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MEASUREMENT OF THE TOOTH PROFILE AND SURFACE ROUGHNESS OF CURVED FACE WIDTH SPUR GEAR

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ABSTRACT

The paper analyses the tooth surface quality and precision for the plastic curved face width spur gears, with modified geometry. Due to the complex geometry of the gear teeth, that makes the design of a die difficult, the gears are cut on a milling machine. The generating method proposed by the authors leads to a variable tooth section along the gear face width. Therefore, an investigation on the tooth flanks geometry is necessary in order to compare the tooth profile with the standard involute. The results of the measurements showed that the gear tooth profile was closed to the involute, suitable for the plastic gears. Manufacturing the gears with a single point cutter and a manual feed, with no lubrication, the roughness of the tooth flanks surfaces is also necessary to be investigated.

Keywords: Curved face width gears, Plastic gears, Involute profile, Roughness

1. Introduction

Curved face width spur gears are not very popular for the gears industry. Due to their complex geometry, the design of the gears is difficult and changes with the generating method and cutting tools. Against this limitation, the advantages of the curved face width gears are the higher contact ratio and higher resistance compared to the standard spur gears. The only reference known by the authors, regarding the study of the gear geometry, rating and manufacture, is a russian book, published by Sidorenko (1984). Also the attempts in gears manufacturing, developed at the University of Galaţi, were useful in gears geometry and particular operating conditions understanding.

Based on this experience, the authors proposed an original method for gear cinematic generation leading to a modified geometry of the gear teeth. The double curvature of the tooth flanks and the variable tooth height. The benefits of the modified tooth geometry make the gear a suitable candidate for manufacture from non-metallic material. Together with developments in material and moulding techniques, the modified gear geometry could increase the power transmission level of the plastic curved face width spur gears.

The cinematic method proposed for the gear generation rises questions about the tooth profiles along the face width. The authors, using numerical and solid modelling methods developed a theoretical investigation on the tooth profile. This paper investigates the tooth flanks for a manufactured plastic gear, cut on a milling machine, with a single point cutter. The investigation is focused on the tooth shape and flanks surface quality.

2. Tooth profile

2.1. Gear tooth generating process

Figure 1 shows a diagrammatic illustration for the process of curved face width spur gear manufacture when the cutters used for the tooth concave flank (fig.1a) and for the tooth convex flank (fig.1.b) are gear mid-facewidth positioned. The normal sections of the cutters show straight lines for the imaginary rack-cutter flanks, with zero pressure angle.

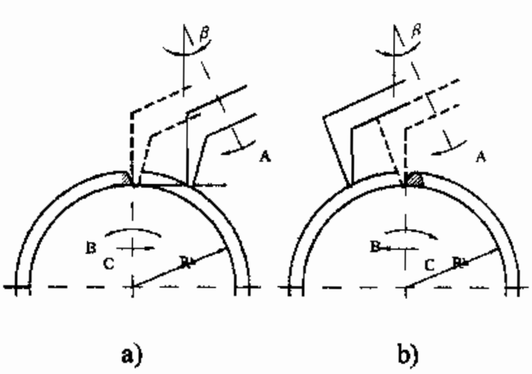


Figure 1. Tooth concave (a) and convex (b) flanks generation

The gear tooth generation process is based on the following kinematics: the cutting tool performs rotational motion (A) about its inclined axis and the gear being generated is rotated about its axis (B) while the imaginary rack-cutter is provided with translational motion (C) in order to obtain the rolling motion required for involute tooth form generation.

1.1. Measurements of tooth profile

Due to the cinematic method for the gear generation, with the cutting tool rotating about its inclined axis, it is obvious that there is no involute for the tooth flanks profiles along the gear face width, except the gear mid-section. Although plastic gears are not very sensitive to the gear tooth profile, there are still limits in tooth shape and dimensions required by a proper mesh.

