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Drafting of involute spur-gears in AutoCAD-VBA customized

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ABSTRACT

The design of efficient and reliable gearing mechanism is governed, among other factors, by its ability to withstand the frictional contact condition and high bending stresses experienced at the tooth root. One of the major impediments facing designers is the effective drafting of gears to required configuration. For involutes spur gears, the geometry is tedious and time-consuming; and the geometric complexity increases with helical, bevel and worm gears. This study presents a model developed by utilizing the integration of VBA technology built in AutoCAD for the drafting of spur gear to standard configuration. The design was based on full-depth involute gears of pressure angles 14½°, 20°, and 25°; with module ranging between 0.3 and 25 mm, and number of teeth varying between 12 and 60. The algorithm employed the conventional manual drafting techniques by navigating the IDE of VBA with AutoCAD objects, properties, methods, events, and application of errors handling techniques that will ensure smooth running of the model. The model was tested by physically comparing gear tooth template of the automated and manual techniques for three cases of 14-tooth spur gears with pressure angles 20° and modules 6, 8, and 10; and gave a good representation of the tested cases. The model was implemented for simulation of cases of varying modules and varying number of teeth to investigate the significance of module and pressure angle on the gear structure and tooth profile. The model's flexibility for simulation makes it a virtual prototyping tool that can enhance design, analysis and also makes it a veritable educational tool.

Keywords: Educational, spur gear, tooth-profile, drafting, AutoCAD-VBA.

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INTRODUCTION

There is an increasing demand for smooth gear transmission mechanisms as they constitute very important components in mechanical power transmission of machines, vehicles, elevators, and other automated devices. The process of designing such systems is both time and effort consuming due to numerous calculations, iterative stress analysis, and drafting of the gear. Meanwhile, existing software to adequately perform the three tasks are limited in terms of flexibility, availability and simplicity. This study is supporting learning and research exercises in the area of mechanical power transmission by presenting an automated drafting model for involute spur gear. This was developed by customizing AutoCAD using Visual BASIC for Application. VBA is a programming language that is included with many applications, such as MS Word, Excel, PowerPoint, Access and AutoCAD. It is a subset of Visual BASIC (VB) that allows for custom automation of the specific application that is built into. VBA inside AutoCAD allows closer integration to the drawing environment and development of application that better suit what is specifically required. It provides a simple way to customize AutoCAD, automate tasks, and program applications from within the package, (Finkelstein, 2007). The fundamental purpose of a mechanical drawing is to convey the exact shape and dimensions of an object. The shape of gear is not easy to draw as it what are known as involute curves as shown in Figure 1.

Several studies have been carried out with respect to automated-drafting of spur gears. Examination of such reveals flaws which justifies the need for this study. *eMachineShop*, in 1998, developed internet-based software to model spur gear. It is equipped with 3-D visualization of the model (Refaat and Meguid, 1995).

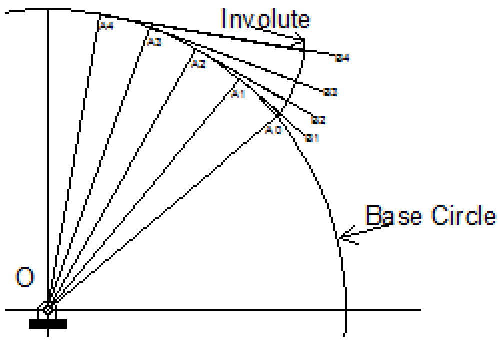

Figure 1. Involute curve.

Hexagon Software, Berling, Germany, in 2005, presented a CAD Software (ZARI+) for the design and drafting of spur gear, but it does not support 3-D visualization. In 2000, *Remco deJong* presented DrawGear Version 2.0. It was developed for drafting of spur gear. The visualization is limited to 2-D only (Nordiana et al., 2007). Artes and Pedrero (1994) presented a graphic method for the analysis of the design of spur and helical gears in 2-D. Cooley (1979) describes computer program which enable the user to define the rack geometry by interactive graphics, to examine the shape of tooth generated by such a rack and to compute such quantities as the area enclosed by meshing teeth for applications in the field of gear-pump design. The authors have proposed modification of geometry of spur gears and investigated the contact pattern and the transmission errors to recommend the appropriate amount of crowning. Based on the investigation, dynamic load of the crowned spur gear drive has been calculated which is helpful to predict the life of the designed gear drive. Computer programs for simulation of meshing and dynamics of the crowned spur gears have been developed (Khoshaba, 2007).

