DEVELOPMENT OF SOFTWARE FOR SPUR GEAR DESIGN

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ABSTRACT

Due to technology advancement from the Industrial Revolution to the present day, the need for closer control over the accuracy, creation, modification, analysis, optimization, storing and communication of design information of systems used for transmitting power made available has also progressed. As a result, an interactive user-friendly and menu-driven CADGEAR '2003 proprietary software is built to assist in the creation, modification, analysis, optimization, and storing of spur gear design information. This low cost software facilitates the design of spur gears, validates users input and eliminates human errors that may result from design process. It generates accurate data used in design process; performs repetitive and routine tasks involved in spur gear design. It also produces precise and efficient 2D (*two dimensional*) design drawings of the gears and stores the information for use in manufacturing and future design activities. It was observed that this proprietary software has the advantage of low cost over other operating software for spur gear design. The introduction of this software to the society will in no small way increase productivity and the reliability of spur gear design in Nigeria.

DEDICATION

This thesis is dedicated to my Late Father, Rev. Gabriel Adewumi Awe, who tirelessly laboured to ensure that I am educated and constantly restored confidence in me of its values.

CERTIFICATION

This is to certify that the research work was carried out under my supervision by **Awe, Oluwaseyi Babatunde** of the Department of Mechanical Engineering in partial fulfillment of the requirements for the award of Master's degree in Mechanical Engineering of the Federal University of Technology, Akure.

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NOMENCLATURE

		Unit
m	= Module	mm
y	= Lewis form factor	
b	= Face width	mm
δ	= Maximum bending stress	N/mm^2
F_t	= Tangential force	N
C_V	= Velocity factor	
z	= number of teeth of gear	
d_1	= Driver pitch diameter	mm
d_2	=Driven pitch diameter	mm
z_1	= Driver number of teeth	
z_2	= Driven number of teeth	
n	= rev. / min	rpm
d	= Pitch diameter	mm
V_m	= Pitch line velocity	m/s
P	= Power transmitted	kw
K_s	= Service factors	
F_d	= Dynamic load	N
i	= Gear ratio	
C	= Constant	N/mm
α	= pressure angle	deg.

δ_{es}	= surface endurance limit of gear pairs	N/mm^2
E_1	= modulus of elasticity on the pinion material	N/mm^2
E_2	= modulus of elasticity on the gear material	N/mm^2
HB	= Brinell hardness	
a	= Center distance	mm
r_b	= radius of base circle	mm
P_d	= Diameter pitch	mm
P	= Circular pitch	mm
λ_a	= Addendum	mm
λ_f	= Dedendum	mm
d_a	= Tip diameter	mm
d_f	= Root diameter	mm
s	= Tooth thickness	mm
λ_p	= Whole depth	mm
h'	= Working depth	mm
c	= Clearance	mm
t_c	= Chord tooth thickness	mm
a_c	= Chordal addendum	mm
d_b	= Base circle diameter	mm
P_b	= Base pitch	mm
r	= Fillet radius	mm
i	= Speed ratio	
t_{min}	= Minimum thickness	mm

CHAPTER ONE

1.0 INTRODUCTION

As technology advancement from the Industrial Revolution to the present day, the need for closer control over the accuracy, creation, modification, analysis, optimization, storing and communication of design information of systems used for transmitting power made available has also progressed. The various types of transmission systems used could be mechanical as in gear system, tracer, hydraulic, pneumatic, air-logic, fluidic, electromechanical, electric, electronic or solid state.

Jain (2001) defined the term 'gear system' as a power transmission element commonly used to transmit power or rotary motion from one shaft to another. According to the American Gear Manufacturers Association (AGMA), gears are machine elements that transmit motion by means of successively engaging teeth. It is a toothed wheel or cylinder used to transmit rotary or reciprocating motion from one part of a machine to another.

Gears are used in metal cutting machine tools, automobiles, tractors, hoisting and transporting machinery, rolling mills, marine engines and other machines (Singh, 1997). The high efficiency, compact layout, reliable service, simple operation and positive motion-transmission performance over friction, made the used of gear system the most used means of transmitting power and multiplying torque in engineering field.

The determination of the proper gears to use in a particular application is a complex problem because of the many factors involved which influence the design procedure. Efforts are being made continuously to effect changes in the design procedure, with a view to better utilization of materials, improvement in efficiency and overall economy.

Modern power transmission requirements for greater loads and higher speeds have demanded improvements in tooth form, cutting methods, materials, e.t.c. It is obvious that the strength of gear teeth has had to improve to meet increased loads, this is a design problem, which will be dealt with as CAD is introduce to the design process of gear system. In gear design, theories relating to failure, wear, strength of materials, form the basis of the design procedure. These theories usually give rise to a set of equations which has to be solved to arrive at a satisfactory result (Joshi, 1981).

1.1 COMPUTER AIDED DESIGN

Computer-Aided Design (CAD) was defined by Farag (1987) to be the use of computer systems to assist in the creation, modification, analysis, optimization, storing and communication of design information. The CAD system allows design modifications to be performed easily and efficiently. The analysis and optimization phases of the design are easily and accurately performed by the computer while the designer will find these tasks time consuming and tedious without the used of computer. The CAD system in this case shall enable the designer to make decisions based on the analytical calculations performed by the computer.