1.1.1. Machine set-up

The tooth profile was measured on a Ferrari co-ordinate measuring machine. The CMM run a program whereby it "felt" its way around the contour of the tooth, in a given plane, recording the co-ordinate of each contact point.

Before starting measurements, the CMM must be initiated so that it knows exactly what the radius of the probe is and where it is positioned relative to the machine's built in error map. The next step is to set the origin to be the centre of the gear, the working plane to be parallel to the gear top surface and the X axis direction to be along the gear hole.

1.1.2. Tooth profiling

The program that profiles the teeth is loaded and the test parameters are entered. The probe is moved to a start position on the tooth flank and shown which direction to begin probing in (fig.2).

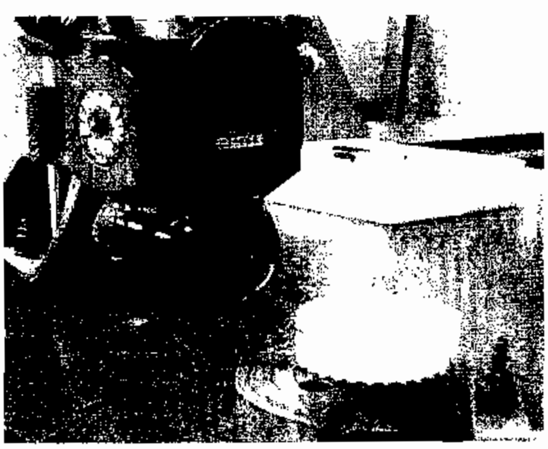


Figure 2. Tooth profiling

The probe moves forwards very slowly, perpendicular to the probing direction until contact with the tooth surface is made, then it backs away by 0.5 mm. It then traverses 0.3 mm in the desired direction and moves forward again. When the probe makes a new contact, it calculates a new probing direction, tangential to the two last contact points, and backs away perpendicular to the new direction and traverses another 0.3 mm, and so on. The final profile consists normally of around 50 or 60 points covering one entire tooth and parts of the flanks of the teeth each side.

1.1.3. Metrology results

The data captured from the CMM was exported to AutoCAD where it was superimpose with a computer generated ideal tooth form of standard proportions with 2 mm gear modulus, 30 number of teeth and 20° pressure angle.

Figure 3 shows the measured tooth profile at gear mid face width section. It can be seen that there is an involute for both concave and convex flanks profiles. The real tooth appears thicker than the ideal tooth. The drawn base and dedendum circles show that there are errors in tooth generation, due to the specific designed installation for gear cutting. So, the whole depth, higher than its theoretical value, and the undercutting shown indicate that the cutting tool was not right positioned.

Figure 4 shows the tooth section measured 10 mm away from the gear half face width. The real tooth profile is still closed to a standard involute, drawn for a different base circle, and the tooth high is reduced as designated.

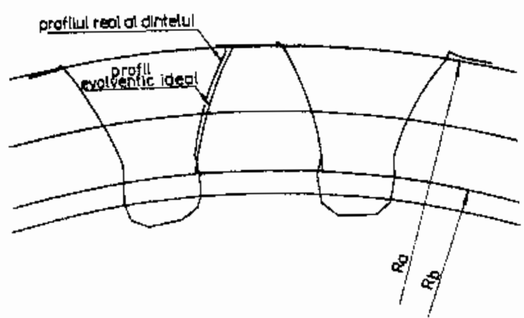


Figure 3. Tooth profile in a mid-facewidth section

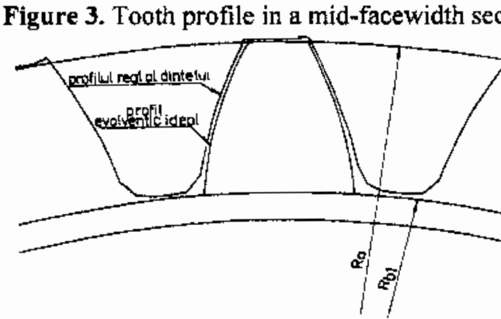


Figure 4. Tooth profile at 10 mm away gear centre

3. Surface roughness

The tooth flanks surfaces roughness is important for the gears operating conditions. For non-metallic gears, usually running with no lubrication, it becomes even more important due to the high friction induced.

