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An Automatic Drawing Spur Gears Based on AutoCAD Program

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ABSTRACT

In this research, a computer-aided drawing system of spur gear was developed. An auto LISP programming language embedded within the AutoCAD design package was used to develop a new program to create a 3D model of a spur gear in two main stages. In the first stage, the developed program of spur gear allows automatic 2D spur gear drawing generation using the technique that depends on the half tooth thickness at the pitch diameter. In the second stage, inner profiles of a 2D spur gear views are used to create a 3D model of a spur gear. The developed program helpful for the user in drawing the spur gear modelling, due to less work and time to be spent when compared with the conventional approach, and it also improves a high degree of accuracy of spur gear modelling. The spur gear resulting from the prepared gear drawing system can also work with other popular CAD software.

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تصميم الشكل الهندسي للتروس الاسطوانية المستقيمة بالاعتماد على برنامج الاوتوكاد

نجاة نجم الدين حميد- قسم هندسة تقنيات ميكانيك القوى- الكلية التقنية الهندسية/ كركوك- الجامعة التقنية الشمالية

الخلاصة

في هذا البحث ، تم إعداد نظام الرسم بمساعدة الحاسوب للتروس الأسطوانية المستقيمة. وقد أعد برنامج البحث باستخدام لغة الاتوليسب المبني تحت بيئة نظام برنامج الاوتوكاد الهندسي .النظام المعد احتوى على جزأين أساسيين، يتناول الجزء الأول إنشاء نظام مؤتمت لعملية توليد الشكل الهندسي للتروس الأسطوانية المستقيمة ثنائية الأبعاد بالاعتماد على مبدأ معرفة نصف سمك السن عند دائرة الخطوة. أما الجزء الثاني فهو يمثل إنشاء نظام مؤتمت لعملية توليد الشكل الثلاثي الأبعاد للتروس الأسطوانية المستقيمة .النظام المعد يوفر الوقت والجهد لإتمام رسم التروس الأسطوانية المستقيمة.وكذلك وفر إمكانيات عالية في إظهار الشكل الهندسي لأسنان التروس بصورة دقيقة وتفصيلية. بينت النتائج من ان التروس الأسطوانية المستقيمة الناتجة من نظام الرسم المعد له القدرة على العمل مع برامج التصميم الشائعة الأخرى.

الكلمات الدالة: اوتوكاد, لغة الاتوليسب, التروس الاسطوانية المستقيمة.

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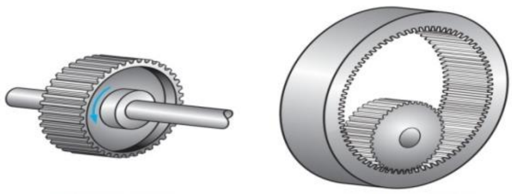
1. INTRODUCTION

Spur gears are designed to transmit motion and power between parallel shafts. There are two basic types of spur gears: external and internal spur gears shown in Fig.1. The advantages of spur gears over other types are their low manufacturing cost, simplest geometry design, and ease of maintenance. The disadvantages include less load capacity and higher noise levels than other types. Spur gear teeth are straight and parallel to the gear shaft axis [1]. To make gears operate smoothly with a minimum of noise and vibration, the curved surface of the tooth profile uses a definite geometric form. The most common form in use today is the involute profile [2]. Researchers have consistently investigated in order to design a 3D spur gear drawing under optimal conditions. The following are some published researches related to the subject of the present research. Oladejo and Ogunsade [3] present a computational and drafting methods, self-determination of geometric parameters and drafting of spur gears to a specific configuration. The model is based on programming language embedded within the AutoCAD design package VBA (Visual Basic Applications), which provides programmatic control of AutoCAD through the Automation interface. Xin lei, et al [4] studied the AutoCAD software through the Auto LISP program and combined with AutoCAD modelling command, has realized the parametric modelling of the involute spur gear. Karma [5] started his research with visual basic 6 and MS access to the developed computer program for the design of spur gears. The developed system can be applied to gear industries making spur gear. Edward and Lucky [6] worked on a combined computational and graphical method for creating accurate standard involute gear tooth profile. The method utilizes the fact that for a specified spur gear module size, the half-angle subtended by a spur gear tooth at its base radius is fixed. All half-angles of the gear tooth between the base radius and addendum circle can be calculated from the contact and involute angles at discrete points. Using the offset function of AutoCAD software, points on the involute curve of the gear tooth were determined. To create the involute curve, the spline function of the software was used. Ming [7] presented the principle of applying the embedded development tool visual lisp in three-dimensional modelling of a straight toothed spur gear in the AutoCAD environment. Hongtao and Zhang [8] developed a collaborative CAD system using Auto LISP software, which implements the standard 2D straight teeth cylindrical gear parametric drawing on the AutoCAD platform. Suresh and Abu backer [9] Worked on generation 2D and 3D spur gears modelling. Microsoft office tool, the Excel spreadsheet software was utilized in determining the basic gear parameters and convert it into (X, Y, Z) coordinate of the involute curve in the excel format. An interactive computer graphics is able to generate accurate data and produce accurate 2D and 3D drawing based on SolidWorks software. Jayakiran and Pandu [10] Presented a method for CAD model of a spur gear design using AGMA (American Gear Manufacturers Association) standards for design. The developed method is based on the integration of modelling CAD software SolidWorks with visual Basic. The results of this investigation led to the development of a computer program with visual basic to compute parametric CAD modelling system for spur gear design and plot with SolidWorks software the spur gear model based on AGMA standards. The different aspects of the present study compared to other studies are developing a computer program to generate automatic 2D spur gear teeth geometry using the technique depends on the half tooth thickness, also reconstruction its 3D solid model by using the press pull command.



