cutter for splintering required profile, the semi-finished used, programming modality method of machine as well as operating modes used.

Figure 1, the composition of "ISEL MSP 4329":
I – machine table on Y-axis; II – machine base frame; III – four supporting soles; IV – sustaining pillars; V – cross bracing; VI – sleigh traverse; VII – sleigh vertical; VIII – motor support; IX – the semi-finished; X – control computer; XI – computer monitor.

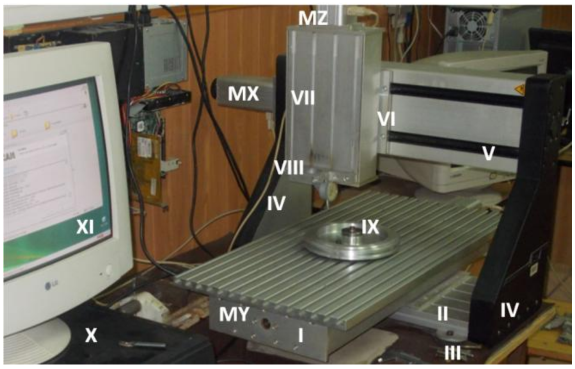

Fig. 1: "CNC" milling machine "ISEL MSP 4329"

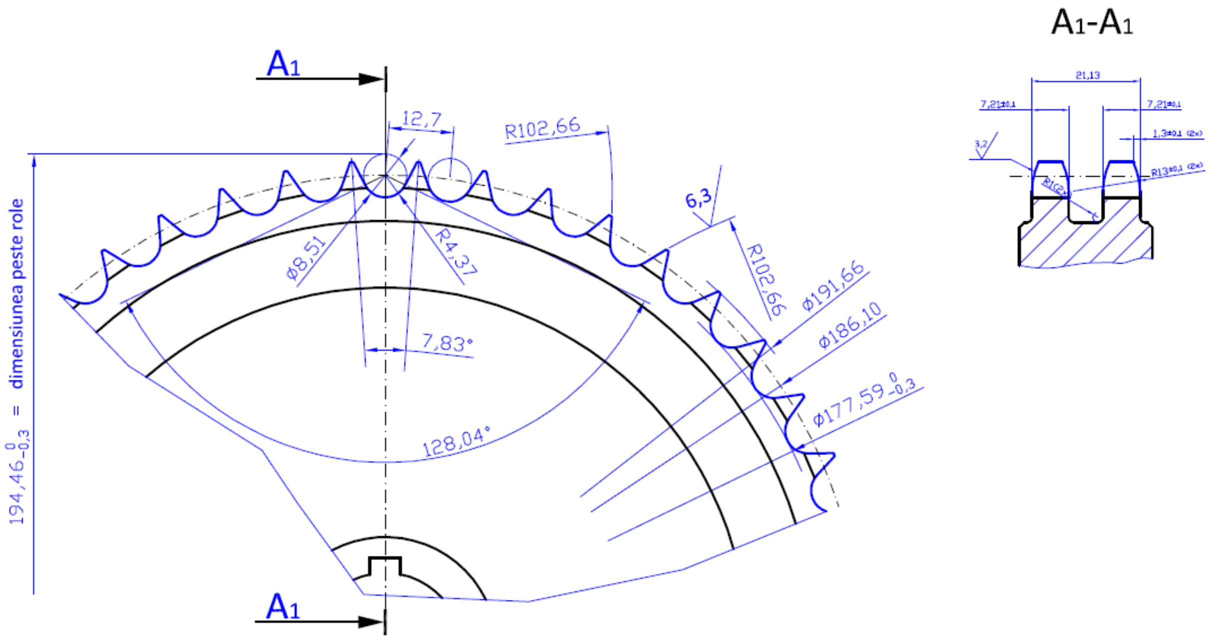

Fig. 2: Double profile of studied sprocket

To perform splintering on “ISEL MSP 4329” machine by means of “ArtCAM PRO”[13] program (“Delcam” Company) are established: technological parameters that will be used to profile milling teeth, the form and size of toothing, position of coordinate system origin assigned to sprocket, cutting regimes, processing mode, the tools form and size, cutting tool parameters, generate toolpaths tool splintering as well as generate port-piece program, next step being placement of program on computer of “CNC” machine and his running to manufacturing the proper toothing profile.