In order to get the modified geometry for the curved face width spur gears, a different cutter was used for the concave and convex tooth flanks generation. To investigate the quality of the tooth surfaces, generated with a single point cutter and a manual tangential feed, measurements of the surface roughness are taken on a Talysurf machine.

3.1. Measuring flanks surfaces roughness

The Talysurf machine is normally used to measure surface roughness of a horizontal surface. Due to the double curvature of the curved face width spur gear tooth flanks, the measured area will be a very small one, taken near the tip of the tooth, to approximate a horizontal surface. The both concave and convex flanks were investigated on the programmed area and the incremental displacement of the machine stylus collected an array of height data points, defining the surfaces (fig.5).

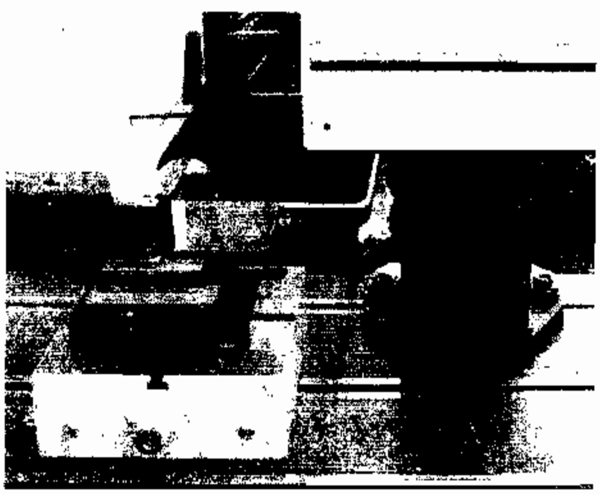
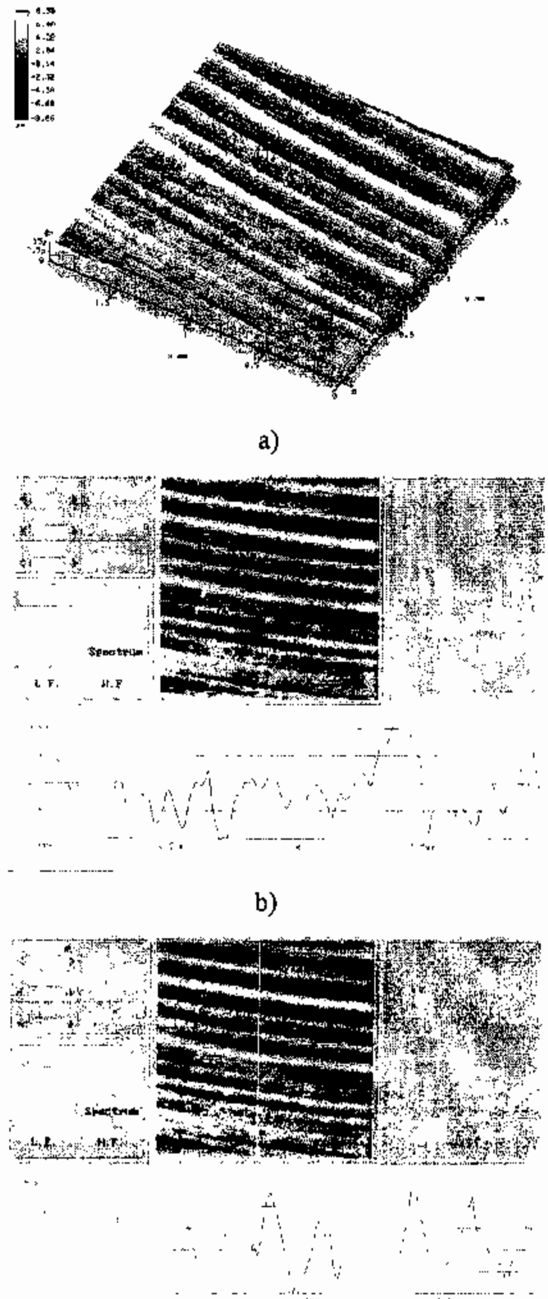


