Design of Spur Gear and its Tooth profile

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ABSTRACT

Gear is a widely used mechanical component whose primary use is to transmit power from one shaft to other. These gears are of many types namely spur gear, helical gears, worm gears etc.. Gear drives are used to various kinds of machines like automobiles, metal cutting tools, material handling equipments, rolling mills, marine power plants etc. The friction and other losses in this type of power transmission equipment is comparatively very low.

In this Work we use a software called "MATLAB" to design gear. MATLAB is extensively used for scientific & research purposes. It is accurate & also has a number of built in functions which makes it versatile. In this project SPUR GEARS are designed. The program is a user friendly one & when executed it ask the inputs and performs the necessary design calculations and gives necessary output values. It also gives the involute gear tooth profile with accurate safe dimensions. As computers are used to perform the task of gear design becomes simple, friendly & error free.

Keywords: gear design, spur gear, bending and Compressive stress, Tooth profile ,matlab.

INTRODUCTION

A Gear can be defined as the mechanical element used for transmitting power and rotary motion from one shaft to another by means of progressive engagement of projections called teeth. Spur Gears use no intermediate link or connector and transmit the motion by direct contact. The two bodies have either a rolling or a sliding motion along the tangent at the point of contact. No motion is possible along the common normal as that will either break the contact or one body will tend to penetrate into the other. Thus, the load application is gradual which results in low impact stresses and reduction in noise. Therefore, the spur gears are used in transmitting power with very less friction losses.

1. GEARS

Imagine two disks are placed side by side, tangent to each other (both touching), if one disk was rotated, due to friction (caused by surface roughness) the other disk would also rotate (in the opposite direction) however, slippage would be introduced due to variation in the surface roughness. Now if we were to increase that surface roughness by cutting the disks and forming teeth on the circumference (circular outer part) then slippage would be eliminated. As a result, we would have one of the most important fundamental mechanical devices, which can manipulate speed, torque and rotational axis. Almost all machines that involve rotation have gears. Gears are found in everything from cars to clocks.

1.1. Requirement of gear:

Gears have neat characteristics which aid in the development of complex machineries:

Gears can transmit power with very less friction loss. Gears can reverse the direction of rotation. It can change the speed or torque (turning force) of rotation. It can transfer rotation to a different axis or translate rotational into linear motion or vice versa.

1.2.CLASSIFICATION OF GEARS:

The basic classification of gears includes the following types, they are

Spur gear

Helical gear

Worm gear etc.

1.3.GEAR MATERIALS:

Desirable properties for gear material are as follows:

(a) Endurance strength in bending to avoid bending failure.
(b) Surface endurance strength to avoid destructive pitting.
(c) Low coefficient of friction to avoid scoring.
(d) Low and consistent thermal distortion during heat treatment.

2.SPUR GEAR

Gear having straight teeth cut on the rim, parallel to the axis of rotation.

Most common & cost-effective type of gear. Designed to transmit motion & power between parallel shafts, which rotates in the opposite direction. Plastic, brass, steel, & aluminum are the materials generally used for manufacturing. Electric screwdrivers, oscillating sprinklers, windup alarm clocks, washing machines, clothe dryers & conveyors are just a few everyday machines where spur gears are used. Spur gears are also used in construction equipments, machine tools, marine hoists, turbine drives, multi-spindle drives, indexing equipments & roller feeds.
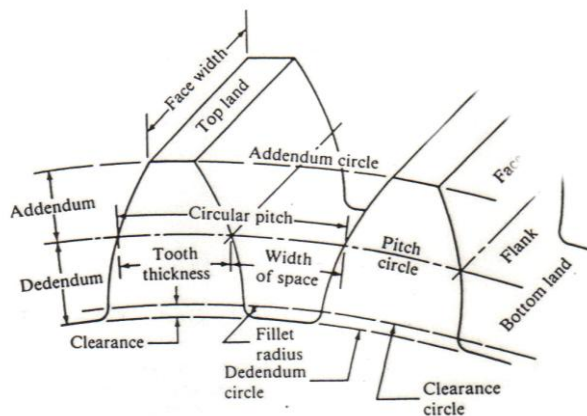
Gear Nomenclature

Fig.1.Gear Nomenclature

3. ABOUT MATLAB

MATLAB (MATrix LABoratory) is an interactive system for matrix-based computation, designed for scientific and engineering use. MATLAB is a high performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notations.

