TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics and Mechanics
Vol. 55, Issue I, 2012

APPLIED MATHEMATICAL ALGORITHM FOR GRINDING CYLINDRICAL GEARS WHITH PROFILE MODIFICATIONS

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Abstract: *In this paper we outline the use of modernized a NILES type gear grinding machine, by integrating numerical command equipment FANUC. After that we present a mathematical algorithm which was developed by us for programming this CNC gear grinding machine with the aim of generating different tooth flank involute sections.*
Key words: *CNC gear grinding machine, teeth modified profile, cylindrical gears, mathematical algorithm*

1. INTRODUCTION

Gears are indispensable machine elements that can be found from the practical mechanical wrist watch to the large multi-megawatt wind turbine, and let's not forget about the automotive industry, machine tools or general gear boxes. The total market is very difficult to estimate, but in any case it is a several billion € business [1] Gear with involute teeth are among the most important components of efficient modern transmissions techniques [2] A wind turbine is one of the—if not the most—demanding applications for a gearbox [3]
With the purpose of manufacturing high precision gears with different profile modification and constructive parameters our team in collaboration with EMSIL TEHNTRANS Oradea and UNIO Satu-Mare modernized a NILES type gear grinding machine, by integrating numerical command equipment FANUC. For obtaining the necessary parameters for programming different grinding process phases, it was necessary to develop a series of algorithms that hold in to about not only the teeth geometrical characteristics but also the machine movement command possibilities. After experimental proofing and testing the algorithm was integrated in current manufacturing at UNIO Company. In this paper we present the main novel elements of the algorithm and its applicability.

2. CNC GEAR GRINDING MACHINE PRESENTATION

As we mentioned in the introduction the machine was developed by modernizing a NILES type machine. The necessary movements for manufacturing and coordinate axis orientation can be seen in figure 1.

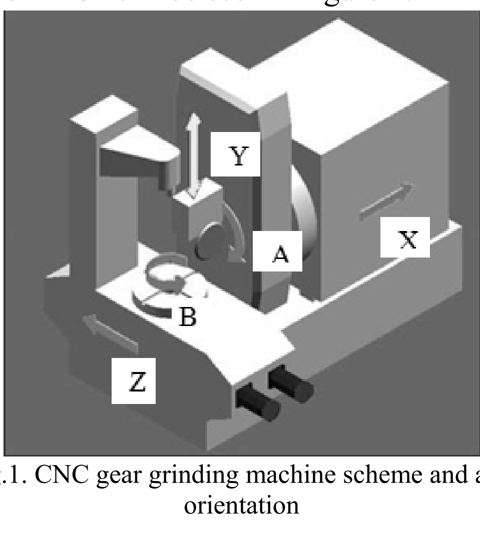

Fig.1. CNC gear grinding machine scheme and axis orientation

For involute spur gear profiles' grinding it is necessary to have a numerical commanded **B** and **Z** axis. For involute helical gear grinding it is necessary to have a numerical commanded for **Z** and **A** axis. In case of modified profile gears, the teeth sections are realized by involute curves with different parameters. At the machine programming we must introduce the effective value of the distance that has to be covered on the **B** and **Z** axis directions. Taking in to account the diversity of gears that had to be grinded it was necessary to elaborate a set of algorithms, which are listed below:

- **A1** algorithm: for spur gears with $R_f \leq R_b \cdot \cos\alpha_t$;
- **A2** algorithm: for spur gears with $R_f \geq R_b \cos\alpha_t$;
- **A3** algorithm: for gears with top profile modifications;
- **A4** algorithm: for gears with foot profile modifications;
- **A5** algorithm: for gears with top and foot profile modifications;
- **B1** algorithm: for with right-hand helical teeth gears;
- **B2** algorithm: for gears with left-hand helical teeth right-hand helical teeth;

For all the above algorithms it was applied the version of grinding with different value of pressure angles with the same grinding wheel. In this paper we will present only the main parts of the A5 algorithm. Also this paper comes in addition to a previous paper we wrote to and is accepted to be published in the XXVI. microCAD International Scientific Conference proceedings, University of Miskolc, where we presented the A1 algorithm.