A numerical scheme is presented to simulate the meshing process of spur gears, based on the material point method (MPM). To allow engagements at successive contact points and subsequent separation between neighboring gear teeth, a contact procedure in a multi-mesh environment without using master nodes is proposed so that the no-slip contact constraint inherent in the existing MPM can be released. Individual drive members rotate around corresponding axes, through which simulated angular velocity transmission is in good agreement with the analytical solution. It appears from the simulation results presented here that the multi-mesh MPM could become a robust spatial discretization tool for gear design problems that involve large rotation, contact and separation (Seola and David, 1998). The authors propose: (i) enhanced computer program for simulation of meshing and contact of gear drives; (ii) application of computer program for analysis of worm gear drive; and (iii) advanced design of worm gear drive with reduced transmission errors and favorable bearing contact. The output of Tooth Contact Analysis (TCA) programmer: function of transmission errors, path of contact and bearing contact. The program is written in Visual Basic language and enables to combine numerical computation and graphical illustration. The improved design of worm gear drive is based on application of an oversized hob and modified worm generated by varied plunging of the generating tool. It is discovered that worm generation without tool plunging may cause positive transmission errors, unacceptable for favorable conditions of force transmission. Positive transmission errors are the herald of possible surface interference. A predesigned parabolic function of transmission errors is provided in order to absorb transmission errors caused by errors of alignment and reduce the level of vibrations, especially in the case of application of multi-thread worms. The investigation is accomplished for a worm-gear drive with the Klingelnberg type of the worm that is ground by a circular cone, but the proposed approach may be applied for other types of worm gear drives with cylindrical worms (Hu and Chen, 2003).

Gearing is the special division of Mechanical Engineering concerned with the transmission of power and motion between the rotating shafts. Gears not only transmit motion and enormous power satisfactorily, but can do so with very uniform motion. It is the best and the economical means of achieving this transmission. Gear teeth fails due to the static and the dynamic loads acting over it, also the contact between the two meting gears causes the surface failures. The gear fails without any warning and the results due to this failure are catastrophic. Since the requirements are broad and are of varying difficulty, gearing is a complex and diversified field of engineering. It includes gear mathematics, geometrical design, strength and wear, material, metallurgy, fabrication and inspection. Therefore for all the reasons mentioned, this work is of more practical importance. To get the gear of more durability we can use improved material, hardening the gear surfaces with heat treatment and carburization, shot penning can be done to improve the surface finish, to change the pressure angle by using asymmetric teeth, introducing the stress relieving features of different shape, changing the addendum of the spur gear and altering the design of root fillet are the other methods (Ashwini and Vijay, 2011).

In this paper an algorithm to describe the ideal spur gear profile is proposed. More precisely, the goal is to describe the point to point movement to be used within a CNC machine. Three parameters are the required algorithm input data: the modulus, the number of teeth and the pressure angle. The algorithm is based upon the equations of the circular head and root thickness. The involute of the base circle is used to draw the tooth. The algorithm can be translated into any machine language, (Reyes et al., 2008). This paper introduces the realization of 3D parametric modeling of involute spur gear with the