Figure 5. Measuring flank roughness

3.2. Processing the data

Once the data is collected, it is processed to produce the surface roughness statistic. The statistics normally quoted are the total peak to valley height (B_t), the average roughness (B_{ek}) and the average peak to valley roughness (B_a). The data is then exported to a 3D mapping program called Toposurf, which can produce an image of the surface with a magnified z-axis. Figure 6 shows a 3D image (fig.6.a) and two topographical maps of the sections measured along the gear face width (fig.6.b) and along the tooth height (fig.6.c), within the programmed area on the gear convex flank. Figure 7 shows the results of similar roughness measurements taken on the gear tooth concave plane. From both figures it can be seen that the physical and statistic roughness parameters have acceptable values for a cutting process using a single point cutter, no lubrication and manual transversal feed. On the 3D map of the measured surface, it clearly appears the cutting direction and the number of cuttings. The tooth concave flank shows a rough surface, with higher values for the roughness parameters, from 11 to 17 μm for the total peak to valley height and about 2 μm for the average roughness.



a) b) c)

Figure 6. Gear tooth flank surface roughness

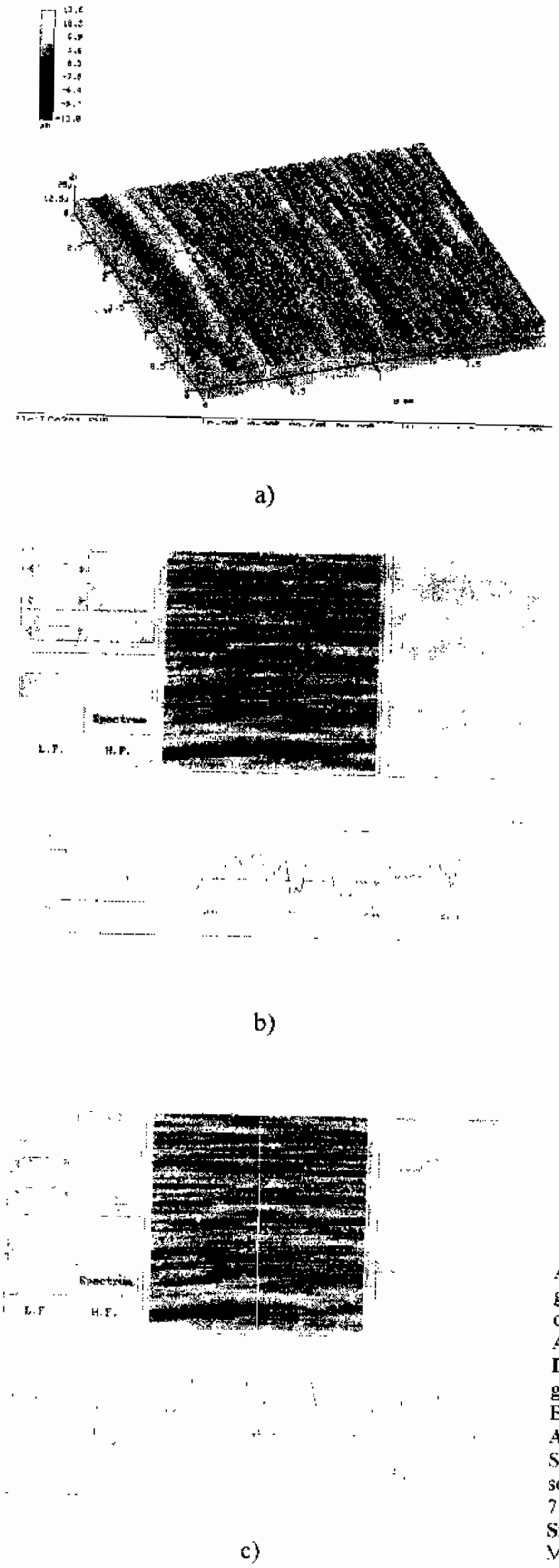


Figure 6. Gear tooth convex flank surface roughness

4. Conclusions

(1) The authors proposed a new geometry for the curved face width spur gears, with a variable tooth height along the gear face width, in order to increase the tooth resistance, to reduce the sliding friction and to improve the lubrication.

(2) Usually, plastic gears are manufactured by injection moulding. Due to their complex geometry, the plastic curved face width spur gears, with modified geometry, were manufactured by cutting on a milling machine. An original method for gear tooth cinematic generation was used, with tool rotating about its inclined axis.

(3) Due to the generation method, there is a proper rolling motion only at gear mid face section, leading to the standard involute shape for both convex and concave tooth flanks. In all other sections along the gear face width the tooth profile is not for an involute. Plastic gears are no so sensitive about the tooth profile errors, so the new geometry was designated for non-metallic gears.

