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EXPERIMENTAL RESEARCH CONCERNING TOOTHING OF SPROCKET WITH DOUBLE PROFILE ON THE „AXA VSC 0-500M" CONTROLLED VERTICAL MACHINING CENTER

Constantin BUCUR[1], Ioan Francisc FEKETE[2]
[1] "Petru Maior" University of Tîrgu Mureş
Nicolae Iorga Street, no. 1, 540088 Tîrgu Mureş, Romania
[1]constantin.bucur@ing.upm.ro
[2]Malu Serv S.R.L. of Tîrgu Mureş, 1 Decembrie 1918 Avenue, no. 27, 540061
Mureş County, Romania
[2]maluserv@xnet.ro

Abstract

The present paper work submit the performed research on processing and measuring carried out in the experiment framework which aims precision determination of execution through splintering with an cylindrical-frontal end mill of an double toothing sprocket profile, on „AXA VSC 0-500M" Controlled Vertical Machining Center. The precision of double toothing sprocket profile is measured, with help of „PC-DMIS" soft on „CNC" „3D Sheffield" measuring machine, and also determining the toothing surface roughness through automatically determining with help of Taly Profile Gold 5.1.1.5374 soft on the Surtronic device. In paper work it is highlighted the experimental conducting of toothing double sprockets on „AXA VSC 0-500M" vertical machining center; with a simple, accessible technology, resulting a processed surface of small roughness and precisions deviations who are confirmed through via realized measurements.

Key words: sprocket, toothing, control, precision, CNC, roughness

1. Introduction

Processed sprocket from the experiment framework it has double toothing geometry of chain standard ISO 606 (2004) – Type (BS/ISO Codification) 08B-2 (Precision roller chain: Double). [1]

The toothing profile of sprocket can be realize in several procedures of processing such as through copying on universal milling machines, through profile generation on hobbing machines with profiled tools afferent desired profile (sprocket hob, wheel knife, wheel comb, profiled disc milling cutter), on the CNC machines, through punching, through casting, through injection of plastic masses, through sintering, etc.

The goal of article include stepwise, the results of a research, which was proposed verification of machining possibility of a sprocket with double toothing, on „AXA VSC 0-500M" Controlled Vertical Machining Center [2], in order to execution precision determination of the said profile, through milling with end-mill cutter.

Fig. 1: „AXA VSC 0-500M" Controlled Vertical Machining Center [2]

The article comprises two main parts, the first one containing details of processing by milling in the coordinate system of toothing profile mentioned above and the second part indicating ways of measuring and control of toothing profile resulting as a result of machining with end-mill cutter.

Measurements taken consist in contour scanning of profile with help of „PC-DMIS”[4], program on coordinate measuring machine „3D Sheffield”[5] and of roughness in the processed zone of the toothing profile with the “Taly Profile Gold 5.1.1.5374” program [6] on Surtronic device [7].

Similarities concerning geometry, technology, material and measurements performed sprocket tooting are find in the works, [11], [12], [13], [14], [15], [16], [17], [18], [19].

2. The necessary conditions of the experiment

Working conditions include main operating parameters of „AXA VSC 0-500M” Controlled Vertical Machining Center, used tool, aspect on work-piece, CNC programming method, as well as the effective control of the double profile of the milled sprocket toothing.

In Figure 1 is observed the Controlled Vertical Machining Center, produced by AXA (Germany), model/type VSC 0-500M, fabrication year 1989, also the main parameters of the processing center are mentioned in Table 1.