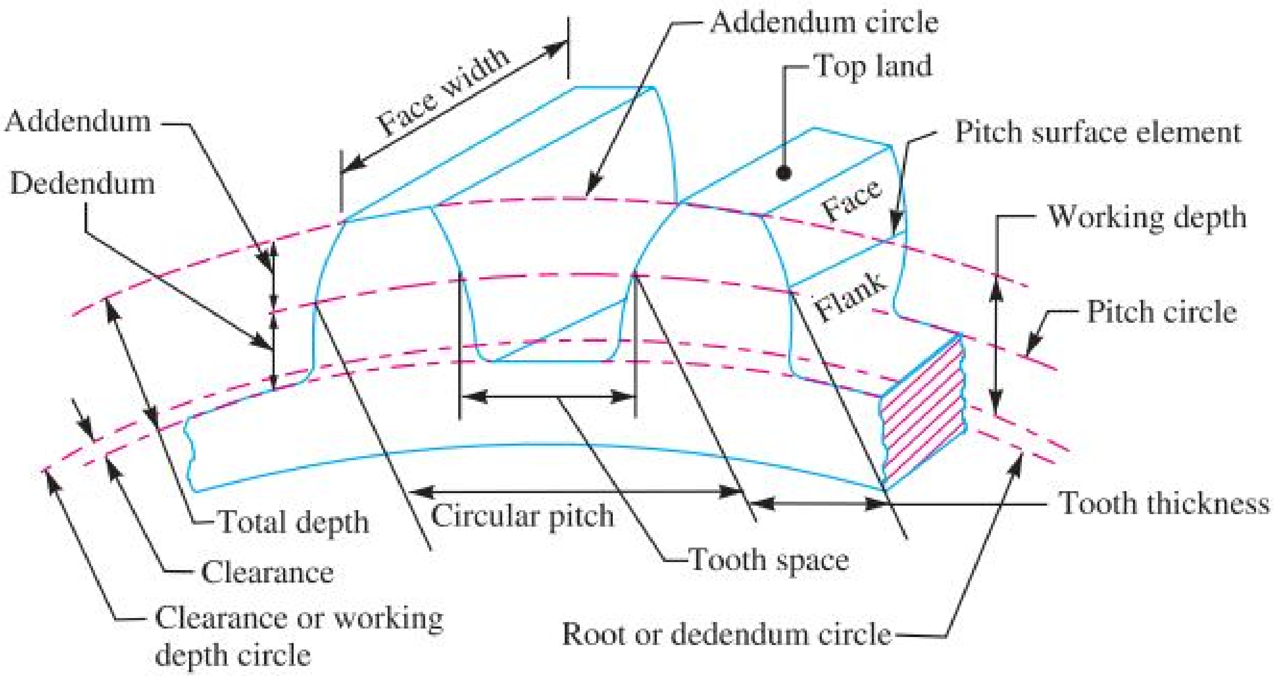

Figure 2. Nomenclature of spur-gear teeth.

use of VBA under AutoCAD 2000. With the input of gear parameters through screen dialogue, the programme can comprehensively deal with the relative design calculating, data processing and graph drawing, and create the 3D model of the gear. This modeling method is fast and accurate, which is an expansion to AutoCAD of the 3D modeling function (Qin and Shao, 2001). However, in this paper, a new method for drafting involute spur gear to required specification has been developed in AutoCAD-VBA customized environment. This will facilitates easy exportation to numerical packages for effective bending and contact stresses analyses.

GEOMETRY OF SPUR GEAR

Gears are toothed members that transmit speed and angular velocity from one shaft to another. They are used in a wide variety of applications, and are highly standardized as to tooth shape and size. They are the simplest of all gear types and represent the BASIC of the gear calculation theories. The basic requirement of gear-tooth geometry is the condition of angular velocity ratios that are exactly constant (Khoshaba, 2007). This requirement is satisfied by designing the gear tooth shape utilizing involutes curves. The terminology of spur-gear teeth is illustrated in Figure 2 (Seola and David, 1998). Important terms for spur gear drafting involve the following: addendum, dedendum, pitch circle diameter, root circle diameter, outside diameter, base circle diameter, circular pitch, and tooth thickness.

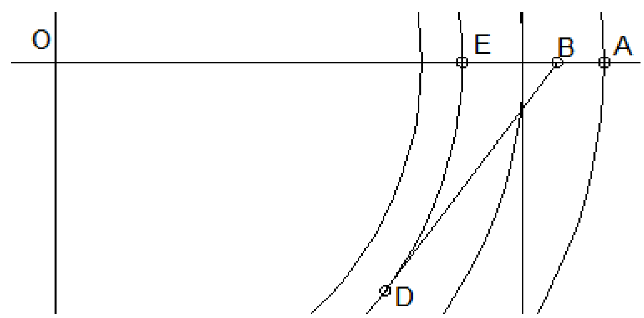

Figure 3. Making point D a tangent point to the base circle.

ALGORITHM OF SPUR GEAR DRAFTING BY UNWINS CONSTRUCTION

(i) Specification of basic geometric parameters of the required gear: coordinates of gear centers module, number of teeth, pressure angle, and tooth thickness.
(ii) Computation of other required geometric parameters for the drafting, radii of the pitch, addendum, dedendum, and base circles.
(iii) Drawing of the four BASIC circles and the pressure angle.
(iv) Mark points A and E, and locate point B such that *AB:BE = 1:2*. Then draw line BD such that point D is a tangent point to the base circle (Figure 3).
(v) Locate point F (Figure 4) by dividing line BD in such that *DF: FB = 1:3* (This is an effort to locate the centre of spur-gear profile).