(a). External spur gear   *(b).*Internal spur gear

Fig. 1. Spur gears [1]

2. SPUR GEAR PROFILE

Drawing an actual involute profile for a spur gear in the metric system requires several mathematical formulas, normally begins with selecting three parameters, the number of teeth, module, and pressure angle. These three basic spur gear parameters determine all other parameters those define the spur gear profile that is given below.

$$R_s = \frac{1}{2}\ mz \qquad (1)$$

$$R_a = \frac{1}{2}\ m\,(z+2) \qquad (2)$$

2.1. Tooth Thickness

The tooth thickness at any radius is defined as the arc length between the face of a singular tooth that is measured on the circumference of the circle at this radius ***(R)***. When we know the tooth thickness at standard pitch radius, it can be calculated at any other. The space width at the radius (***R)*** is defined as the distance between two teeth that are measured on the circumference of a circle of radius ***(R)***, where the summation of tooth thickness and the space width is equal to the circular pitch, as shown in Fig.2 [11]. On the other hand, the width of the space at a pitch radius equals tooth thickness at the pitch radius for uncorrected standard tooth [12, 13].

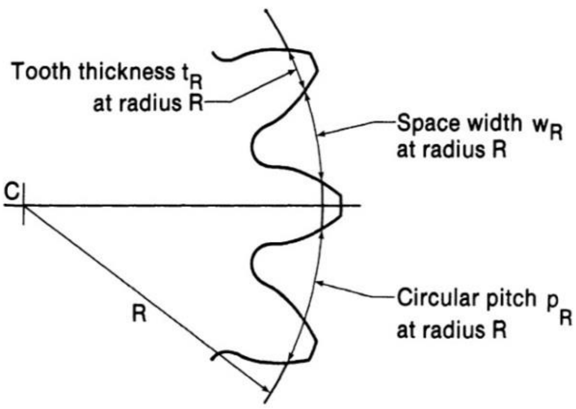


Fig. 2. Tooth thickness [11].

Fig. 3, shows an involute curve has been generated from the base circle of radius R_b . ***(A)*** and ***(B)*** are two points on this involute at distances of R_A and R_B respectively from the base circle center (O). From geometry, we get The following relations.

$$R_b = R_A \times \cos\phi_S = R_B \times \cos\phi_R \qquad (3)$$

Whence we get

$$\cos\phi_R = \frac{R_A}{R_B}\cos\phi_S \qquad (4)$$

From Eq. (4) we can determine the pressure angle at any radius on the involute in relation to the parameters of another known radius. If the circle passing through ***(A)*** happens to be the pitch circle the diameter of which is known, then for the standard system [13].

$$\cos\phi_R = \frac{R_S}{R_B}\cos\phi_S \qquad (5)$$

A gear tooth thickness is shown in Fig. 4, with points ***(E)***, ***(A)***, and ***(B)*** on the involute tooth profile at radius R_b, ***Rs*** and ***(R)*** respectively. By assuming the tooth thickness on pitch radius (t_s) is known, a formula for tooth thickness (t_R) at the radius (***R***) can be derived through the following procedure:-