Typically uses include:

Math and computation

Algorithm development

Modeling, simulation, and prototyping

Data analyzing, exploration and visualization

Scientific and engineering graphics

Application development including graphical user interface building

MATLAB is a software package for high-performance numerical computation and visualization. It provides an interactive environment with hundreds of built-in functions for technical computation, graphics, and animation. Best of all, it also provides easy extensibility with its own high-level programming language. MATLAB is an interactive system whose basic data element is an array that does not requires dimensioning. This allows solving many technical computing problems especially those with matrix and vectoring foundation.

3.1.MATRIX OPERATORS

MATLAB has several operators for our use.

+ addition
- substraction
* matrix multiplication
/ division
^ exponentiation
.* term-by-term multiplication
./ term-by term division
. term-by term exponentiation
>> MATLAB prompt

4.Spur gear Design procedure

1. From the statement of problem, note down them power to be transmitted, pinion, speed, gear ratio, life of gear drive and other working conditions.

2. Based on the transmitting power and gear ratio, select a suitable material. Usually the pinion is subjected to more loading cycles then gear and hence the material selected for pinion should be strong than gear material.

3. Note the design surface compressive stress and bending stress for the selected material from design data book (or) find them by using the formula.

$$[\sigma_c] = C_B.HBK_{cl} \ (or) \ [\sigma_c] = C_R.HRC.K_{cl}$$

And $[\sigma_b] = \dfrac{1.4K_{bl}\sigma_e}{nK_\sigma}$ for rotation in one direction only.

$$= \dfrac{K_{bl}\sigma_e}{nK_\sigma} \ \text{for rotation in both directions.}$$

4. Based on surface compressive stress, determine the minimum center distance required for the gear drive as

$$a \geq (i \pm 1)\sqrt[3]{\left\{\dfrac{0.74}{[\sigma_c]}\right\}^2 \dfrac{E[M_t]}{i\varphi}} \ \text{For 20 degree pressure}$$

angle.

$$a \geq (i \pm 1)\sqrt[3]{\left\{\dfrac{0.85}{[\sigma_c]}\right\}^2 \dfrac{E[M_t]}{i\varphi}} \ \text{For 14.5 degrees pressure}$$

angle.

In the above expression

   a= Center distance

   i= Gear ratio= $\dfrac{Z_2}{Z_1}$

(i+1) for external gearing and (i-1) for internal gearing

$[M_t]$ = Design torque

   = $M_t.K.K_d$ Where M_t is the normal twisting moment and is obtained from the power as,

$$P = \dfrac{2\pi n_1 M_t}{60}$$

P =   power in Watts.

n_1 =   speed in rpm of pinion.

M_t =   Normal twisting moment in N-m.

Initially $K.K_d$ may be assumed as 1.3,

And $\varphi = \dfrac{b}{a} = 0.3$

   E = Equivalent young's modules

$$= \dfrac{2E_1E_2}{E_1 + E_2}$$

The design stress [σ_c], to be substituted in the above expression should be the minimum value, and usally formula based on 20 degrees pressure angle is preferred.