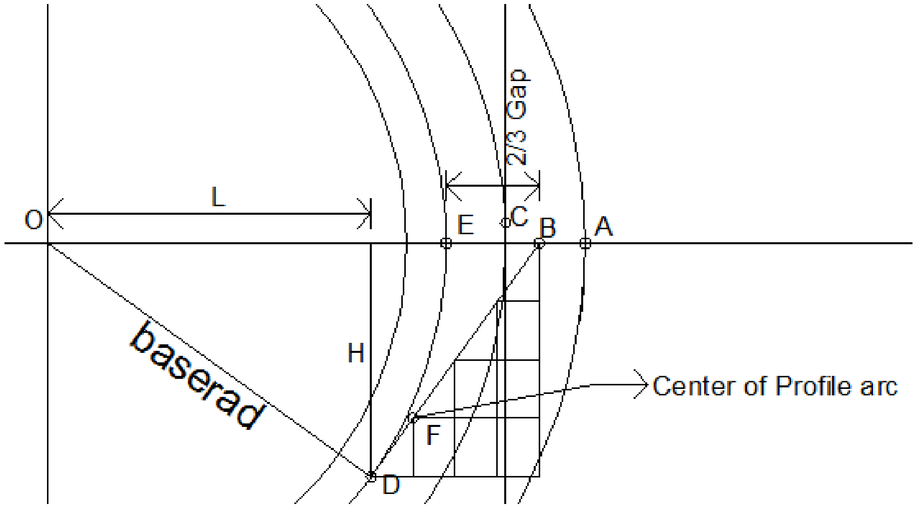

Figure 4. Locating the centre of spur-gear profile.

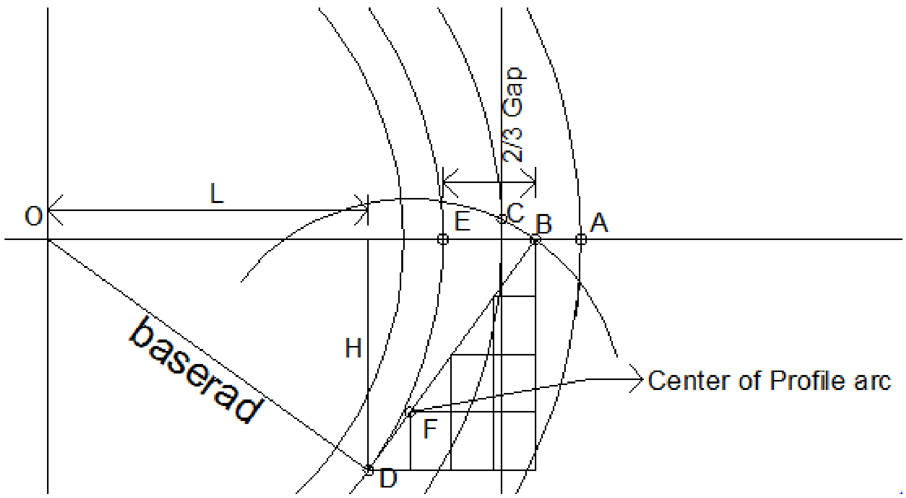

Figure 5. Locating the point of intersection of the arc and the pitch circle.

(vi) Draw the tooth profile arc with radius FB and locate point C (point of intersection of the arc and the pitch circle) as show in Figure 5.
(vii) Employ the mirror and rotation commands to get the complete tooth profile of the gear (Figure 6).
(viii) Employ rotation command at angle of circular thickness in point C, and apply principle of tangency to obtain fillet circle which will intersect the profile arc with dedendum circle.
(ix) Erase the excess in the tooth profile to get a complete tooth profile.
(x) Polar array the tooth profile about the centre of the gear with the number of teeth. Array allows copying objects at evenly spaced intervals along both the X and Y axes. Having one tooth, array command could be used to generate the remaining number of teeth.
(xi) Extrude, with the tooth thickness, to obtain 3-D solid.

MODEL DEVELOPMENT

The development of the model utilizes the integration of VB for Applications technology in AutoCAD environment for the implementation of the algorithm. It employed navigating the Integrated Development Environment (IDE) of VBA with AutoCAD objects, properties, methods, events, and error handling techniques that will help to ensure smooth running of the model. AutoCAD VBA permits the Visual BASIC environment to run simultaneously with AutoCAD and provides programmatic control of AutoCAD through the ActiveX Automation Interface. It is not only controlling AutoCAD objects, but it also sends data to or retrieves data from other applications. The integration of VBA into AutoCAD provides an easy-to-use visual tool for customizing AutoCAD. Three fundamental elements define VBA