Finding the polar coordinate (θ_R) of point ***(B).***

θ_R = angle ***(FOB)***

Angle ***(FOB)*** =angle ***(FOA)*** + angle ***(AOE)*** – angle ***(BOE)***

Where the (***BOE)*** is equal to involute function ***inv*** ϕ_R, and since the profile angle at the standard pitch radius is equal to the pressure angle (ϕ_S), the angle ***(AOE)*** is equal to ***inv*** ϕ_S. Thus, the expression for (θ_R) can be written.

$$\theta_R = \frac{t_S}{2R_S} + inv\,\phi_S - inv\,\phi_R \qquad (6)$$

Finally, after found the polar coordinate (θ_R) of point (A), the formula of the tooth thickness at the radius (***R***) can be expressed as:

$$t_R = 2R\theta_R = R(\frac{t_S}{R_S} + 2(inv\,\phi_S - inv\,\phi_R)) \qquad (7)$$

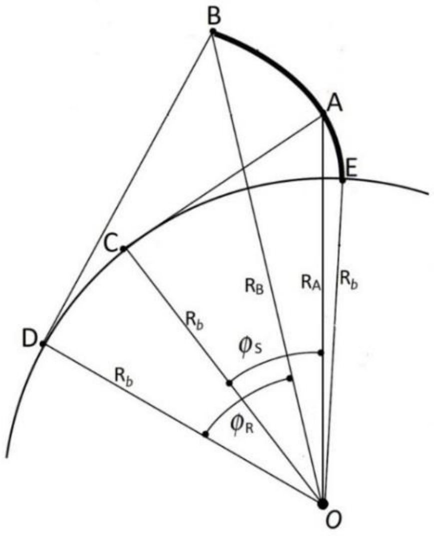


Fig. 3. Involute profile [14]

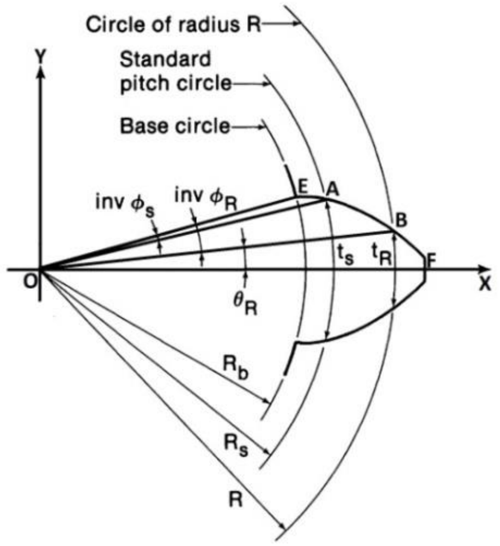


Fig. 4. Gear tooth thickness [11]

3. A DEVELOPMENT OF THE SYSTEM

The computer-aided drawing of spur gears system was proposed and developed, using the AutoLISP programming language embedded within the AutoCAD design package. It consists of two main stages. In the first stage, automatic ***2D*** spur gear drawing generation using the technique depends on the fact that when you know the tooth thickness at standard pitch radius, you can calculate it at others radius. In the second stage, inner profiles of ***2D*** spur gear views are extruded using the press pull command. The flow chart of the development system is shown in Fig.5.