Figure 2, the semi-finished taken as object of research it is a sprocket with double toothing. Geometrical main parameters of toothing studied sprocket and projected in an “CAD” environment - “AutoCAD” [14], [7]:

Transmission calculation of which makes part the studied sprocket, was carried out according to DIN ISO 10823 (2006), extracted data it is calculated with the KISSsoft program – Release “04-2010G – Hochschullizenz” from University “Petru Maior”[17]; Chain type which engages with sprocket corresponds from the standard ISO 606 (2004) – (BS/ISO coding) 08B-2 Type (Short pitch precision transmission roller chain: double).

Geometrical features:

- Number of strands [n_s] = 2 [21];
- Sprocket pitch [p] = 12.70 (mm);
- Roll caliber diameter [d_1Max] = 8.51 (mm);
- Distance between inner plates [b_1]= 7.75 (mm);
- Height splice plate inner [h_2] = 11.81 (mm);
- Transverse step [P_t] = 13.92(mm) [21];
- Radius of surface sitting roll [R_1] = 4.37 (mm);
- Tooth flank radius [R_2] = 102.66 (mm);
- Angle of surface sitting roll [delta]=128.04 (˚);
- Outer diameter [D_e] = 191.66 (mm);
- Bottom diameter [D_i] = 177.59 0/-0.3 (mm);
- Tooth height over the refer. cir.[h_a] = 3.00 (mm);
- The tooth face width [b_{f1}] = 7.21 h14 (mm);
- Dimension over rolls [M_R] = 194.61 (mm);
- Number of teeth [z_2] = 46.

To achieve the proposed technological research, for the toothed crown execution of sprocket it was chosen for machining the aluminium alloy, because this material provides an good processing.

In order to generate the machining program of profile toothing it’s require to export in “CAM” machining program the sprocket drawing, respectively in this case the post-processor “ArtCAM”, the sprocket drawing realized in “AutoCAD” program is exported in format “.dxf”, such possibility representing in present the communication mode between environments “CAD” and “CAM”.

After defining the dimensions of the semi-finished in menu “File – Import – Vector Data” shall be selected previous file with the extension << .dxf >>.

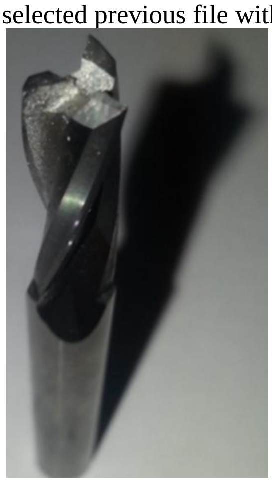
Fig. 3: The end-mill cutter used at splintering the toothing sprocket profile

In the next step it's generated the route fixed for tool (in "CAM" machining program) depending on the chosen tool and the technological process parameters wanted.

Figure 3, the end-mill cutter who is used for splintering of profile - has diameter ø = 7 (mm) and z = 3 (teeth).

Figure 4, for setting the toolpaths of the end-mill cutter it entering in menu "Toolpath" for selecting of profile sprocket.

Fig. 4: Acces the menu "Toolpath"

Figure 5, in the menu "Toolpath" will shall select an another menu "Area Clearence", where are established the following parameters thus: "Finish Deph"; "Machine self Z"; "Home Position"; "Tool List".

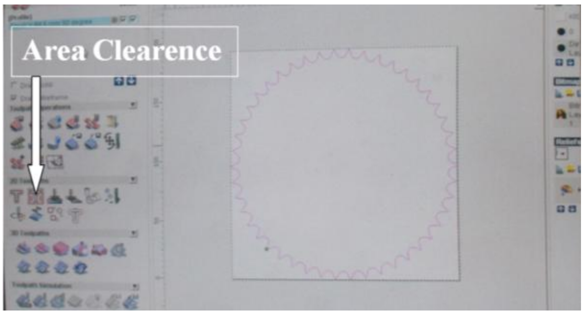

Fig. 5: Acces the menu "Area Clearence"

Figure 6, also in the "Toolpath" menu will shall select "Profiling" to generate the contour of wheel.