The use of computers and the development of computer aided design techniques have resulted in significant reductions in design project costs, working hours, inconsistencies and mistakes (Ray, 1987). The introduction of CAD to engineering design has yielded economic benefits. Farag (1987) reported that the work of 32 draftsmen working without a CAD system may be done by 8 draftsmen with the CAD system in the same time.

Computer-Aided Design is finding increasing use in industries today due to its increase productivity, improved quality of design and communication through better communication and more consistent quality of engineering drawings and creation of a database for future design modifications.

1.2 SPECIFIC OBJECTIVES OF THE RESEARCH

The specific objectives are to:

(a) identify parameters influencing spur gear design; and

(b) develop a low cost proprietary software, which automatically designs spur gear systems based on minimum specification of input parameters.

1.3 EXPECTED CONTRIBUTION OF RESEARCH TO KNOWLEDGE

The research is expected to:

(a) enhance the analytical and logical power of the designer in the design of spur gear system.

(b) generate reliable data for efficient design of spur gears.

1.4 RESEARCH METHODOLOGY

Different theories and procedures involved in the determination of optimum spur gear design geometry were reviewed. Visits to some industries such as Machine Tools, Osogbo, were conducted to assess how spur gears are designed and produced. Oral interviews were also conducted with experienced gear designers. A thorough research into the art of software development was done so that a good basis can be established for the coding of identified procedure for the design of spur gear. This resulted into Computer-Aided Design Software for Spur Gears (CADGEAR 2003).

The software generated was used to validate users input and eliminate human errors that may result from manual design process. The software is written to be menu-driven and user's friendly.

1.5 RELEVANCE TO NATIONAL DEVELOPMENT

With the numerous variations in sizes and configurations across gear elements, design/production engineers could waste a lot of time recreating existing designs, fixing errors caused by using outdated design files, and searching for data. In the area of Computer – Aided Engineering analysis, the successful design of this software will immensely contribute to the knowledge of design and production engineers in the design of spur gears in various gear design industries and research institutes in Nigeria in that the designer is assisted in:

- The determination of the proper pitch and face width for adequate strength, durability and economy of manufacture.
- The determination of the smallest possible module and optimum number of teeth which will provide the most economical design.
- The determination of the allowable stress for gear tooth design based on the selected material and pitch line velocity.
- The determination of the dynamic tooth loads for accurate tooth profiles, spacing, proper alignments and quietness in mounting.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Gears are some of the most important elements used in machinery. There are few mechanical devices that do not have the need to transmit power and motion between rotating shafts. Gears not only do this most satisfactorily, but can do so with uniform motion and reliability. In addition, they span the entire range of applications from large to small. However, there is the need for a thorough research into the various factors influencing the design of spur gear systems and the act of software development so that spur gear designers who are beginners or only superficially knowledgeable about gearing are provided with fundamental, theoretical and practical information. If one considers the design of spur gears used to transmit power, the importance of CAD in the design becomes prominently apparent.

2.2 BASIC GEAR TYPES AND AXIAL ARRANGEMENTS

In accordance with the orientation of axes, Dudley (1994) identified three categories of gears:

1. Parallel Axes Gears
2. Intersecting Axes Gears
3. Nonparallel and Nonintersecting Axes Gears

Spur and helical gears are the parallel axes gears. Bevel gears are the intersecting axes gears. Screw or crossed helical, worm and hypoid gears handle the third category. Table 2.1, lists the gear types per axes orientation.

Also, included in Table 2.1 is the theoretical efficiency range of the various gear types. These figures do not include bearing and lubricant losses. Also, they assume ideal mounting in regard to axis orientation and center distance. Inclusion of these realistic considerations will downgrade the efficiency numbers.

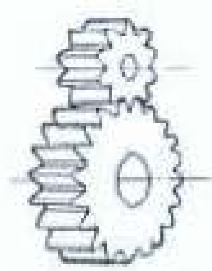
Table 2.1 : Type of Gears and Their Categories

Categories of Gears	Types of Gears	Efficiency (%)
Parallel Axes Gears	Spur Gear Spur Rack Internal Gear Helical Gear Helical Rack Double Helical Gear	98 ... 99.5
Intersecting Axes Gears	Straight Bevel Gear Spiral Bevel Gear Zerol Gear	98 … 99
Nonparallel and Nonintersecting Axes Gears	Worm Gear Screw Gear Hypoid Gear	30 … 90 70 … 95 96 … 98

Source: *Singh (1997)*

2.2.1 PARALLEL AXES GEAR

I. Spur Gear

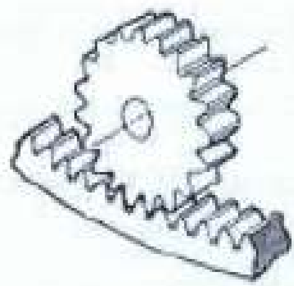


This is a cylindrical shaped gear in which the teeth are parallel to the axis. It has the largest applications and, also it is the easiest to manufacture. Also, it is easy to find, inexpensive, and efficient. However, it cannot be used when a direction change between two shafts is required.