5. Based on beam strength or bending stress, determine the minimum module as

$$m \geq 1.26 \sqrt[3]{\frac{[M_t]}{y[\sigma_b]\varphi_m Z_1}}$$

Where [σ_b] = Design bending stress which should be the minimum value.

$$\varphi_m = \frac{b}{m} = 10 \text{ (initially assumed)}$$

Z_1 = Number of teeth on pinion

(usually selected from 14 to 20 initially)

Y = From factor corresponding to Z_1 (PSG)

6. After calculating the minimum module, select the next standard module from table (PSG).

7. Then correct the number of teeth on pinion using the standard module and minimum centre distance as

$$Z_1 = \frac{2a}{m(i+1)}$$

8. Similarly finalise the centre distance using standard module and corrected number of pinion teeth as

$$a = \frac{mZ_1(i+1)}{2}$$

9. Find out the pitch circle diameters for pinion and gear as $d_1 = mZ_1$ and $d_2 = mZ_2$ Where $Z_2 = iZ_1$. Also the centre distance "a" is equal to $\frac{d_1 + d_2}{2}$

10. Find the face width "b" as $b = \varphi.a$ (or) $b = \varphi_m.m$ and Adopt the higher value.

11. Calculate the pitch line velocity using $v = \frac{\pi d_1 n_1}{60 \times 1000}$ m/s and also note the values of load concentration factor (k) and the dynamic load factor (K_d) from PSG based on (b/d_1) ratio and pitch line velocity and evaluate the actual transmitted torque as $[M_t] = M_t.K.K_d$

12. Then determine the induced surface compressive stress and bending stress as

$$\sigma_c = 0.74\left(\frac{i\pm 1}{a}\right)\sqrt{\frac{(i\pm 1)}{ib}E[M_t]} \quad \text{for} \quad 20$$

degrees pressure angle.

And $$\sigma_b = \frac{(i\pm 1)[M_t]}{a.m.b.y} \text{ (Hear y=form factor for}$$

corrected Z_1)

13. Evaluate the other parameters of gear such as addendum, dedendum, tipcircle diameter, root circle diameter, circular pitch etc.. as follows.

Addendum = $f_0.m$

Dedendum= $(f_0 + c)m$

Where f_0=Height factor

=1 for full depth teeth

=0.8 for stub teeth

C= clearance factor

=0.25 for full depth

=0.3 for stub teeth

Tipcircle diameter=   Pitchcirclediameter+(2*Addendum)
Root circle diameter=Pitch circlediameter-(2*Dedendum)
Tooth height= Addendum+Dedendum
Working depth=2*Addendum
Clearence= Dedendum- Addendum

Circular pitch= $\frac{\pi.d}{Z}$.