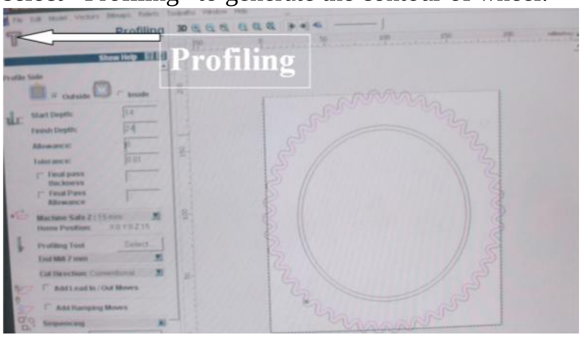

Fig. 6: The option "Profiling" in menu "Toolpath"

Shall will select with "click" the profile of the toothing, it's validated by pressing "Now", thereby generating toolpaths of tool. Machined area will be in outside.

Communication between post-processor "ArtCAM" and the "CAM" software of the milling machine, it is possible using the common language called machine code "Flexicam G-Code" [18]. In the menu "Toolpath" through typing on the command "Save Toolpaths", automatically it will generate the machine code. It will follow the semi-finished position verification in relation with machine axes and the origin adjustment with work-piece.

Figure 7, guideline work-piece supposedly as parallelism to the machine table – Z axis, it will be checked with an comparator clock.

Fig. 7: Checking the work-piece position

Figure 7, origin as against on X and Y shall will make with the device "Edge Finder" located in the fixing device on main shaft.

Figure 8, with help of the test program, partly presented below, and with "MACH 3 Mill" software [19] shall be check overlapping the scheduled geometrical origin with the real of the piece:

```
%
G90
G71
G40
S15000
T1
G0 X0.000 Y0.000 F1000.000
 Z-15.000
G0 X-0.005 Y95.800 Z-15.000
G1   Z0.000 F300.000
G1 X-0.005 Y95.800 Z0.000 F600.000
X0.003 Y97.037
..............................................................................
X-0.005 Y95.800
G0   Z-15.000
G0 X0.000 Y0.000
G0 Z-15.000
G0 X0 Y0
M30
M2
%
```

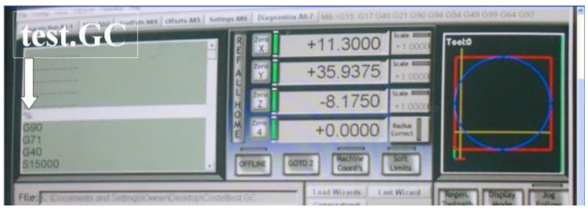

Fig. 8: Interface of "MACH 3 Mill" software

Fig. 9: Checking origin established previously

Figure 9, the origin verification established previously shall be made by the splintering (with minimal addition) on the inner diameter at felloes wheel [being concentric quota (is turned from a grip), nonfunctional of the sprocket].

3. Toothing splintering of profile sprocket

Processing through splintering of the teeth sprocket profile is carried out on the machine “ISEL MSP 4329”, using the “CNC” software “Artsoft MACH 3 Mill”.

Mentioned above, the semi-finished material is performed from aluminium according to EN AW-2011 T6/ISO: AlCu6BiPb [12]. Hardness measured at work-piece it’s 110 (HBW).

Fig. 10: Splintering evolution at first strand of the wheel toothing

Figure 10, fig. 11 and fig. 12, the splintering program (partially written):

```
%
G90
G71
G40
S15000
T1
G0 X0.000 Y0.000 F1000.000
 Z-15.000
G0 X26.841 Y27.068 Z-15.000
G1   Z3.250 F150.000
G1 X26.841 Y27.068 Z3.250 F600.000
X26.748 Y26.721
X26.690 Y26.358
.......................................................................................
X27.973 Y30.333
X27.393 Y28.705
X26.841 Y27.068
G0   Z-15.000
G0 X0.000 Y0.000
G0 Z-15.000
G0 X0 Y0
M30
M2
%
```