2. Spur Rack

This is a linear shaped gear which can mesh with a spur gear with any number of teeth. The spur rack is a portion of a spur gear with an infinite radius. The rack gear is used to transfer circular motion into straight-line motion.

3. Internal Gear

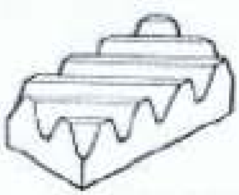


This is a cylindrical shaped gear but with the teeth inside the circular ring. It can mesh with a spur gear. Internal gears are often used in planetary gear systems.

4. Helical Gear

This is a cylindrical shaped gear with helicoids teeth. Helical gears can bear more load than spur gears, and work more quietly. They are widely used in industry. They may be used to mesh two shafts that are not parallel and even perpendicular shafts, although they are very expensive and much more difficult to find. A negative is the axial thrust force the helix form causes.

5. Helical Rack



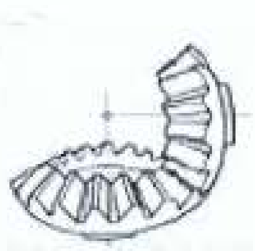
This is a linear shaped gear which meshes with a helical gear. Again, it can be regarded as a portion of a helical gear with infinite radius.

6. Double Helical Gear

This is a gear with both left-hand and right-hand helical teeth. The double helical form balances the inherent thrust forces.

2.2.2 INTERSECTING AXES GEAR

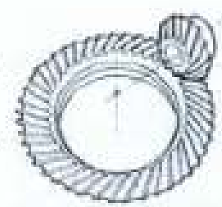
1. Straight Bevel Gear



This is a gear in which the teeth have tapered conical elements that have the same direction as the pitch cone base line (generatrix). The straight bevel gear is both the simplest to produce and the most widely applied in the bevel gear family.

2. Spiral Bevel Gear

This is a bevel gear with a helical angle of spiral teeth. It is much more complex to manufacture, but offers a higher strength and lower noise.



3. Zerol Gear

Zerol gear is a special case of spiral bevel gear. It is a spiral bevel with zero degree of spiral angle tooth advance. It has the characteristics of both the straight and spiral bevel gears. The forces acting upon the tooth are the same as for a straight bevel gear.

2.2.3 NONPARALLEL AND NONINTERSECTING AXES GEARS

1. *Worm and Worm Gear*

Worm set is the name for a meshed worm and worm gear. The worm resembles a screw thread; and the mating worm gear a helical gear, except that it is made to envelope the worm as seen along the worm's axis. The outstanding feature is that the worm offers a very large gear ratio in a single mesh. However, transmission efficiency is very poor due to a great amount of sliding as the worm tooth engages with its mating worm gear tooth and forces rotation by pushing and sliding. With proper choices of materials and lubrication, wear is contained and noise is low.

2. *Screw Gear (Crossed Helical Gear)*

Two helical gears of opposite helix angle will mesh if their axes are crossed. As separate gear components, they are merely conventional helical gears. Installation on crossed axes converts them - to screw gears. They offer a simple means of gearing skew axes at any angle. Because they have point contact, their load carrying capacity is very limited.

2.3 BASIC GEOMETRY OF SPUR GEARS

The fundamentals of gearing are illustrated through the spur gear tooth, both because it is the simplest, and hence most comprehensible, and because it is the form most widely used, particularly for instruments and control systems. The basic geometry and nomenclature of a spur gear mesh is shown in Fig. 2.1.

The essential features of a gear mesh as stated by Dudley (1994) are:

1. Centre distance.
2. The pitch circle diameter (or pitch diameters).
3. Size of teeth (or module).
4. Number of teeth.
5. Pressure angle of the contacting Involutes.

Details of these items along with their interdependence and definitions are given in Fig. 2.1.