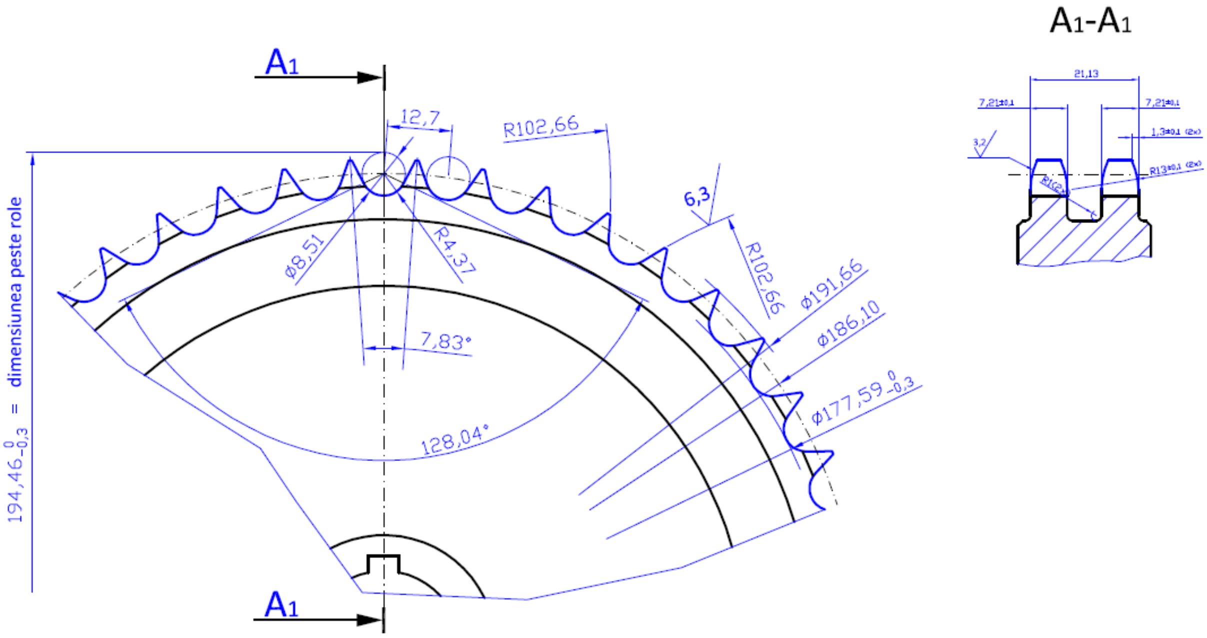


Fig. 2: Double profile of studied sprocket

The drawing in Figure 2 – sprocket with double toothing, [19] represented in an environment „CAD” - „AutoCAD” [8] it is the subject studied in this article. Principal geometrical parameters of the researched sprocket toothing are register in Table 2.

Table 1: Parameters of vertical center AXA

Displacement axes on machining center	X (longitudinal) = 500 [mm]
	Y (transversal) = 300 [mm]
	Z (vertical) = 250 [mm]
Control block	SIEMENS Sinumerik 3 M/4
Table dimensions	= 800x420 [mm]
Retaining tool cone	SK 30 DIN 69 871
Number of positions in tool magazine	= 16[pcs]
The carrying capac. of driving screw	= 11,2 [kW]
Principal spindle speed	= 30 → 3000 [U/min]
Working advance	= 1 → 9999 [mm/min]
The rapid advance	= 15 [m/min]
Total power	=20 [kW]

Fig. 3: End mill characteristics used at machining of the profile are ø = 8 [mm] and z = 4 [teeth]

Transmission calculation of which makes part the studied sprocket was performed according to DIN ISO 10823 (2006), extracted data was calculated using the program „KISS soft“[9];

The chain type which engages with the sprocket corresponds to standard ISO 606 (2004) – Type (Encoding BS/ISO) 08B-2 (Short pitch precision transmission roller chain: Double) [1].

Table 2: Geometric characteristics of transmission

Number of rows	$[n_s] = 2$
Sprocket pitch	$[p] = 12.70$ (mm)
Roll caliber diameter	$[d_1Max] = 8.51$ (mm)
Dist.between inner plates	$[b_1]= 7.75$ (mm)
Height splice plate inner	$[h_2] = 11.81$ (mm)
Transverse pitch	$[P_t] = 13.92$(mm) [20]
Radius of surface sitting roll	$[R_1] = 4.37$ (mm)
Radius of the tooth flank	$[R_2] = 102.66$ (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 reference circle	$[h_a] = 3.00$ (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 was used the 34CrMo4 improvement steel according to standards SR EN 10083-3:2009/1.7220 and SR EN 10060, since this material is recommended for mechanical constructions, respectively, for gears.

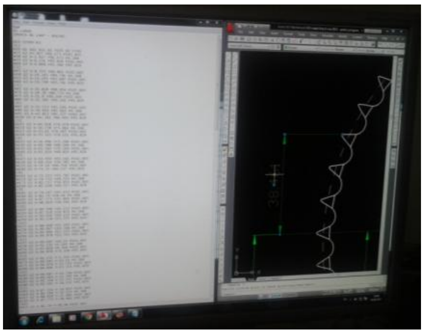


Fig. 4: Introduction of G codes in processing program, simultaneously with determining points on toothing profile

The next step consist in manually conception of program machining program (line by line) by entering G codes (the extremely laborious..., because it simultaneously requires and sampling all the points on the toothing profile,... appeared situation is due to the „AXA VSC 0-500M" Controlled Vertical Machining Center that has limited possibilities of functionality and command).