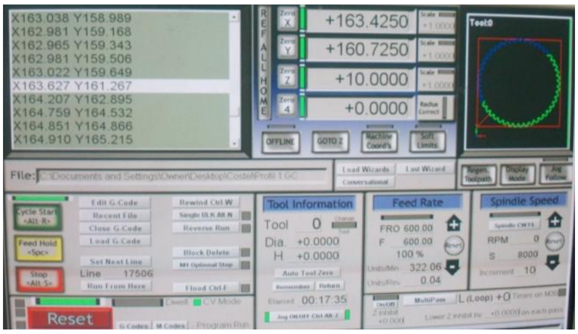

Fig. 11: “MACH 3” – in the machining moment

Fig. 12: Machining at to second side of toothing

Figure 12, the programs runs continuously to machining the one of second toothing of the wheel, thus will be processed the integer profile double-symmetrical of the sprocket.

Fig. 13: Sprocket with double toothing

Technologic parameters working who it was used at machining:

- speed rotation of end-mill cutter n = 20000 (rpm),
- end-mill cutter diameter D = 7 (mm),
- cutting depth t = 1 (mm),
- cutting speed v = 439.81 (m/min),
- advance s = 600 (mm/min).

Figure 13, machining of the profile toothing was carried out in normal conditions without incident. The toothing duration of sprocket machining was: 42 min.

4. Checking dimensional precision and roughness

Modality to verify the dimensional precision is achieved in three steps, the first stage being measurement through scanning on the toothing machined surface with touch on machine coordinate measuring “3D Sheffield”, the second one is measuring the size over rolls with help of an micrometer having opening until at 200 (mm) and the last one stage consist in determining surface roughness of profile toothed.

At the “3D” measuring machines, the software recognizes the type of surface at simple touch of work-piece surface with probe “TIP”, realizing graphic representation of the measured surface on the monitor screen.

“PC-DMIS” software [20] accomplished the cod lines manually, with automated forms or directly on the 3D model.

The main stages of the program scan:

I. Program recognition;

II. Start, the machine axes alignment - “3D”;

III. Beginnings program; selecting probe/“TIP”;

IV. Alignment the semi-finished with machine;

V. Alignment of machines axes; Commutation “DCC”;

VI. Alignment in automatically mode by scanning continues;

VII. Outer profile scanning;

VIII. Defining the bases for dimensional ratio;

IX. Deviation of form – dimensional ratio;

X. The circle construction of division;

XI. Dimensional ratio;

Fig. 14: Laying out sprocket on the machine table

The results of the measurements made:

- Figure 14, after fixing the sprocket on the machine table shall imported drawing of wheel from environment “CAD-Inventor” [15] which ending in with <<.stp>>. The axes of machine are aligns, and the “TIP” used is selected;

- It will identify the surface plane and circles 1-2, as bases of sprocket, placing the 3Dcenter;

- Figure 16, which by automatically mode “DCC” automatic scans “PLN2, CIR3, CIR6, CIR9”;

- Shall scans twice (“SCN1 şi SCN2”), the machined profile of sprocket;

- Figure 15, Defining bases for dimensional ratio - (“PLN2, A - CIR3, B - CIR9, C”);

- 0.032 (mm) / tolerance - +/-0,050 it’s deviation

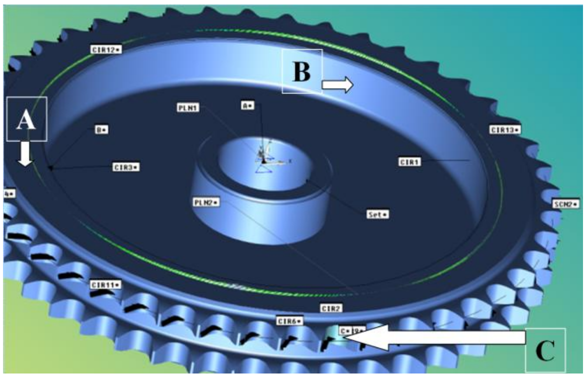

Fig. 15: Defining bases (A, B, C)

from parallelism on the “PLN2” (of face A) at the face plan of machine table;

- Figure 17, showing the dimensional ratio of deviations;

- Due machined surface through splintering it was chosen for reading, the tolerance +/- 0.7 (mm);

- Figure 17, the total deviation as against to the “3D” system with bases “ABC” (plan and two circles), at the first scanning of the surface profiled “SCN1” has deviation resulted 1,638 (mm) with 0,938 (mm) over the tolerance, and in the case the one of the second “SCN 2” it is 1,407 (mm) having 0,707 (mm) over the tolerance. The final deviation was 1,638 (mm) with 0,938 (mm) over the tolerance of +/- 0.7 (mm).