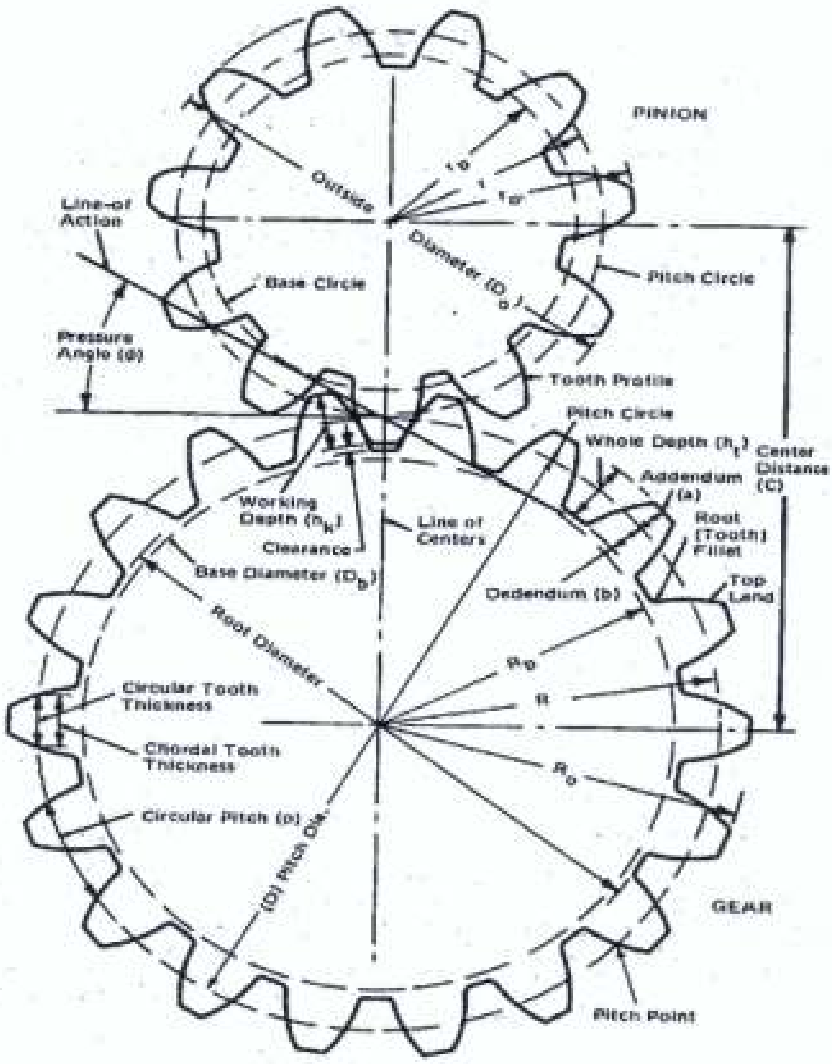


Fig. 2.1: **Basic Geometry of Spur Gears**

2.4 BASIC GEAR TERMINOLOGY

Module **(m)**: represents the size of an involutes gear tooth expressed in mm of pitch diameter. It is defined as the pitch circle diameter per unit number of teeth.

$$m \quad = 2a/ (z_1+z_2) = d/ z = 1/ P_d = P/ \pi \qquad \text{..... (2.1)}$$

Pitch diameter **(d)**: is the theoretical or imaginary circle diameter on which the teeth of mating gear mesh. These circles actually touch each other, as if gears are driven purely by the friction of the circles.

$$d \quad = Pz/ \pi = zm \qquad \text{..... (2.2)}$$

Diameter pitch **(P_d)**: is defined as the number of teeth of the gear divided by the pitch circle diameter.

$$P_d \quad = z/d = 1/ m \qquad \text{..... (2.3)}$$

Circular Pitch **(P)**: is the distance on the pitch circle from a point on a tooth to the corresponding point of the adjacent tooth.

$$P \quad = \pi d/ z = m\pi \qquad \text{..... (2.4)}$$

Addendum **(λ_a)**: is the radial distance from the pitch circle diameter to the outside diameter.

$$\lambda_a \quad = m \qquad \text{..... (2.5)}$$

Dedendum **(λ_f)**: is the radial distance between the pitch circle and the root diameter.

$$\lambda_f \quad = 1.157m \qquad \text{for } 14\tfrac{1}{2}^\circ \text{ full depth involutes} \qquad \text{..... (2.6)}$$

$$= 1.25m \qquad \text{for } 20^\circ \text{ full depth involutes} \qquad \text{..... (2.7)}$$

Outside diameter/ Tip diameter (**d_a**): is the diameter over the tape of the teeth. It is equal to the pitch diameter, plus 2 times the addendum.

$$d_a = m(z + 2) = d + 2m \quad \text{..... (2.8)}$$

Root diameter (**d_f**): is the diameter of the base of the teeth

$$d_f = m(z - 2.5) = d - 2.5m \quad \text{..... (2.9)}$$

Tooth thickness (**s**): is the thickness of the tooth measured on the pitch circle. It is also the distance between opposite faces on the same tooth measured at the pitch circle diameter.

$$s = \pi m/ 2 = P/ 2 \quad \text{..... (2.10)}$$

Centre distance (**a**): is the distance between the axes of rotation of mating spur gears. It is also the distance between the centres of two gears in mesh.

$$a = \tfrac{1}{2} (d_1 + d_2) = \tfrac{1}{2} m (z_1+z_2) \quad \text{..... (2.11)}$$

Pressure angle (α): is the angle between a line tangential to the pitch circles and a line perpendicular to the tooth profiles at the point of contact. It is equal to the side angle K of the basic rack for standard gears. Pressure angle of various degree are 14½° or 20°.

Tooth depth/Whole depth (**λ_p**): is the total depth of a tooth space.

$$\lambda_p = \lambda_a + \lambda_f$$

$$= 2.25m \quad \text{for } 20° \text{ full depth involutes} \quad \text{..... (2.12)}$$

$$= 2.157m \quad \text{for } 14½° \text{ full depth involutes} \quad \text{..... (2.13)}$$

Working depth **(h')**: is the distance that a tooth projects into the mating space. It is equal to gear addendum h_a plus pinion addendum.

$h' \quad = 2h_a = 2m$ ..... (2.14)

Clearance **(c)**: is the amount by which the whole depth is cut deeper than the working depth. It is also the difference between the dedendum of one gear and the addendum of the mating gear.

$c \quad = \lambda_f - \lambda_a$

$= 0.25m$ for 20° full depth involutes ..... (2.15)

$= 0.157m$ for 14½° full depth involutes ..... (2.16)

Chord tooth thickness **(t_c)**: is the thickness of a tooth on a straight line or chord on the pitch circle.