3. Conceiving the machining program for milling of double profile of the sprocket

The building of program requires successive emplacement of the G codes bearing in mind the emplacement of points determined on double profile of toothing.

Below partial is presents the machining program (written in Microsoft Notepad), with specifying the important milestones in his development:

- **Behalf of the main program:**
  %2309
  (ROATA DE LANȚ - BUCUR)
- The work-piece zero point:
  N5 G59 x-156.599 Y-139.214 Z-394.554
- System selection in the absolute coordinates:
  N10 G90
- Selection of the number 2 tool out of the „AXA VSC 0-500M" vertical machining center:
  N15 L900 T2
  (FREZA DEGET D8)
- Correction of tool length „D2" (with displacement on z-axis), and establishing rotation to „s2000" [rpm], of the shifting sense of the tool in a clockwise direction „M3" and coolant start „M8":
  N20 G0 D2 z100 s2000 M3 M8
  …………………………………………………….
- Displacement to center axis of the blank {at height „z100" [mm]}:
  N25 G0 x0 y0
- The tool is positioned on the 105 [mm] diameter in outside of the blank:
  N30 y105
- Milling tool goes down to 5 [mm] above the blank:
  N35 z5
- Milling tool enters with work advance at 2 [mm] processing addition in work-piece:
  N40 G1 z-2 F500
- Entering the subprogram „L03":
  N45 L03
  ....
- Entering more 2 [mm] in processing:
  N60 G1 z-4 F500
  ....
- By mentioned that between „N100" and „N140" itself meets the free space from the two profiles of the double wheel, opting for swift scroll of its.
  N100 G1 z-8 F500
  ....
  N140 G1 z-15 F500
  ....
- At the end of program the rotation stops with „M5" and the coolant with „M9", the program finally ends with the commands „M02":
  N215 G0 z150 M5 M9
  N220 M02.

- **Subprogram name:**
  %SP
  L0300
  (ROATA DE LANȚ - BUCUR)
- Is inserted rotation of „s2000" [rpm] and displacement in a clockwise direction „M3":
  N10 s2000 M3
- The tooth number 1:
  (1)
- Quota at which milling tool enters in compensation, „D2" – comprising the features of the tool used (length, diameter):

N20 G1 G42 x11.61 y105 D2 F300

- „P102.665” it is radius that is generates of tool:

N25 G3 x3.927 y91.175 p102.665
N30 G2 x-3.927 y91.175 p4.368
N35 G3 x-6.231 y95.626 p102.665
N40 G3 x-6.848 y95.584 p95.829

- The tooth number 2:

(2)
N45 G3 x-8.525 y90.861 p102.665
N50 G2 x-16.305 y89.791 p4.368
N55 G3 x-19.195 y93.887 p102.665
N60 G3 x-19.799 y93.761 p95.829
(3)
N65 G3 x-20.818 y88.854 p102.665
……………………………………………………….
(46)
N905 G3 x28.38 y86.735 p102.665
N910 G2 x20.818 y88.854 p4.368
N915 G3 x19.799 y93.761 p102.665
N920 G3 x19.195 y93.887 p95.829

N925 G3 x16.305 y89.791 p102.665
N930 G2 x8.525 y90.861 p4.368
N935 G3 x6.848 y95.584 p102.665
N940 G3 x6.231 y95.626 p95.829

- Cancel radius compensation of tool with „G40” to the avoidance the occurrence of some processing errors, and with „y105” itself take out milling tool outside the profile toothing:

N945 G1 G40 x0 y105 F500

- Linear interpolation with rapid advance „G0 z5” at 5 [mm] above the blank:

N950 G0 z5

- The end of program with „M17”, and with „M02” closes program:

N955 M17
M02

4. The effective milling of double profile of the sprocket

The images what's next in continuation to this paragraph, highlights the milling stages of the sprocket toothing on „AXA VSC 0-500M” Controlled Vertical Machining Center.