3. THE DEVELOPED MATHEMATICAL ALGORITM

In figure 3 we can see the graphical representation of the relative position between the left flank of the gear teeth space and the double conical grinding wheel, corresponding to the left tooth space flank grinding with tip and foot profile modifications. Where R_{qf} - is the radius of the circle on which we can find the point where the profile modification of the addendum of the tooth starts, respectively R_q - is the radius of the circle on which we can find the ending point of the profile modification of the foot segment.

$\Delta\alpha_a$ and $\Delta\alpha_f$ - are the top respectively the foot profile modifications of the tooth in mm.

The profile grinding for one teeth space flank can be divided in several phases as listed in the table1.

Table 1

The profile grinding phases.

Nr.	**Profile grinding phases**
0	Center alignment in the tooth gap
1	Rotating in the position at the beginning of the left flank
2	Eliminating the clearance between the grinding wheel and the left flank of the teeth space
3	Grinding of the left teeth space flank
4	Rotating in the position at the beginning of the right flank of the teeth space
5	Eliminating the clearance between the grinding wheel and the right flank of the teeth space
6	Grinding of the right teeth space flank

The grinding process starts by rotating into position with the angle ϕ given by the following expression, after removing the clearance. And a translation along the axis **Z** with ***b*** into ***M₀*** . After a series of calculations the main parameters are:

$$\phi^* = \frac{\sqrt{R^2 - R_b^2} - \frac{\pi \cdot m}{4} \cdot \cos\alpha}{R_b} + \Delta\varphi_f \tag{1}$$

$$b^* = \frac{\left(\sqrt{R^2 - R_b^2}\right)}{\cos\alpha} - \frac{\pi \cdot m}{4} + \frac{\Delta\alpha_f}{\cos\alpha} \tag{2}$$

For the grinding of the left teeth space flank foot profile segment:

$$\varphi_{qf} = \varphi_1 + inv\alpha_{qf} \tag{3}$$

$$l_{qf} = \frac{1}{\cos\alpha}\left[\Delta\alpha_f + \sqrt{R_{qf}^2 - R_b}\right] \tag{4}$$