$t_c \quad = d \sin(90°/z)$ ..... (2.17)

Chordal addendum **(a_c)**: is the distance of a tooth from the top to the chord connecting the circular thickness arc.

$a_c \quad = \lambda_a + s/4d$ ..... (2.18)

$\cong m + \pi/2z$ ..... (2.19)

Base circle diameter **(d_b)**: is the diameter of the base cylinder from which the involute is generated.

$d_b \quad = d \cos \alpha$ ..... (2.20)

Base pitch **(P_b)**: is the pitch along the base circle or line of action.

$P_b \quad = \pi m \cos \alpha = P \cos \alpha$ ..... (2.21)

***Face width* (b)**: is the width of the tooth over the toothed part of a gear, measured along a straight line generator of the reference cylinder.

$b \quad = k\pi m$ ..... (2.22)

where:

$3 \le k \le 4$

***Fillet radius* (r)**: is the radius of the fillet curve at the base of the gear tooth.

$r \quad = 0.375m$ ..... (2.23)

***Transmission ratio / Speed ratio* (i)**: is the ratio of the angular speed of the first driving gear of a train of gears to that of the last driver gear.

$i \quad = w_1/w_2 \; = n_1/n_2$ ..... (2.24)

***Gear ratio* (i)**: is the ratio of the number of teeth of the gear to that of the pinion.

$i \quad = z_2/z_1$ ..... (2.25)

***Minimum thickness* (t_{min})**: is the minimum thickness of metal between the keyway and the root circle.

$t_{min} \quad = m\ \mathrm{sqrt}\ (z/5)$ ..... (2.26)

2.5 GEAR MATERIALS

Gears are manufactured from a wide variety of materials, both metallic as well as non metallic. While selecting a gear material, its cost, strength, wear resistance, noise level etc has to be compromised (Farag, 1987). The tensile strength of various gear materials is given in Table 2.4.

1. Cast Iron

Cast Iron is one of the most commonly used gear materials. Its low cost, ease of casting, good machinability, high wear resistance and good noise abatement property make it a logical choice. The primary disadvantage of cast iron as a gear material is its low tensile strength.

2. Steels

Steel gears are usually made of plain carbon steels or alloy steels. They have the advantage over cast iron of higher strength without undue increase in cost.

3. Non-ferrous Metals

Copper, Zinc, Alumimium and Titanium are materials used to obtain alloys that are useful gear materials. The copper alloys known as bronze are the most widely used. They are preferred where corrosive resistance is important and also here large sliding velocities exist.

4. Non-Metallic

Raw hide, nylon, various types of plastics and so on, have been used for gears. The advantage obtained by using these materials is quietness of operation, internal lubrication, dampening of shock and vibration, and manufacturing economy. Their primary disadvantage is laver load carrying capacity and low heat conductivity, which results in heat distortion of the teeth. Recently, Thermoplastic resins, with glass-fiber reinforcement and a lubricant as additives have been used as gear materials. They are continuing to displace metal gears in a widening arena of applications. Their unique characteristics are also being enhanced with new developments, both in materials and processing.

Some recommended combinations of materials for driver and driven are given in Table 2.3 and their hardness combinations are given in Table 2.2.

Table 2.2: Typical Driver and Driven Gear Hardness Combination

Diven HB	180	210	225	245	255	270	285	300
Driver HB	210	245	265	285	300	315	335	350

Source: *Singh (1997)*

Table 2.3: Recommended Combination of Materials for Driver and Driven

Gear Ratio i	***Surface Hardness HB***	***Driver***	***Driven***	***Driver***	***Driven***	***Driver***	***Driven***
<8	≤350	45 C 8	35 C 8	55 C 50 C 12	45 C 8	50 C 8	35 C 8
		40 Cr 4	50 C 8 55 C	35 Ni 5 Cr 2	40 Cr 4	16 Ni 4 Cr 3	35 Ni 5 Cr 2
<4	>350	45 C 8 50 C 8	35 C 8	55 C	45 C 8	40 Cr 4	50 C 8 50 C
		35 Ni 5 Cr 2	40 Cr 4	16 Ni 4 Cr 3	35 Ni 5 Cr 2	40 Ni 6 Cr 4	15 Ni 7 Cr 4
≥4	HB_1>350 HB_2 ≤350	45 C 8	Cast Steel Grade 1	50 C 8	35 Ni 5 Cr 2	40 Cr4	35 Ni 5 Cr 2
		15 Ni 7 Cr 4 Mo 2	45 C 8	48 Ni 6 Cr 4 Mo 3	55 C 55 Cr 3		

Source: *Singh (1997)*

Table 2.4: Materials for Spur Gears

Material	Condition (finished gear)	Minimum Tensile Strength δ (N/mm^2)	Brinell Hardness (HB)	Basic Surface Stress Factor S_c	Basic Bending Stress Factor S_b
Cast Steel:					
Grade 27-54	-	540	145	1.125	13.38
Grade 1	Annealed	620	182 min	1.47	15.30
Grade 1	H + T	790	229 min	1.90	19.70
Grade 1	Surface	620	165(core) min 460 (case) min	1.97	13.36