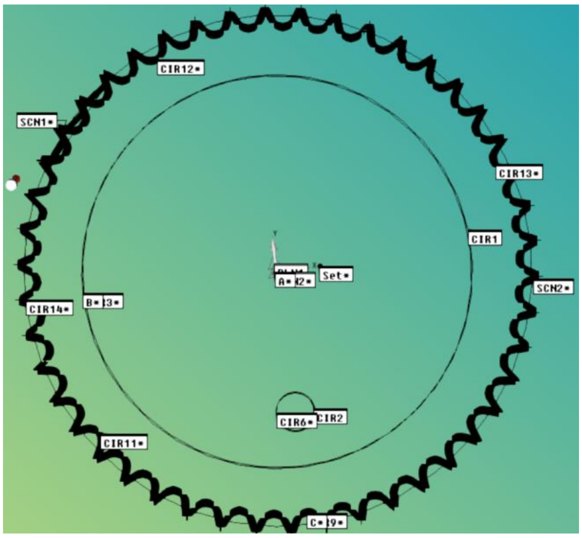

Fig. 16: The measured profile of sprocket

- Figure 17, the deviation of division diameter (ø = 186.10) with tolerance of +/- 0,050 (mm) as against X = 0,204 (mm) and of Y = 0,138 (mm) and the total deviation of concentricity on the dividing diameter is 0,034 (mm).

- Figure 18, the circle circularity measuring “CIRC 3 - base B”. Deviation of the circularity is 0,017 (mm), tolerance +/- 0,050.

Figure 19, one parameter over of which have been made the determinations consisted it in the dimension of the outer radius of the profile. Through reference bases B and C it traces an axis, against which it will more construct a line with the angle 3,915(°).

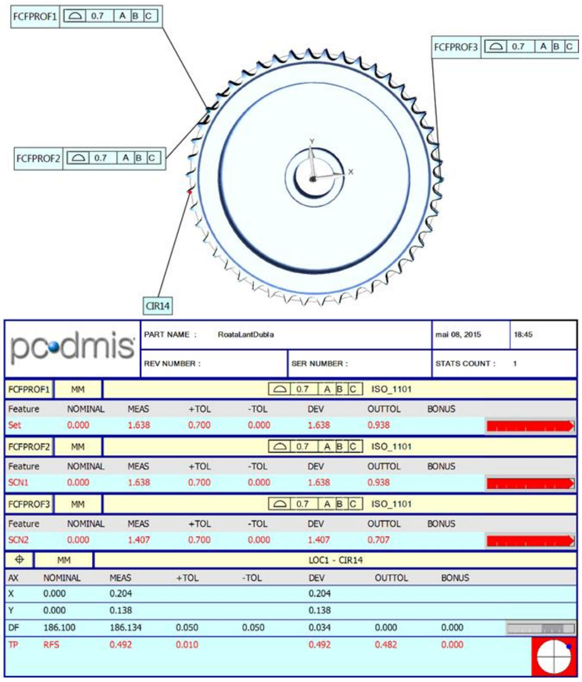

Fig. 17: Dimensional ratio of deviation of form and position – the scans SCN1 şi SCN2

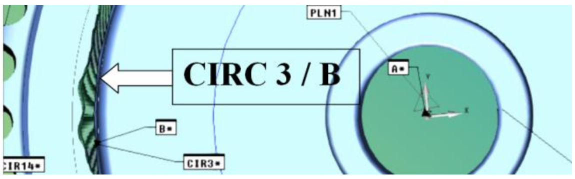

Fig. 18: The circle circularity measuring “CIRC 3”

Figure 20, at the intersection with the resulting scanned surface “PNT 1”. Shall will build one new axis by rotating the system with 7.83(°), it obtaining “PNT 2”. Idem will proceed to obtain the point “PNT 3”. Shall be measure the rays in “PNT 1”= 95,598(mm), “PNT 2” = 95,559(mm), “PNT 3” = 95,612(mm).