5. DESIGN OF SPUR GEAR USING MATLAB

In this present work we designed a matlab code and a matlab script file is developed to design a spur gear and its involute profile.
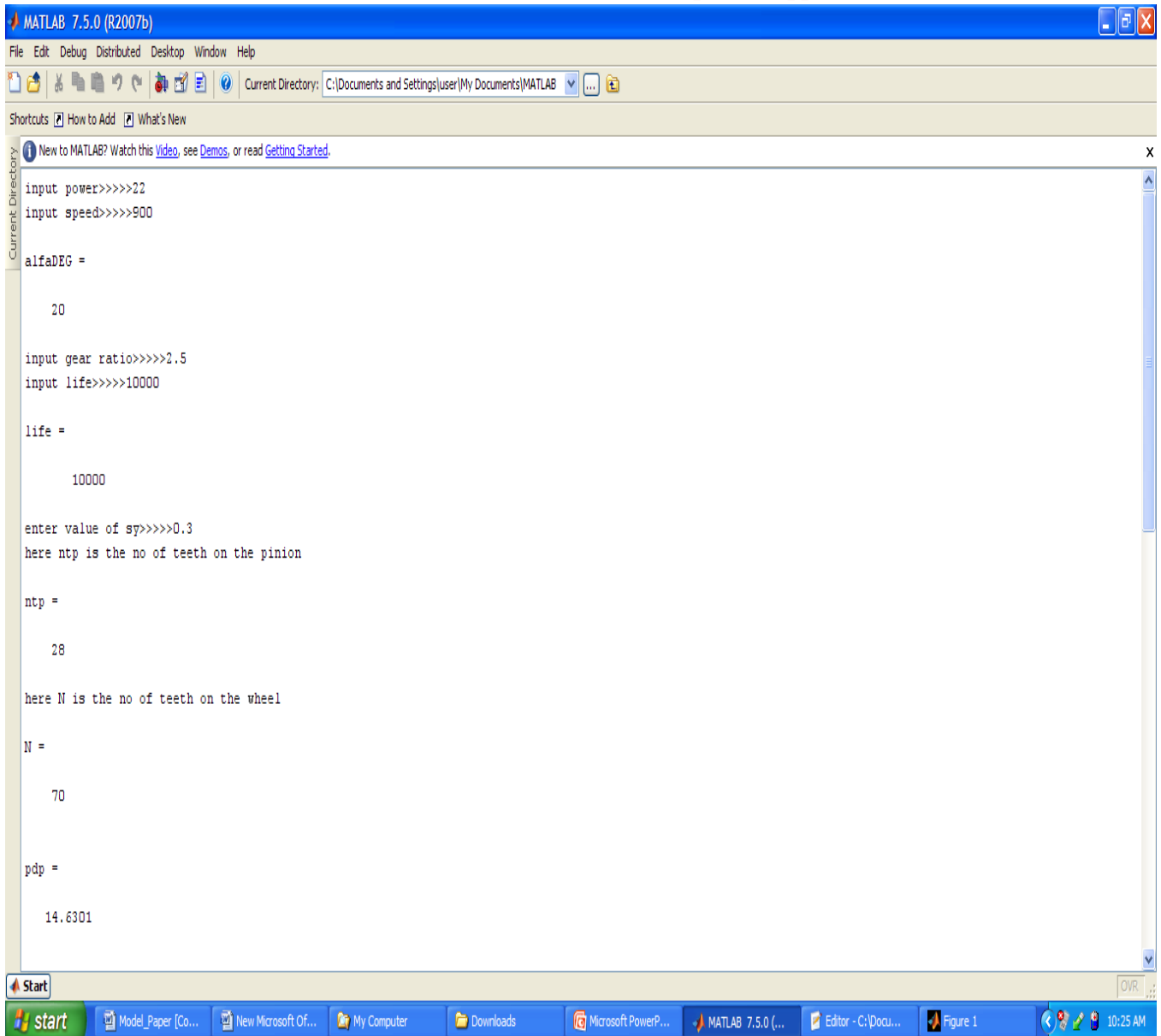
Inputs used in this work are Speed, Power, Gear ratio, Life and we get the outputs as Number of teeth, pitch circle diameter, Face width, Module, Tip circle diameter etc.

5.1. MATLAB OUTPUT WINDOW

The Matlab program we designed takes the input values as shown in the below figure and the logic that we have formulated gives the output values such as pitch circle diameter and the remaining required parameters with minimum input variables.

It also gives the tooth profile of the spur gear with given values and also tells weather the design of the gear is safe or not.

The input values given can be solved and the output values such as pitch circle diameter and other parameters are shown as below.

Figure.2. Inputs given to the Matlab Program

The output gear parameters we attain through this are as follows

Number of tooth on pinion.

Number of tooth on wheel.

Pitch circle diameter on pinion.