Material	Condition (finished gear)	Minimum Tensile Strength δ (N/mm²)	Brinell Hardness (HB)	Basic Surface Stress Factor S_c	Basic Bending Stress Factor S_b
Forged Steel:					
(a) Carbon Steels					
30 C 8	N	490.3	143	0.985	11.95
30 C 8	H + T	588.4	152	1.125	14.80
40 C 8	N	568.8	152	1.125	14.05
40 C 8	H + T	588.4	179	1.44	14.80
55 C	N	706.1	201	1.69	17.60
55 C	H + T	686.5	223	1.83	16.90
55 C	-	784.5	248	2.11	19.70
(b) Carbon Chromium steels					
55 Cr 3	H + T	882.6	225 min	2.105	22.2
55 Cr 3	H + T	980.7	285 min	2.47	24.6
40 Cr 4	H + T	784.5	229 min	1.90	19.7
(c) Chromium molybdenum steels.					
40 Cr 4 Mo 3	H + T	686.5	201 min	1.69	16.9
40 Cr 4 Mo 3	H + T	784.5	229 min	1.90	19.7
40 Cr 4 Mo 3	H + T	882.6	225 min	2.105	23.2
40 Cr 4 Mo 3	H + T	980.7	285 min	2.47	24.6
40 Cr 5 Mo 6	H + T	882.6	248 min	1.75	23.2
40 Cr 5 Mo 6	H + T	980.7	293 min	2.06	24.6
(d) Nickel Chromium Molybdenum					
40 Ni 6 Cr 4 M6	H + T	882.6	255 min	2.11	23.2
40 Ni 6 Cr 4 M6	H + T	1520.0	444 min	3.87	37.3
31 Ni 10 Cr 3 M6	H + T	882.6	255 min	2.11	23.3
31 Ni 10 Cr 3 M6	H + T	1520.0	444 min	3.87	36.6
31 Ni 10 Cr 3 M6	H + T	1078.7	311 min	2.60	26.7
40 Ni 10 Cr 3 M6	H + T	980.0	285 min	2.47	24.6
40 Ni 10 Cr 3 M6	H + T	1520.0	444 min	3.81	37.3
40 Ni 10 Cr 3 M6	H + T	1176.8	341 min	3.82	28.8
Surface hardened steels:					
(a) Carbon steels					
40 C 8	-	540.6	145 core 460 case	1.97	8.35
55 C 6	-	694.9	200 core 520 case	2.80	10.55
(b) Carbon chromium steels					
55 C 3	-	849.3	250 core 500 case	3.58	12.91
40 Cr 4	-	694.9	500 case	2.80	10.55

Source: *Singh (1997)*

2.6 METHODS OF GEAR MANUFACTURE

Gear teeth are formed by the following generating processes (Jain, 2001).

(a) Milling Cutter

Spur gears may be made from a blank by removing the material between the teeth on a milling machine that uses the formed cutter. Gears of the $14^{1}/_{2}^{\circ}$ composite system are usually made by this method. Since the geometric curves forming the sides of the teeth vary with the number of teeth in the gear, eight cutters are required for each pitch if gears of all sizes are to be cut. The eight cutters and the range of each are as follows:

No 1:	135	rack
No 2:	55 – 134	teeth
No 3:	35 – 54	teeth
No 4:	26 – 34	teeth
No 5:	21 – 25	teeth
No 6:	17 – 20	teeth
No 7:	14 – 16	teeth
No 8:	12 and 13	teeth.

Cutters are theoretically correct only for the lowest number of teeth in each range. If, when gears are being cut near the higher end of the range, a more accurate tooth form is desired, cutters in half-numbers suitable for gears with such numbers of teeth are also available. Gears with large – size teeth are frequently made by formed cutters because of the lack of suitable generating machines and tools.

(b) Rack Generation

Gear tooth forms may be produced by another method, know as generating. Since a rack may be considered a gear of infinite radius, a tooth of this shape may be constructed of hardened steel with cutting edges around the boundaries of the teeth. The tool is given a reciprocating motion parallel to the gear axis. At the same time, the gear blank is slowly rotated, and the rack is given a lateral motion equal to the pitch – line velocity of the gear. The material between the gear teeth is cut away and involute teeth are generated. Only one tool for each pitch will be required to cut gears of any number of teeth.

(c) Hobbing

The hobbing process generates teeth from a straight – sided tool. The hob may be considered a cylinder around which a thread of the same cross section as a rack tooth has been helically wound. The resulting worn is gashed, the edges are relieved, and are then hardened and ground. The hob is located to give the proper depth of cut and is then rotated, kinematically, the action of the hob on the blank is equivalent to that of the rack cutter. The lead of the helix of the hob as it rotates simulates the lateral motion of the rack. As the cutting progresses, the hob is fed axially along the blank until the teeth extend across the entire width of face. The hobbing process accounts for the major portion of gears made in quantity production.

(d) Fellows gear shaper method

This is a generating process using a cutter that resembles a hardened gear with properly relieved edges. Cutter and blank are mounted on parallel axes and are slowly rotated; the cutter is given an additional reciprocating motion on its axis. Teeth are generated in the blank. At the beginning, the cutter is fed "radially" into the blank a distance equal to the depth of the tooth. The Fellow's method must be used for cutting internal gears. The method is also suitable for shoulder gears where space is restricted at one end of the teeth, as in cluster gears of automobile transmissions, Fellows cutters are made to cut gears of all system.