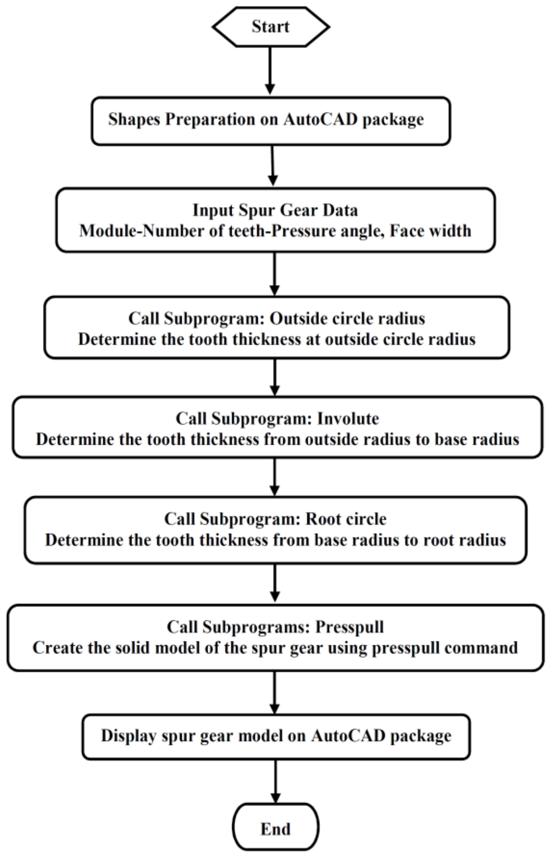


Fig. 5. Flow chart of the developed system

3.1. *The system development procedure*

The following are the procedures to draw a complete spur gear profile using AutoLISP programming language embedded within the AutoCAD design package: -

3.1.1 Shapes Preparation on AutoCAD package

After AutoCAD program is initiated select> New> acadiso template. Then in Tool > Auto LISP> Load Applications> Load/Unload Applications dialog box >select an Auto LISP (.lsp) file.

3.1.2 *Entering the Spur Gear parameters by the user*

In this section, the value of the spur gear parameters, such as module, number of teeth, pressure angle, and face width should be entered manually. Fig. 6, provides the sample inputs for the drawing of the spur gear.

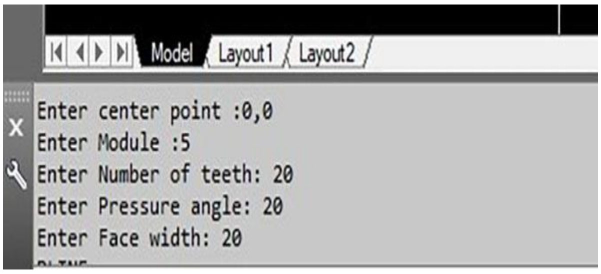


Fig. 6. Sample inputs for the drawing of spur gear

3.1.3 *Draw an involute curve*

In this section, coordinates point ***(F)*** on the involute curve can be calculated based on formulating that are given below:

$$x = R_a \tag{8}$$

The tooth thickness at the pitch radius is given by:

$$ts = \frac{\pi\, m}{2} \tag{9}$$

Referring to Eq. (5) the $\emptyset_a$ is given by:

$$\cos \emptyset_a = \frac{R_S}{R_a} \cos \emptyset_S \tag{10}$$

Referring to Eq. (7) the outside circle radius tooth thickness ***(t_a)*** at pressure angle **20°** is given by:

$$t_a = R_a \left(\frac{ts}{R_s} + 2(inv\, 20° - inv\, \emptyset_a)\right) \tag{11}$$

So, (**y**) coordinates can be obtained as:

$$y = \frac{t_a}{2} \tag{12}$$

These processes then are repeated for other coordinates of the involute curve at a finite number of positions within the range from outside circle radius to the base circle radius to define coordinates of each point on the involute curve and connecting them with a polyline command function of the AutoCAD design package. The complete profile of the one side first tooth is presented in Fig. 7.

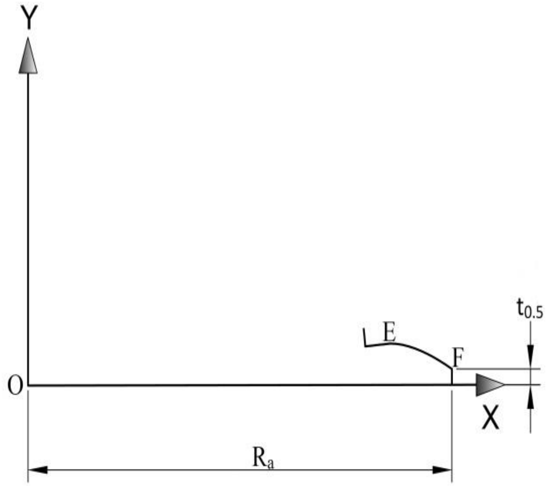


Fig .7. The complete profile of the one side first tooth.

3.1.4 Program automatic replicate another half of tooth curve using Mirror command about the centerline. The complete profile of the first tooth is presented in Fig. 8.