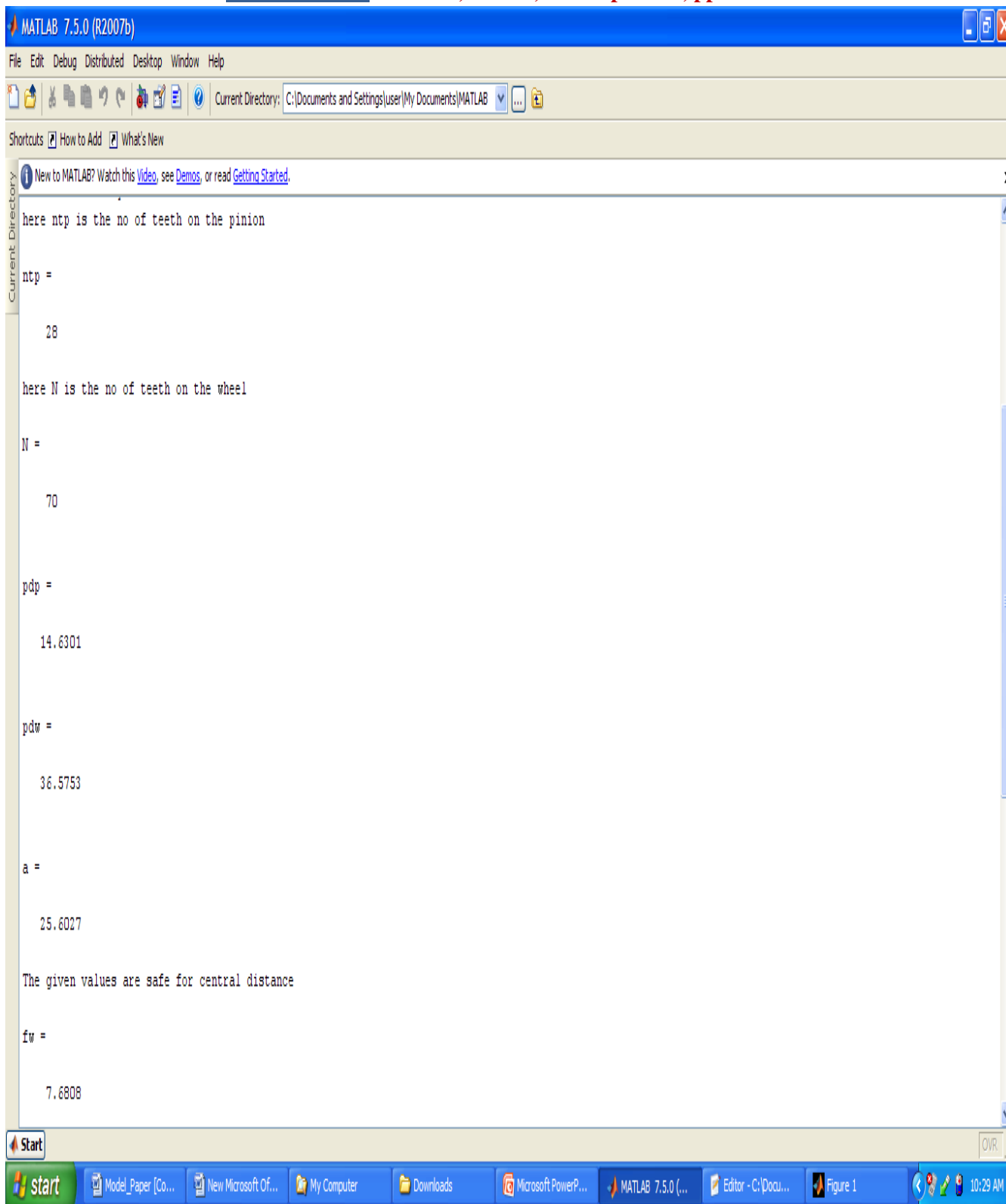Pitch circle diameter on wheel.

Face width.

Center distance.