Hobbed and shaped teeth are usually provided with a small amount of tip relief. The cutting tools are modified to cut tooth slightly narrower in the outer portion. The oncoming pair of teeth picks up the load more gradually, and errors in tooth form and spacing have less effect in producing noise and vibration.

(e) Other gear manufacturing methods

Other methods used in gear manufacturing can be summarized as follows:

- Die casting
- Drawing
- Extruding
- Stamping
- Injection moulding
- Sintering process

2.7 GEAR FINISHING METHODS

For high speeds and heavy loads, a finishing operation, subsequent to cutting, may be required to bring the tooth outline to a sufficient degree of accuracy and surface finish. According to Jain (2001) the following methods are in use:

(i) Gear Shaving

The gear is run with a specially made cutter resembling a gear rack. The cutter tooth has an axial component of motion on the tooth surface, which removes fine hairlike chips. Shaving is done prior to hardening, and sufficient stock must be allowed for this operation. Shaving is a widely used finishing method for gears made in large quantities. It removes small amounts of material to accomplish the same result as grinding.

(ii) Honing

Here the hardening gear is run with an abrasive impregnated plastic helical gear-shaped tool, which will make minor tooth-form corrections and improve the smoothness of the surface. This is a process that employs a tool known as a hone to drive the gear to be finished. The hone, which can be abrasive impregnated or coated, drives the gear in both directions.

(iii) Lapping

The gear is run with a gear shaped lapping tool in an abrasive-containing medium. Sometimes two mating gears are similarly run. An additional relative motion in the axial direction is required for spur and helical teeth. Excessive lapping can be detrimental to the involute shape. This is a method whereby a gear is run with another gear that has some abrasive material embedded in it.

(iv) Grinding

Grinding can be used to give the final form to the teeth after heat treatment. It is a process where by the finish on gears is improved and the tolerance of the dimension to which the gear is to be cut is enhanced. This is accomplished by the use of some form of abrasive grinding wheel. Errors resulting from distortion in hardening can be corrected.

When cutting, sufficient stock must be allowed on the tooth surface. Some fine-pitch gears are ground from solid blanks.

(v) Burnishing

This is a plastic smearing process resulting from rubbing pressure, which flattens and spreads minute surface irregularities. A special hardened burnishing tool is used. The process will not correct errors due to improper cutting.

Of the refining methods discussed, grinding and shaving are used to finish precision gears, while the others are used mostly for low quality gears.

2.8 FUNDAMENTALS OF CAD

Computers have grown to become essential in the operations of business, government, military, engineering and research. Groover and Zimmers (1984) reported it to be universally recognized as the most powerful and effective tool in the design of gears, which is the single most important concern of every manufacturing manager.

According to Juneja and Sekhon (1987) the term Computer – Aided Design (CAD) is used to refer to the development and use of special computer programs (software) to help the designer carryout routine computations for the design of specific parts, components and productions. By obtaining quick analytical results, the designer is able to evaluate many more design alternatives than would otherwise be possible. In addition, a sophisticated program can be used to obtain optimum design solutions for specific parts and components, thereby realizing significant savings in unit costs. Further numerically controlled drafting machines producing part and assembly drawings from the computational results of CAD are nowadays available. Stephenson (1986) saw that in CAD, the drafting board and T – square are replaced by a computer.

2.8.1 Interactive Computer Graphics (ICG) System

Modern CAD systems are based on Interactive Computer Graphics (ICG). ICG is a user-oriented system in which the computer is employed to create transform, and display data in the form of pictures or symbols.

A typical ICG system is a combination of hardware and software.

The hardware – includes a central processing unit (CPU), one or more workstations (including the graphics display terminals), and peripheral devices such as printers, plotters and drafting equipment.

The software – consists of the computer programs needed to implement graphics processing on the system. They also include additional specialized application programs to accomplish the particular engineering functions required by the user company.

The CAD software consists of the computer programs to implement computer graphics on the system plus application programs to facilitate the engineering functions of the user company. Such application programs are developed for specific or specialized purposes. Examples of these application programs include stress-strain analysis of components, dynamic response of mechanisms, heat-transfer calculations, and numerical control part programming. The collection of application programs varies from one user firm to another because their product lines, manufacturing processes, and customer markets differs. These factors give rise to differences in CAD system requirements (Groover and Zimmers, 1984).

Computer – Aided Design (CAD) can be defined as the use of computer systems to assist in the creation, modification, analysis, or optimization of an engineering design. Heathcote (1992) noted that Computer – Aided Design project is a very complex one for it involves the understanding of the mathematics involved in rotating an object; it is best implemented using a Graphic User Interface (GUI).

The computer systems consist of the hardware and software to perform the specialized design functions required by the particular user firm. The computer – Aided Design (CAD) hardware typically includes the computer, one or more graphics display terminals, keyboards, and other peripheral equipment.

2.8.2 Computer Program/ Software

Program is the set of procedural statements (instructions) and declaratives written in a specific order, in a very exact form, which on execution produce the desired results from the given input (Sharad, 1992). William et. al. (1990) saw the word software as a term coined to contrast computer programs with the hardware of a computer system. According to them, Software refers to other programs specifically developed to fit the users need.