Fig. 5: Checking with the comparator clock of the precision of fixing the blank on the mass of „AXA” center

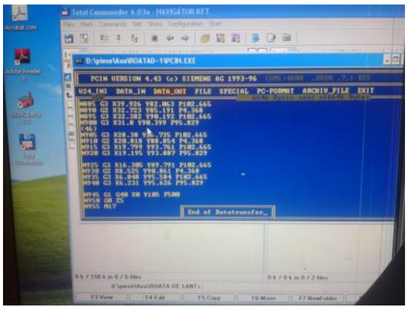


Fig. 6: Completion of transferring the processing program (amounting to 6646 bits), from memory of your computer to the memory of „AXA VSC 0-500M” center

Fig. 7: Milling of first addition of processing at the double sprocket profile

Fig. 8: Aspect with the first addition of processing completed

Fig. 9: Milling of the second part of the toothing

Fig. 10: Milling program presently working out it is viewed on the „AXA” center's monitor

Fig. 11: Double toothing of sprocket in final stage of execution

Fig. 12: The blank and the sprocket-completed

Figure 12 contains those two poses of sprocket, before and after processing the toothing profile.

5. Control of the dimensional deviations and surface roughness of the contact toothing

The following images contained in this paragraph, shows dimensional determinations realized on the double profile of the sprocket toothing so:

- scanning by tapping the processed of the toothing on the „CNC" „3D Sheffield" center [5];
- dimension measurement over the rollers with the micrometers, having opening until 200 [mm];
- roughness determination on contact surface of the toothing.

Figure 13 shows the mounting and scanning of sprocket on the center's table of measuring - „3D Sheffield".

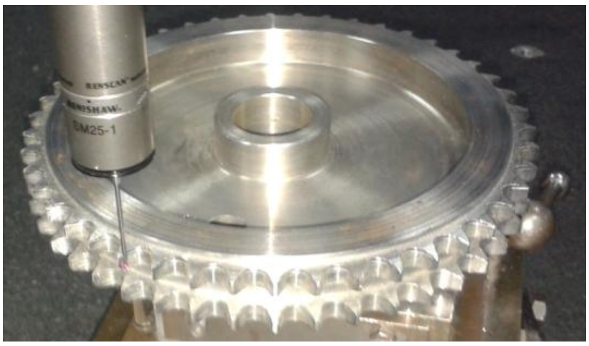


Fig. 13: Image from during performs of automated scanning of the sprocket profile

Figure 14 contains the main steps succession of dimensional scanning program to determination on the coordinate measuring center, of the dimensional deviations of the toothing.

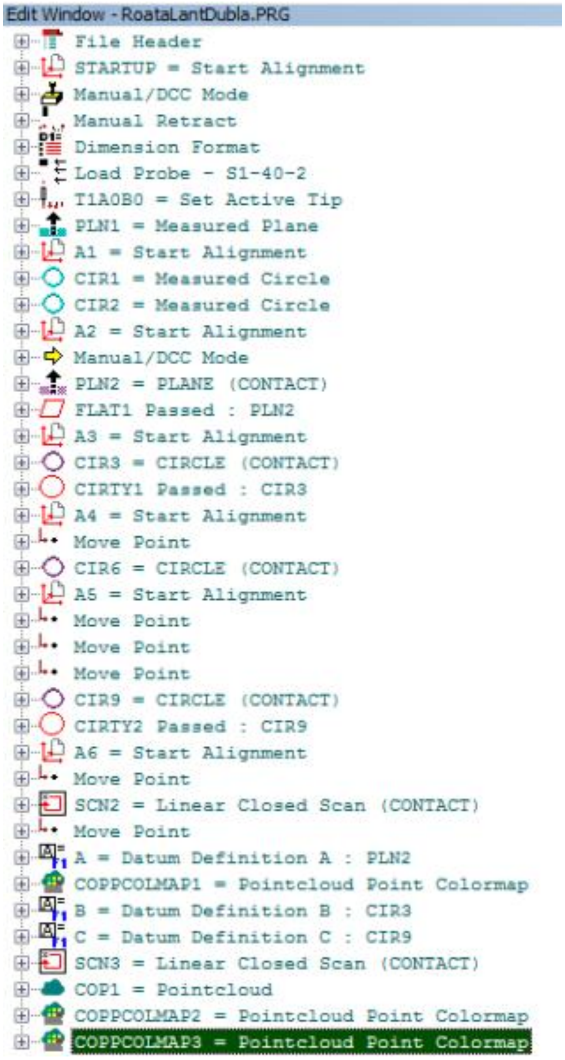


Fig. 14: Program of control measurements carried out for determining the dimensional deviations of toothing profile

Figures 15, 16 and 17 contain the landmark points „A", „B" and „C" of defining the sprocket position on the center's table for to identify the existing deviations, such as:

- „A" in function of „PLN_2" and „A_3";
- „B" in function of „CIR_3" and „A_4";
- „C" in function of „CIR_9" and „A_6".