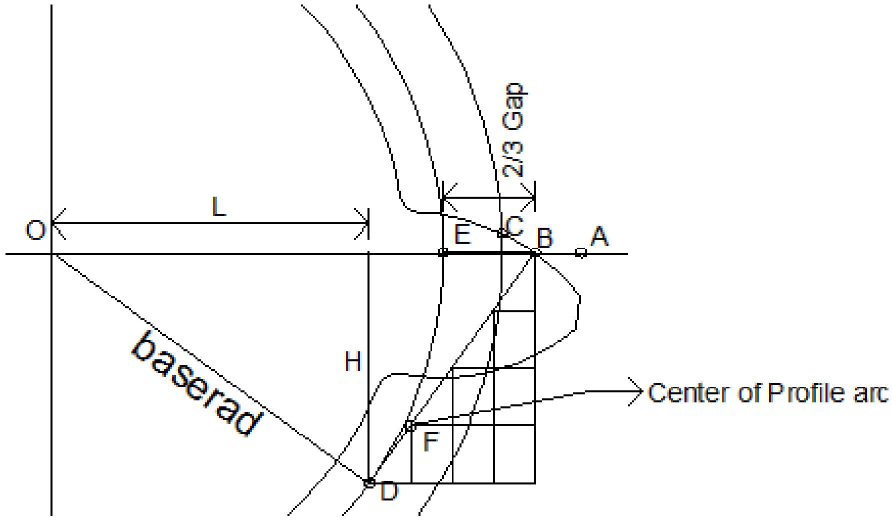

Figure 6. Getting the complete tooth profile of the gear.

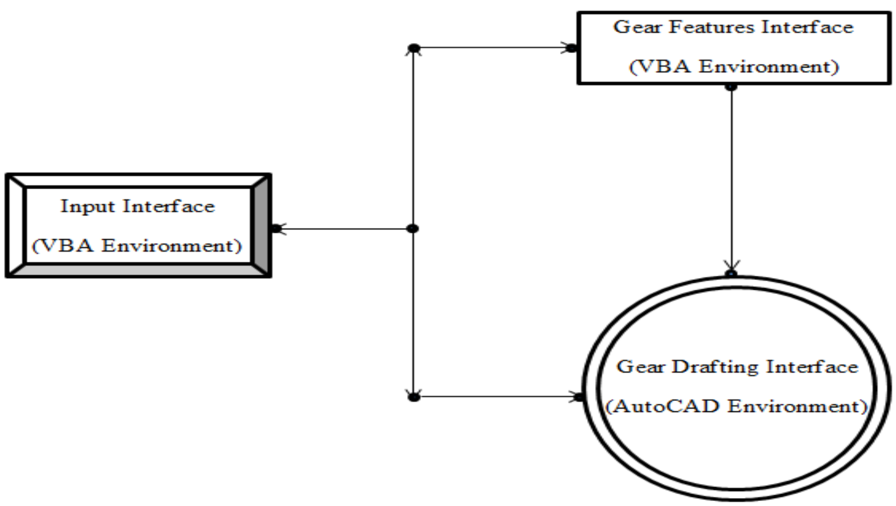

Figure 7. Architecture of the automated drafting model.

programming in AutoCAD. The first is AutoCAD itself, which has a rich set of objects that include AutoCAD entities, data, and commands. The second element is the ActiveX Automation Interface, which establishes messages with AutoCAD objects. Programming in VBA requires a fundamental understanding of ActiveX Automation. The third element that defines VBA programming is VBA itself. It has its own set of objects, keywords, constants, and so forth, that provides program flow, control, debugging, and execution.

The developed model consists of three major screen shots as shown in Figure 7:

(i) Graphical User Input (GUI) Interface – where user can enter the BASIC geometric parameters of the spur gear required;

(ii) Gear Drafting (GD) Interface – where the drawing of the gear will be displayed with or without construction lines; and
(iii) Gear Features (GF) Interface – where the values of the detailed gear features (used for the drafting and required for machining) are displayed.

The GUI screen shot was created with VBA forms incorporated with labels, textboxes and command objects to enable user to supply coordinates of gear centre, module, number of teeth, pressure angle, and tooth thickness as detailed in Figure 8. During the run-time mode, the command button, named “Draft” activates both the GD and GF screen shots respectively. The GD (Figure 9a) was developed in AutoCAD environment and shows the drafted gear developed by automatically

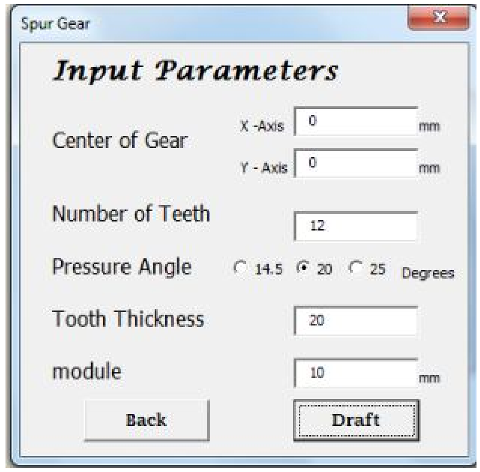

Figure 8. Graphical user input interface.