Figure.3. Output of the program

5.2. THE GENERATED TOOTH PROFILE IN MATLAB

The generated tooth profile using matlab is as shown below. It gives the diagrammatic representation of pitch circle diameter, face width, root circle diameter, tip circle diameter etc.
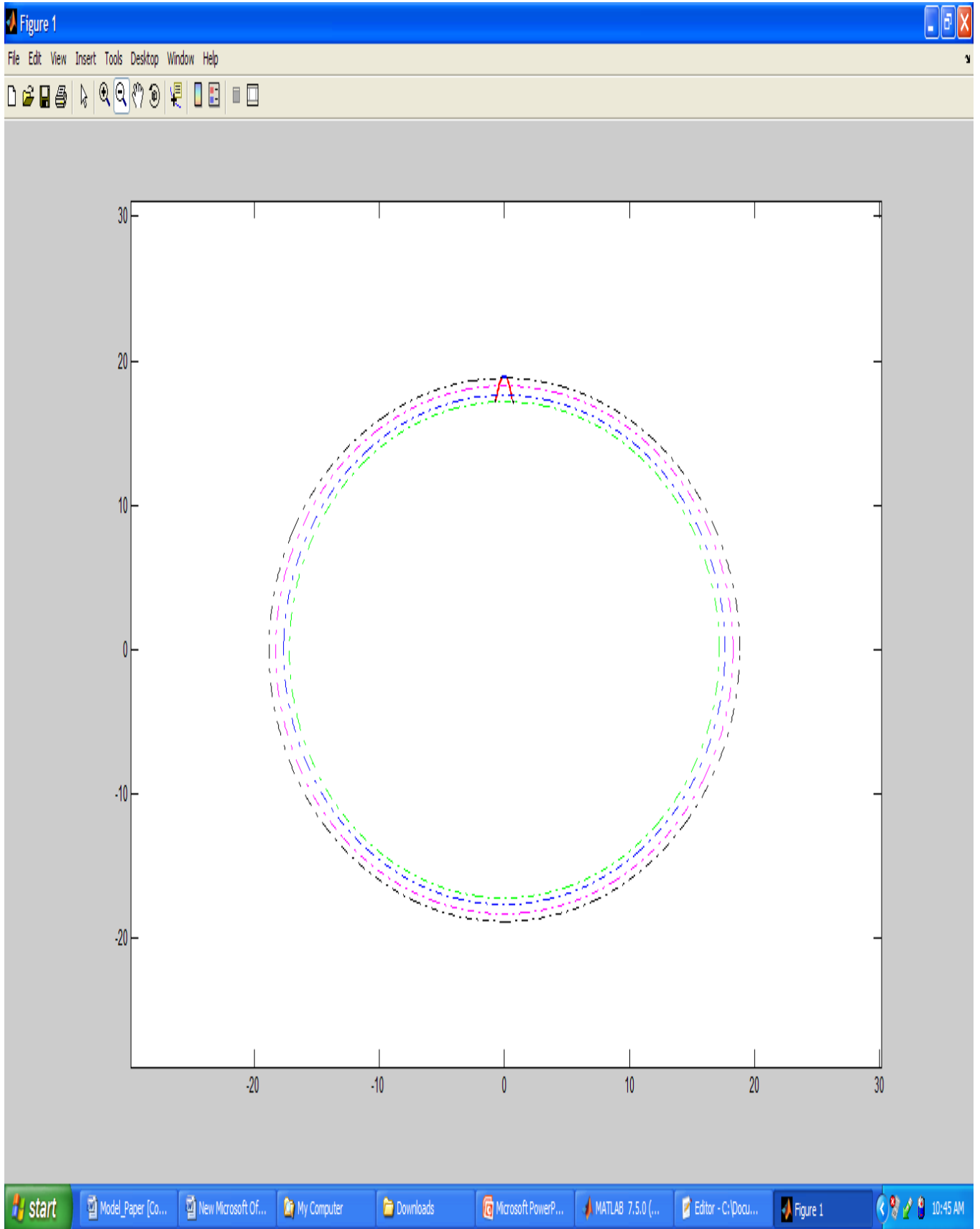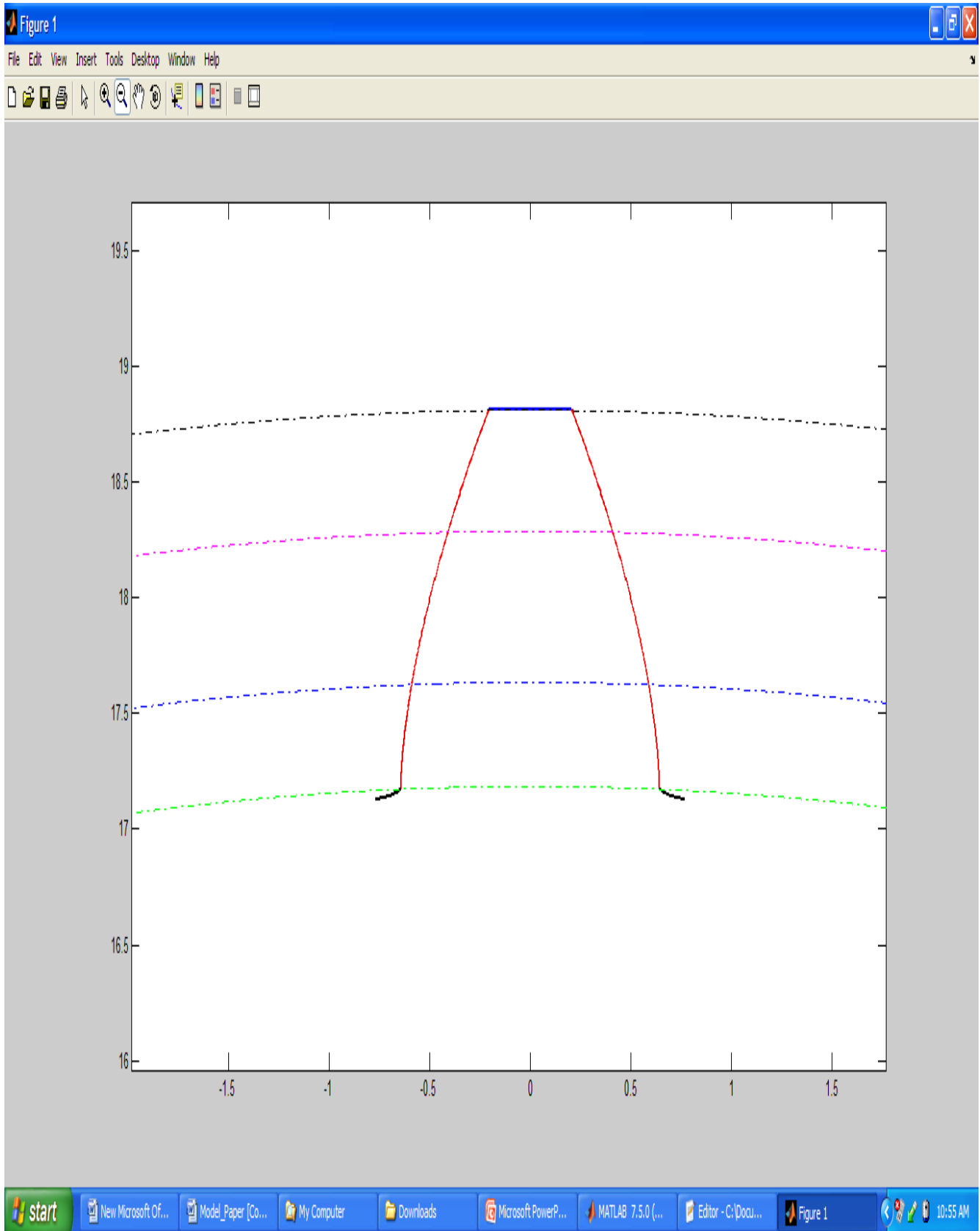
Figure .4. Gear tooth profile

Figure.5 Gear tooth

6. CONCLUSION

The analytical outputs and the tooth profile for the Spur Gear were obtained by using Matlab software and the given outputs also suggest that the designed Spur Gear was either safe or unsafe.

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