(4) Tooth profile was investigated on a CMM and the measurements showed that the real tooth shape is not far from the theoretical involute, in the sections away from gear centre. Also, undercutting and thicker teeth were obtained due to the generating errors.

(5) Surface roughness is very important for non-metallic gears operating conditions. Measurements of surface roughness were taken on a Talysurf machine for both convex and concave tooth flanks. Acceptable values for the physical and statistic roughness parameters were found.

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O INVESTIGARE A FLANCURILOR DANTURII ANGRENAJULUI CILINDRIC CU DINŢI CURBI, DIN MATERIAL PLASTIC

(Rezumat)

În această lucrare este analizată calitatea şi precizia angrenajului cilindric cu dinţi curbi şi geometrie modificată, din materiale plastice. Datorită geometriei complexe a danturii care face dificilă realizarea unei matriţe corespunzătoare, angrenajul a fost prelucrat prin aşchiere pe o maşină de frezat. Metoda de generare folosită la prelucrare a determinat obţinerea unei secţiuni variabile a dintelui, pe lăţimea roţii. De aceea a fost necesară o cercetare a geometriei flancurilor danturii cu scopul de a compara profilul real al dintelui cu profilul evolventic. Rezultatele măsurărilor au arătat că profilul danturii este aproape identic cu profilul evolventic, corespunzător angrenajelor plastice. A fost de asemena necesar să se analizeze rugozitatea suprafeţei flancurilor, având în vedere că prelucrarea s-a realizat cu un singur punct de tăiere a aşchiei, cu avans manual şi în absenţa fluidului de răcire.

MESURE DU PROFIL DE DENTS ET DE LA RUGOSITÉ DE SURFACE DES ENGRENAGES CYLINDRIQUES À DENTURE COURBE

(Résumé)

Le papier analyse la qualité extérieure et la précision des dents pour les engrenages cylindriques à denture courbe, en plastique, avec la géométrie modifiée. En raison de la géométrie complexe des dents, les engrenages sont coupées sur une fraiseuse. La méthode proposée par les auteurs mène à une section variable de dent le long de la largeur de la roue dentée. Par conséquent, une recherche sur la géométrie de flancs des dents est nécessaire afin de comparer le profil de dent au profil théorique. Les résultats des mesures ont prouvé que le profil de dent a été bien coupé, d'une façon satisfaisante pour les engrenages en plastique. Fabriquant les engrenages avec un coupeur simple et une alimentation manuelle, sans la lubrification, la rugosité des surfaces de flancs des dents est également nécessaire pour être étudiée.