Figure 18 illustrates scanning „SCN_2" of the profile 1 of the sprocket which is carried out in a number of the 1158 profile points (resulting -0.7[mm] deviation as against „A"), without compensation „CAD", and as against of theoretic profile a deviation from -0.3 ... +0.5 [mm];

„COPPCOLMAP" it is the command for extracting the color graphics for profile 1 and 2 as well as for the one common of the sprocket with double toothing, itself making straight on the reference „COP_1" from the measuring program of deviations.

Figure 19 - scanning „SCN_3" of the 2 profile is done in a number of 2252 points on profile (resulting

-1.9[mm] deviation as against „A”), without compensation „CAD”, and as against to theoretical profile one deviation of -0.3 ... +0.6 [mm];

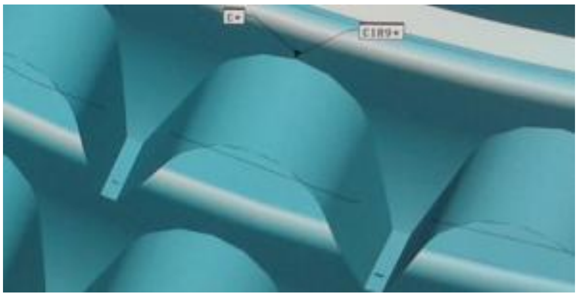


Fig. 15: Identifying the landmark „C” on the circle surface „CIR_9”

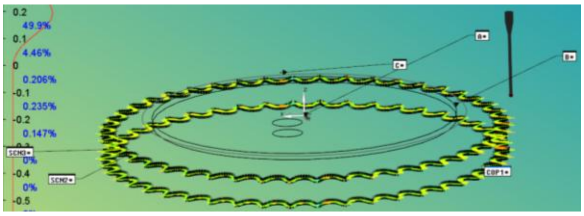
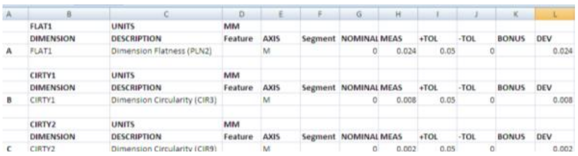


Fig. 16: The surfaces of the toothing profiles 1 and 2 scanned with „SCN_2” respectively „SCN_3” and the landmarks „A,B and C” corresponding to the surface of on sprocket with double toothing „PLN_2”, circles „CIR_3” and „CIR_9”



A	B	C	D	E	F	G	H	I	J	K	L
	FLAT1	UNITS	MM								
	DIMENSION	DESCRIPTION	Feature	AXIS	Segment	NOMINAL	MEAS	+TOL	-TOL	BONUS	DEV
A	FLAT1	Dimension Flatness (PLN2)		M		0	0.024	0.05	0		0.024
	CIRTY1	UNITS	MM								
	DIMENSION	DESCRIPTION	Feature	AXIS	Segment	NOMINAL	MEAS	+TOL	-TOL	BONUS	DEV
B	CIRTY1	Dimension Circularity (CIR3)		M		0	0.008	0.05	0		0.008
	CIRTY2	UNITS	MM								
	DIMENSION	DESCRIPTION	Feature	AXIS	Segment	NOMINAL	MEAS	+TOL	-TOL	BONUS	DEV
C	CIRTY2	Dimension Circularity (CIR9)		M		0	0.002	0.05	0		0.002

Fig. 17: The deviations of the surface „PLN_2” (planarity) =0.024 [mm], of the circles „CIR_3” and „CIR_9” (circularity) = 0.008 respectively 0.002 [mm]

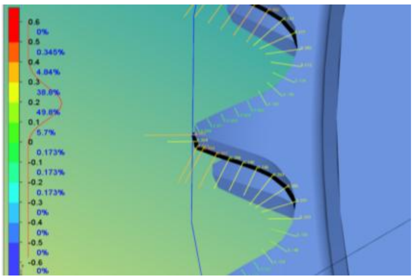


Fig. 18: The color graph of the scanning „SCN_2” of the profile 1 of sprocket with double tooting

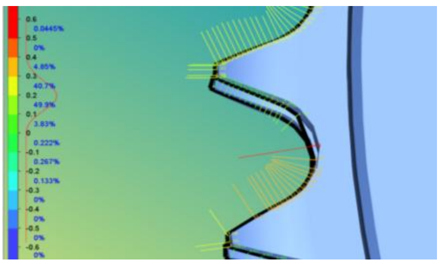


Fig. 19: The color graph of the scanning „SCN_3” of the profile 2 of sprocket with double toothing