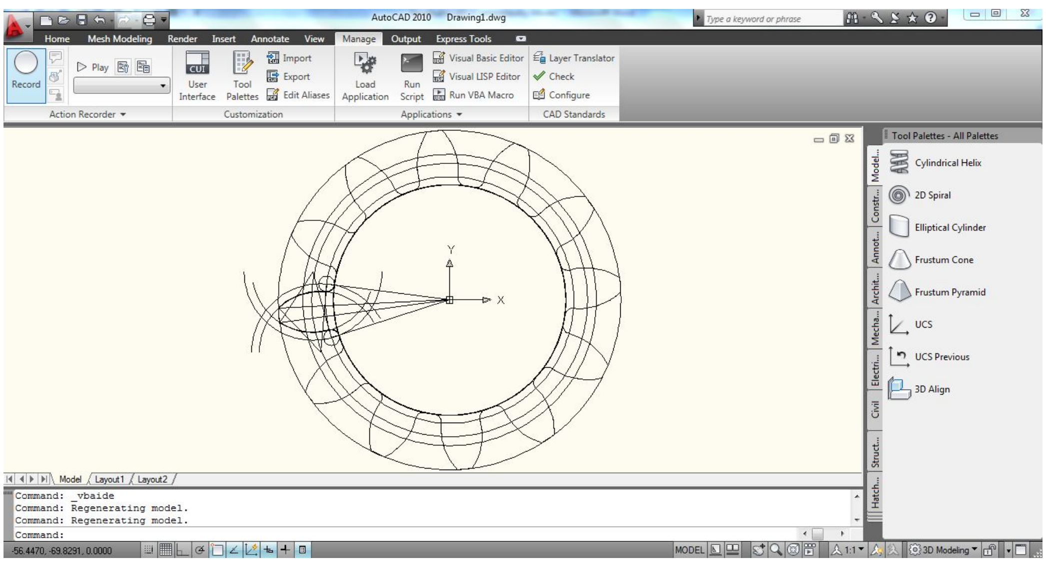

Figure 9a. Gear drafting interface.

implementing the following tools: circle, line, construction line, mirror, rotation, erase, trim, array, and extrude. The GF screen shot presents all the computed gear features whose corresponding mathematical relations for their computation are embedded in the command button of GUI screen in interface (Figure 9b).

MODEL VALIDATION

This involves actual execution of the model and checking of the outputs. The model was tested by comparing three tooth profile templates obtained from the model, for pressure angle 14½°, 20° and 25°, with those obtained from manual techniques. The three automated-drafted gears were illustrated in Figure 10. The values of all the geometrical parameters were also compared with those manually computed for the cases of spur-gear drafting with configuration $m = 6$, $N = 14$, and $PA = 14.5°$. Later, the model was implemented for simulation of cases of varying modules and varying number of teeth to investigate their significance on the gear structure and tooth profile.

RESULTS AND DISCUSSION

Based on the gear profile teeth, the three templates of pressure angles 14½°, 20° and 25° gave a good match with those obtained manually at a faster rate. On the basic geometric parameter, the model gave very close results with a percent error varying between 0.000 and