Figure 20 and fig. 21, the average of the three rays resulting is 95,589 (mm), at least in the respectively area, that the outer radius of the profile of the sprocket is with 0,241(mm) less than that the nominal 95,83(mm).

Figure 19, fig. 20 and fig. 21, at the intersection of those three axes of “PNT 1 - PNT2 - PNT 3” with the opposite part of the profile which is not longer symmetrical, fact observed and from the scan performed at the profile of toothing machined surface.

Figure 22, the deviation of profile from image is examined with help of the “pc-dmis” software.

Specific for the sprocket is to determine the toothing dimension over the rolls.

The dimension measured over the rolls in four distinct areas:

I. 194.105(mm);
II. 194.01(mm);
III. 193.84(mm);
IV. 193.91(mm).

For comparison, the nominally dimension over the rolls is $[M_R]$ = 194.61 +/- 0.3 (mm).

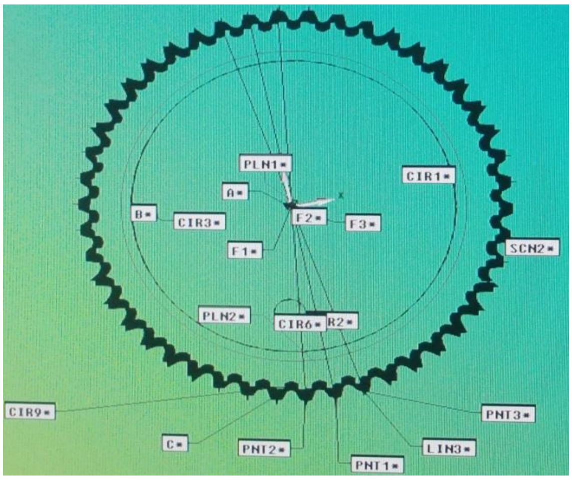

Fig. 19: The integrally drawing of scanned profile and intersected by the three axes constructed according to the calculation carried out

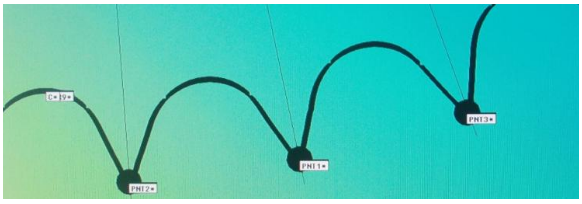

Fig. 20: Location of points “PNT 1” = 95,598(mm), “PNT 2” = 95,559 (mm), “PNT 3” = 95,612 (mm), on the outer ray of the profile of toothing sprocket

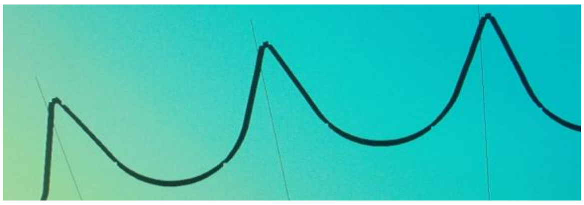

Fig. 21: The intersection of those three axes from “PNT 1- PNT 2 - PNT 3” with the opposite part of profile it is no longer symmetric

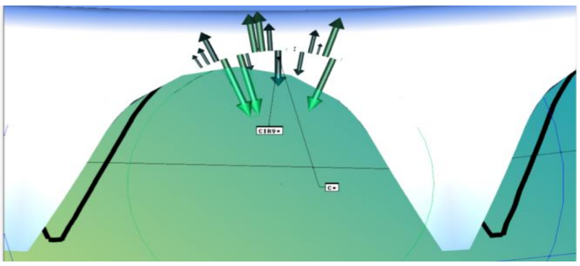

Fig. 22: Deviation of profile is revealed graphically with help of possibilities of scanning and playback to “pc-dmis” software

Figure 23 and fig. 24, another parameter to whose it was given attention in the research framework has been accounted by roughness machined surface on toothing profile. For roughness checking it was used Surtronic 25 device [23], that use for the determination, Taly Profile Gold 5.1.1.5374 software [24].