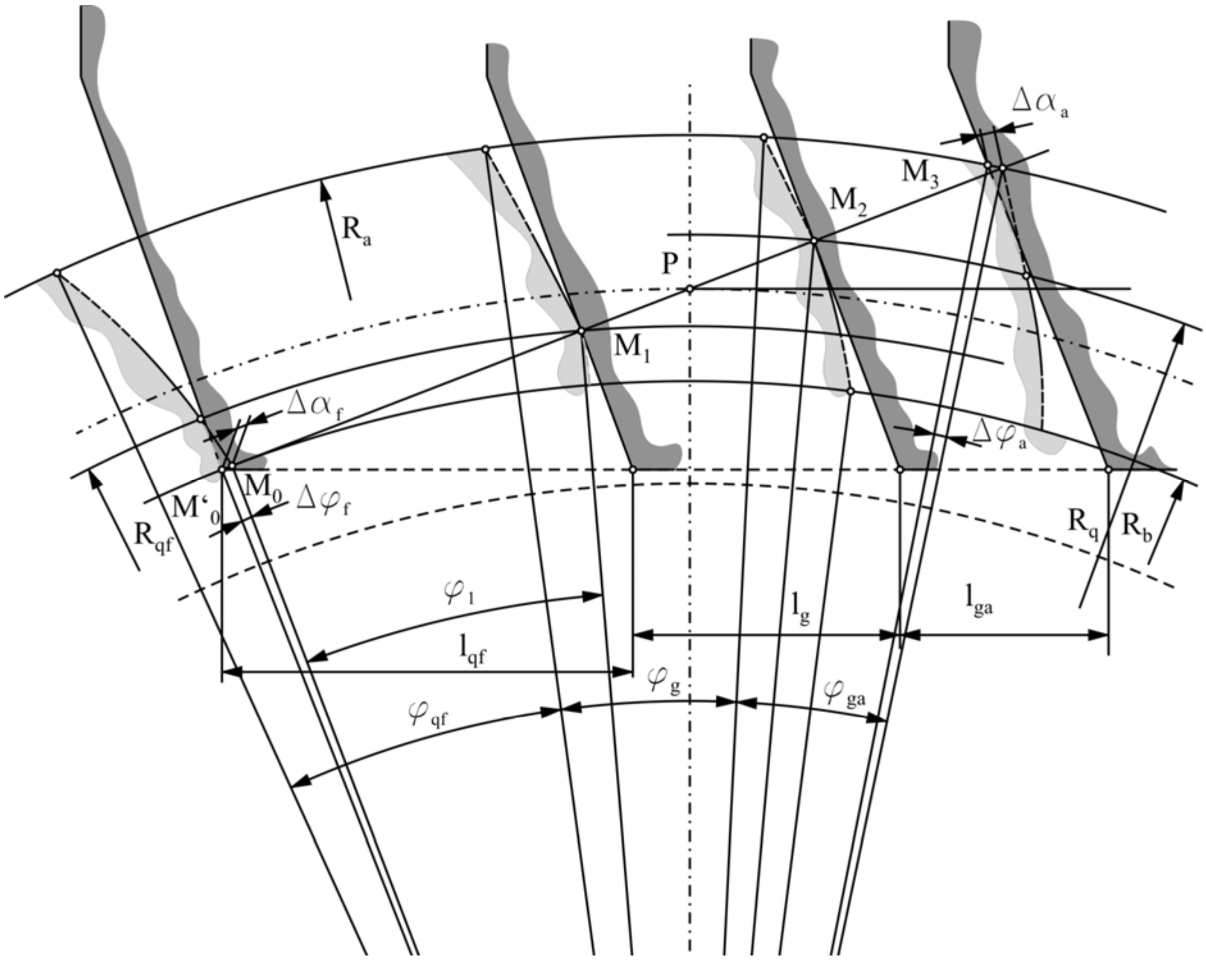

Fig.3. Graphical representation of the relative position between the technologic systems elements at the left tooth gap flank grinding of gears with top and foot profile modifications;

For the middle segment:

$$\varphi_g = \arccos\frac{R_b}{R_g} - \varphi_1 - inv\alpha_{qf} + inv\alpha_g \quad (5)$$

$$l_g = \frac{1}{\cos\alpha}\left[\sqrt{R_g^2 - R_b^2} - \sqrt{R_{qf}^2 - R_b^2}\right] \quad (6)$$

For the top segment:

$$\varphi_{ga} = \arccos\frac{R_b}{R_g} + inv\alpha_a - \varphi_{qf} - \varphi_g - \Delta\varphi_a \quad (7)$$

$$l_{ga} = \frac{1}{\cos\alpha}\left[\sqrt{R_a^2 - R_b^2} - \sqrt{R_g^2 - R_b^2} - \Delta\alpha_a\right]. \quad (8)$$

After grinding the top segment of comes the grinding of the right teeth space flank is idem to the left teeth space flank. The movement from the left to the right teeth space flank is given by:

$$\Delta\varphi^* = \Delta\varphi_a + \Delta\varphi_f + \frac{\sqrt{R_a^2 - R_b^2}}{R_b} - 2tg\alpha + \frac{\pi}{z} \quad (9)$$

$$\Delta b^* = R \cdot \Delta\varphi^* \quad (10)$$

4. CONCLUSION

With the presented algorithm we can determine very precise the values of the parameters necessary for programming of gear grinding, determined after different standards (STAS, DIN, AGMA, etc.). The large number of experimental results has highlighted the faultlessness of the method. After the measurements was found that the gears witch have been manufactured using the elaborated method are included in the range of precision classes 5...7. As a repercussion the most important requirements such as low functioning noise, resistance to micro pitting are reached.

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ALGORITM MATEMATIC APLICAT LA RECTIFICAREA ROTILOR DINTATE CILINDRICE CU MODIFICARI DE PROFIL

Abstract. In scopul fabricatiei roților dințate de precizie cu diferite modificări de profil şi parametri constructivi, colectivul nostru, în colaborare cu firmele EMSIL TEHNTRANS Oradea si UNIO Satu-Mare a modernizat o maşină de rectificat roți dințate tip NILES, prin echiparea cu comandă numerică FANUC. Pentru obținerea parametrilor necersari programării diferitelor faze ale procesului de rectificare, a fost necesară elaborarea unor algoritmi care țin cont atât de caracteristicile danturii cât şi de posibilitățile de comandă a mişcărilor maşinii. După testare şi experimentare algoritmul a fost introdus în fabricația curentă la firma UNIO. În lucrare prrezentăm principalele elemente de noutate ale algoritmului şi modul de utilizare al acestuia.

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