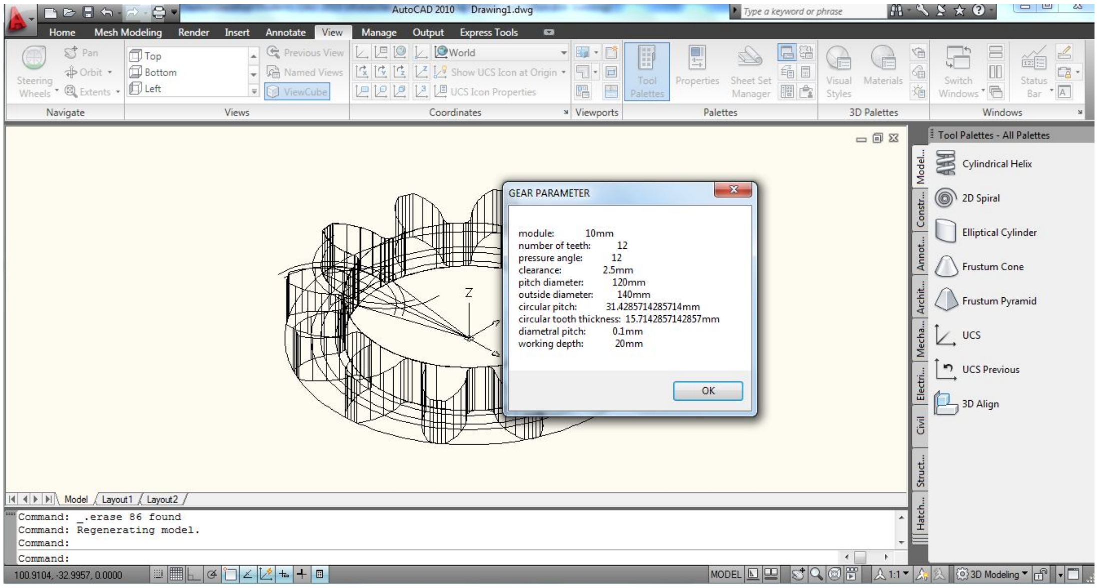

Figure 9b. Gear features interface.

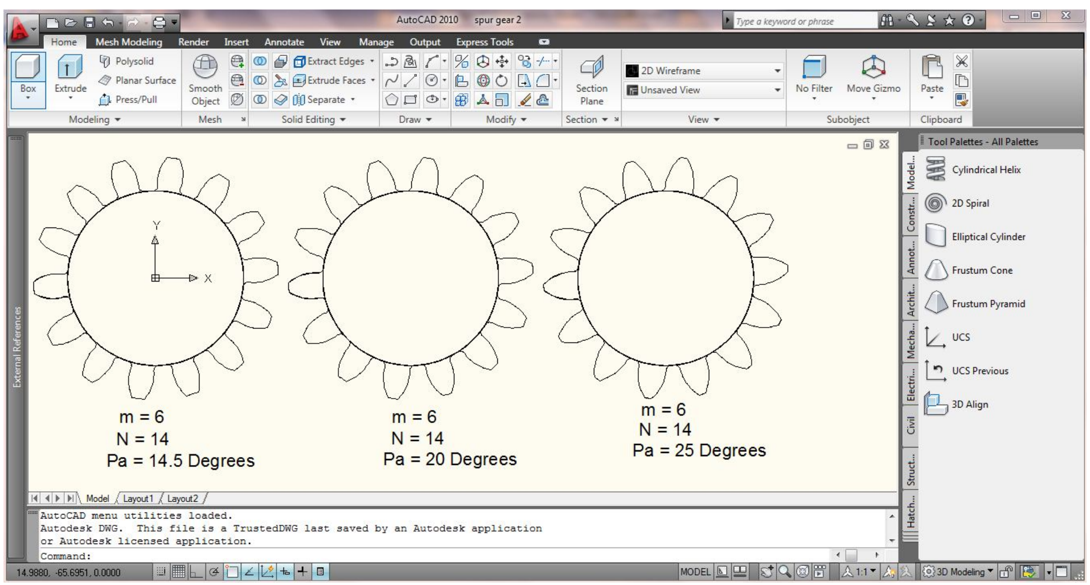

Figure 10. Three spur gears with different pressure angles.

0.007% as details in Table 1. These confirm the accuracy, reliability and consistency of the model. The simulation exercise reveals the claims that:

i) Increase in pressure angles gives the teeth a wider root, hence a higher bending strength (Figure 10);
ii) Increase in the value of module will increase the structure of the gear but the tooth profile remains the same (Figure 11); and
iii) Increase in the number of teeth increase the structure of the gear but the tooth profile does not change (Figure 12).

CONCLUSIONS

This paper presents a computational and drafting model for determination of inherent geometric parameters and drafting of spur gears to specific configuration. The model is based on AutoCAD-VBA customized environment, which provides programmatic control of AutoCAD through the Active X Automation interface. The user can change design variables at will to satisfy any constraint applied. The model was tested with nine case studies; and the results obtained were in good agreement with the available manual results. However, the model is simple to

Table 1. Verification of the model computed parameters.