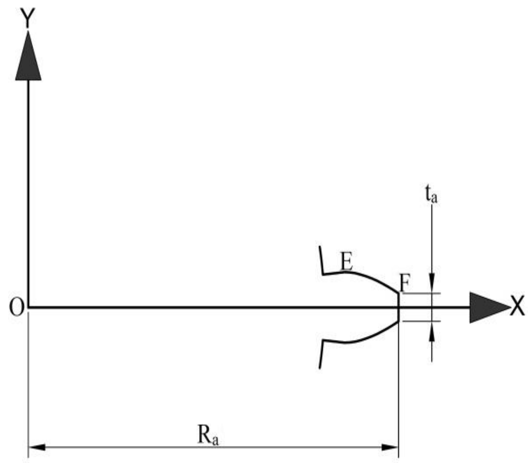


Fig .8. The complete profile of the first tooth.

3.1.5 Program automatic rotate the first tooth of the spur gear and add a number of teeth, using the polar option of the array command to form all the teeth of the spur gear. The complete ***2D*** spur gear with the involute tooth profile is illustrated in Fig. 9.

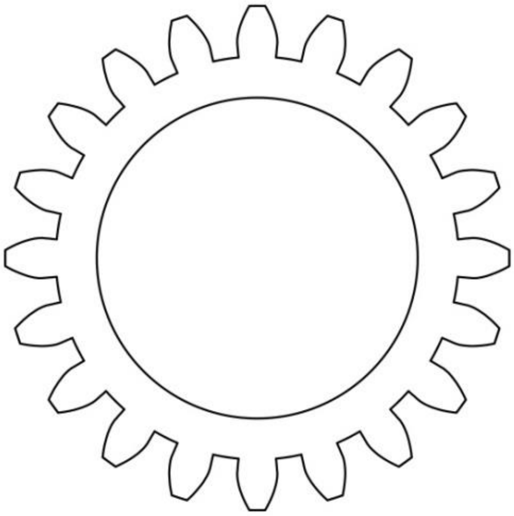


Fig .9. The generated 2D spur gear model with the developed computer system

3.1.6 Last operation, program automatic generation 3D spur gear using the Press pull command of the AutoCAD design package from 2D spur gear views in Fig. 9. The complete 3D spur gear is illustrated in Fig. 10.

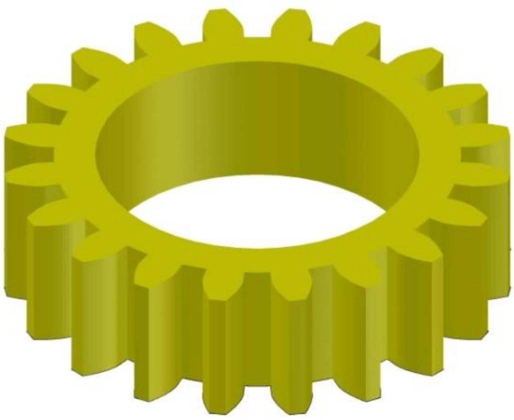


Fig .10. The generated 3D spur gear model with the developed computer system

4. RESULTS AND DISCUSSION

The aim of this paper is to develop a computer-aided drawing system to enable geometrical shape drawing of spur gears. Fig. 6, provides the value of the inputs of the spur gear parameters, such as module, number of teeth, pressure angle, and face width should be entered manually. Using this input data, the developed system automatically calculates (x, y) coordinates of each point on the involute curve at a finite number of positions within the range from outside circle radius(R_a) to the base circle radius (R_b) and connecting them with a polyline command function of the AutoCAD design package to generate a geometrical shape of 2D spur gear model as shown in Fig. 9. The paper also generates a high degree of accuracy shape of 3D spur gear modelling using the presspull command function of the AutoCAD design package as shown in Fig. 10, this is a simple and quick method to generate an extruded shape from a closed boundary.

5. CONCLUSIONS

This paper concludes that, the software Which was developed was helpful for the user in the drawing an actual form of 2D and 3D spur gear model with different modules and number of teeth, due to less work and time to be spent when compared with the conventional approach. and it also improves a high degree of accuracy of spur gear modelling. The spur gear resulting from the prepared gear drawing system can also work with other popular CAD software such as Autodesk inventor, SolidWorks, etc.

NOMENCLATURE

m = Module (mm)

Ra = Outside circle radius (mm)

R_b = Base circle radius (mm)

R_S = Pitch circle radius (mm)

t_a = Tooth thickness at the outside diameter (mm)

t_S = Tooth thickness at the pitch diameter (mm)

$t_{0.5}$ = Half tooth thickness (mm)

Z = Number of teeth

$\emptyset_R$ = Profile angle at radius (R) (deg)

$\emptyset_S$ = Pressure angle (deg)

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