The values measured by the equipment mentioned above can be found in Table 1.

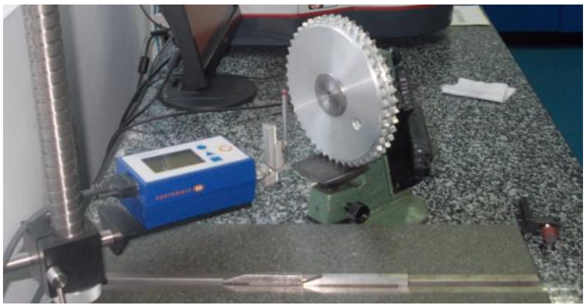

Fig. 23: Surtronic 25 – Portable and flexible surface finish measurement system

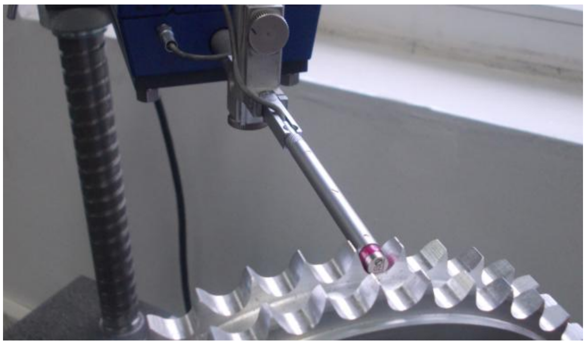

Fig. 24: Automatic determination of roughness

Table 1: Flanks roughness

No.	ISO 4287			ISO 12085	OTHER 2D PARAM.
	R_aµm	R_zµm	W_tµm	R µm	R_{max} µm
1	0.885	5.12	8.40	2.85	6.93
2	0.590	3.77	7.21	1.73	4.29
3	1.24	6.80	13.4	4.40	8.05
4	1.33	7.17	11.9	2.82	7.77
5	0.841	5.18	8.32	2.88	5.47

Ra: Arithmetic Mean Deviation of the roughness profile.

Rz: Maximum Height of roughness profile.

Wt: Total Height of waviness profile.

R: Mean Depth of the Roughness Motifs.

Rmax: Maximum Peak-to-Valley height of the sampling lengths on the roughness profile.

It may be ascertain that the R_a roughness shall in the range among of 0.59 (µm) and 1.33(µm).

Figure 2, this roughness range can be considered at least acceptable in terms of the sprocket functioning, considering recommended roughness in the execution drawing – 6,3 (µm).

5. Conclusions

From experimental research carried out, it was resulted a series of the conclusions of practical nature from which the most important are the following:

- the “CNC” milling machine “ISEL MSP 4329” allow an maxim machining diameter of outer profile of toothing sprocket of ø = 350 (mm);

- an advantage is simple and accessible programming, the totally time assigned at toothing machining, including the generation of machining program, and adjustments afferent to the preparation of manufacture, being 2:23 (hours), it having a relatively short of toothing duration in compared with other modalities of toothing.

- construction features of the machine, especially those related to stiffness, were determined the emergence of some machining errors of the toothing in clearly at the bottom diameter dimension and at the outer one, as well as deviations of toothing profile;

- an auxiliary machine construction with the possibility of rotation on Z – axis would improve performance of accuracy because the tool will no longer have to carry large on amplitude displacements in the XOY plan, generating displacement with processing errors from due to the wears retrieved and existing on the machine guides. In this situation, the tool would have a short move adapted to teeth profile height between the bottom and the outer diameter.

Acknowledgement

The authors transmit sincere thanks to Dr.eng. Peti Ferencz and to Eng. Petru Şerban from the Measuring Laboratory of CieMatricon S.A. - Tîrgu Mureş, for their assistance at measurements made at the double toothing of sprocket, manufactured, measured and analyzed in this article.

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