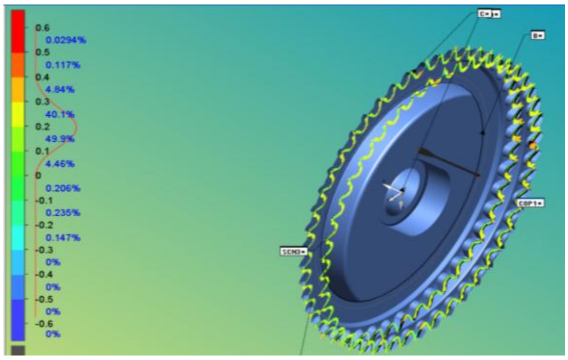


Fig. 20: - The graph of the profile deviation on the double toothing of the sprocket, in overall

Figure 20 – itself extract the profile deviation graph, in overall, for both sides of the double toothing, resulting a deviation of -0.3 ... +0.6 [mm], with tolerance of +/- 0.6[mm], bearing into account of the reference „COP_1”.

A specific situation encountered at the sprocket regarding the measurements is to determine the dimension of the toothing over rollers.

Measuring share over rollers in four distinct areas:

I. 195.10 [mm];
II. 195.05 [mm];
III. 195.01 [mm];
IV. 194.99 [mm].

Informative in the Figure 2, nominally dimension over rollers in this situation, it is $[M_R] = 194.61\ ^{0}_{-\,0,3}$ [mm].

Figure 21 – another parameter determined under the experiment is the roughness of the processed surface of double profile. For verification it is used the Surtronic 25 apparatus [7] which using for determination the TalyProfile Gold 5.1.1.5374 program [6].

The measured values in the above condition are visible in Table 3.

Fig. 21: Surtronic 25 – Portable and flexible surface finish measurement system [7]

Table 3: Flanks roughness

No.	ISO 4287			ISO 12085	OTHER 2D PARAM.
	R_aµm	R_zµm	W_tµm	R µm	R_{max} µm
1	1.96	11.3	22.3	7.13	14.6
2	1.83	10.3	10.2	5.49	11.7

R_a: Arithmetic Mean Deviation of the roughness profile.
R_z: Maximum Height of roughness profile.
W_t: Total Height of waviness profile.
R: Mean Depth of the Roughness Motifs.
R_{max}: Maximum Peak-to-Valley height of the sampling lengths on the roughness profile.

It may be noted that the roughness R_a is within the range 1.83 [µm] up to 1.96 [µm], in this range the roughness will be considered at least acceptable in regard to functioning of sprocket, considering roughness of 6.3 [µm] recommended in the execution drawing.

6. Conclusions

What was experienced and described above, conduct to the establishment of practical conclusions, mentioning the ones most important:

- an supplementation of the machining center construction with possibility of rotating of axis Z would improve the accuracy of surface execution, because the tool will no longer have to carry of large amplitude displacements in the plane XOY, realizing the displacement with processing errors caused by taken over wear from the guides of the machine. Thus, tool would have a short motion, only at the teeth profile height between the bottom diameter and the outer one;
- „AXA VSC 0-500M" has the opportunity to keep the accuracy misconducts using corrections what can be realized in the program to the used tool;
- lack of a dedicated fixation device to sprocket on the table of the processing center, lead to increase of time spent with measurement on establishment of zero point of the blank;
- a drawback is the long time for programming, due to necessity of measuring of all the points on the profile (in present case) and manually introduction of the program; although there is the possibility of repetitive use of the realized program;
- Once the programs is realized... is interesting to noted that the time of actual milling of toothing 01:20, is relatively short compared to the other ways to generating of the sprocket double toothing, except, making the settings and fixing of sprocket on the center's table.
- constructive characteristics of the center „AXA VSC 0-500M", especially those related to wear of the guides (having in sight manufacturing year - 1989), has determinate the occurrence some processing errors profile toothing in obviously at the bottom diameter (maximum difference +0.51 [mm]) and at the outside one (maximum difference +0.3 [mm]), as well as the deviations from the theoretical profile of the toothing;
-through this method of toothing can't be processed parts arranged in "packet", only individual;
-tool diameter, ø = 8 [mm] being small, is resulting a pronounced wear in relatively short time.

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