S/N	Parameters	Manual results	Model results	Percent error (%)
1	Addendum	6	6	0.000
2.	No of teeth	14	14	0.000
3.	Pressure angle (°)	14.5	14.50	0.000
4.	Pitch circle diameter (mm)	84.000	84.00	0.000
5.	Outside circle diameter (mm)	96.000	96.00	0.000
6.	Root circle diameter (mm)	69.000	69.000	0.000
7.	Circular pitch (mm)	18.852	18.86	0.008
8.	Circular tooth thickness (mm)	9.4260	9.430	0.004
9.	Fillet radius (mm)	1.930	1.930	0.000
10.	Face width (mm)	20.00	20.00	0.000

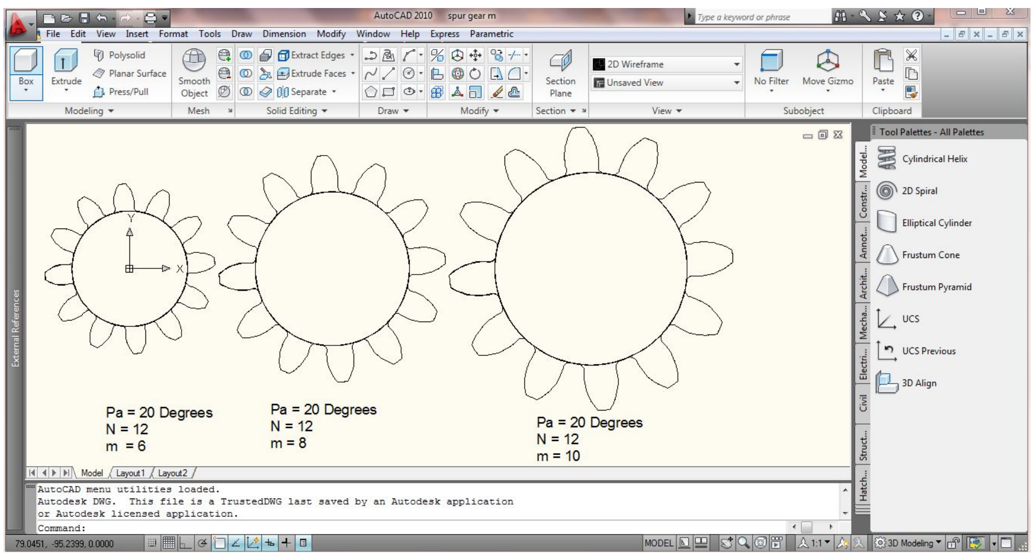

Figure 11. Spur gears with varying modules.

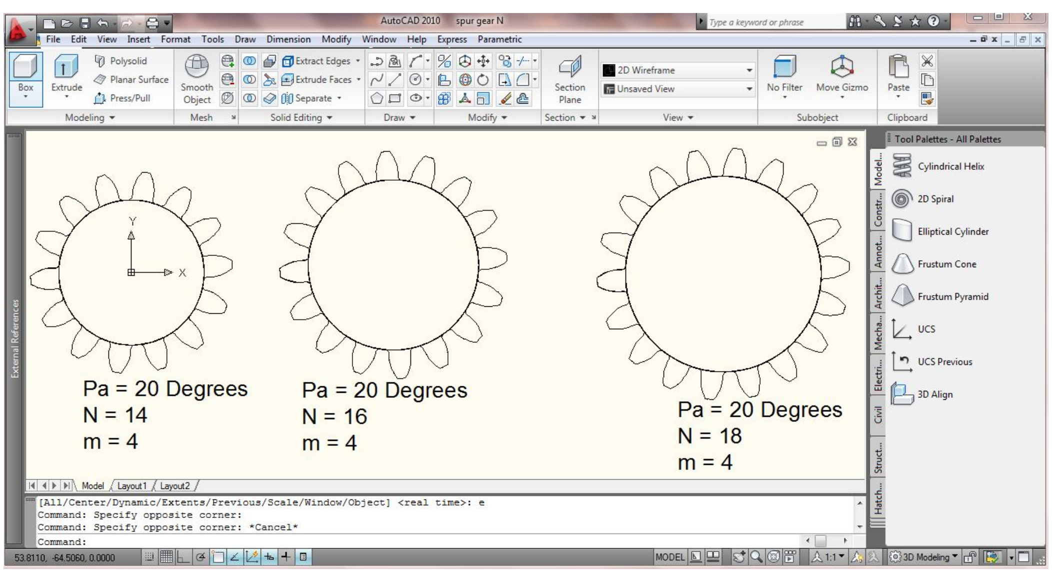

Figure 12. Spur gears with varying modules.

use, but can be further improved to accommodate straight-helical, straight-bevel, and single-enveloping worm gears.

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