2.8.3 CAD System Software Structure

There are different types of software used in a CAD system. According to Peter et. al., (1994) some of these types are:

(a) Operational software

(b) Graphics software

(c) Applications software

(d) Users software

(i) Operational Software

A CAD system uses a set of instructions called the 'operating' or 'system' software. This ensures that the computer operates correctly when it is switched on, when certain keys are pressed or if errors occur. It is usually stored on the hard disc and manages all the computer activities including memory allocation, processor timing and input/output driving. (If the operating system is stored in ROM, the Read-Only Memory, it is called 'firmware'). Updating is required when it has not been fully tested before release. Occasionally the operating software is stored on a floppy disc; the system then has to be 'booted-up' i.e., the software has to be copied from the disc to the computer memory before work can begin.

(ii) Graphic Software

This is used to create the data that is represented by an image on a design screen. It is usually written in a high-level language which processes the mathematical formulae involved. The software allows the creation of CAD entities (lines, circles, text), editing (facilities such as hatching and erasing), revising (such as stretching or scaling a design), manipulation (copying, moving or rotating a design element), and calculation of, for instance, line lengths, radii or areas. It is also used to store retrieve, edit and plot graphical data.

(iii) Applications Software

This is CAD software that is specific to certain design area, such as production engineering, civil engineering and architecture, PCB design, and so forth. As CAD becomes less expensive, new uses for it continue to develop.

(iv) User Software

When CAD package closely meets a users needs, it may be customized to provide the missing features. A customized system is called 'user' software. A case study is the creation of 'standard' gear systems, such as those used on regular basis in different assemblies. A typical example of such is CADGEAR '2003.

2.9 ENGINEERING APPLICATION OF COMPUTER

Computer are used widely throughout design and manufacturing industries. They are applied to all aspects of company operations. Adejuyigbe (2002) highlighted the various engineering applications of computers as follows:

- Computer – Aided Design (CAD);
- Computer – Aided Design and Drafting (CADD);
- Computer – Aided Manufacturing (CAM);
- Computerized Numerical Control Machine Tools (CNC);
- Computer – Integrated Manufacture (CIM);
- Computer – Aided Production Control and Management (CAPM);
- Computerized Materials Handling System (CMHS); and
- Computer – Aided Quality Assurance (CAQA);

2.10 BENEFITS OF COMPUTER – AIDED DESIGN

The benefits derived from the use of CAD are numerous. Groover (1987) enumerated some of the benefits which were presented by Adejuyigbe (2002) as scheduled below:

- Reduce draftsman labour.
- Reduce production turn around time.
- Enables designer to monitor the process of a design problem solution and terminate the run or modify the input data as required.
- Reduce the amount/number of drawings required.
- Increase the productivity of the designer.
- Improve the quality of design.
- Increase communication among departments of a company.
- Create a database for manufacturing.
- Evaluate alternative designs.
- Increase drawing speed up to about three times faster than drafters using tools.
- Reduce direct cost on product design.
- Increase reliability of product and design.

CHAPTER THREE

3.0 METHODOLOGY OF DESIGN

3.1 DIFFICULTIES ENCOUNTED IN GEAR DESIGN

The determination of the proper gears to use in a particular application is a complex problem because of the many factors involved. Singh (1997) highlighted some of the factors involved in the design of gears as:

(i) The gears must operate together without tooth interference with a proper length of contact and without undue noise.

(ii) The gear teeth must have the ability to transmit the applied loads without failure and with a certain margin of safety. This load is commonly referred to as the *dynamic load.*

(iii) The wearing qualities of the teeth must be considered. This is known as the *wear load.*

According to Farag (1987) mechanical parts that are subjected to sliding or rolling contact are bound to suffer some degree of wear. Examples of such parts are bearings, gears, brakes and clutches. The amount of wear which the part can suffer before it fails to function efficiently depends on the accuracy and tolerances involved.

3.2 DESIGNS FOR ADEQUATE STRENGTH OF GEAR TEETH

The static strength of the gear tooth of a gear is determined by Wilfred Lewis in 1892 to be a cantilever beam acted upon by the moment resulting from the transmitted load obtained from the power transmitted. The design stress based upon the ultimate strength of the material with a factor safety of about 3 being a steady load on a single pair was analyzed. This led to the design equation known as Lewis equation Eqn. (3.1).

$F_t = \delta b y \pi m$ ..... (3.1)

where :

m	= Module,	mm
y	= Lewis form factor,	
b	= Face width,	mm
δ	= Maximum bending stress,	N/mm^2
F_t	= Tangential force,	N

In Table 3.1 is the factor of safety for gears.

Table 3.1: Factor of Safety K_1 for Gears

Type of drive and load	***Factor of safety***
Steady load on a single pair	3
Suddenly applied load on a single pair	4
Steady load on gears of train beyond first mesh	5
Sudden load on gears of train beyond first mesh	6

Source: *Singh (1997)*

Earle Buckingham in 1932, modified the Lewis equation by a velocity factor in order to take into account the effects of tooth fabrication and additional loads due to impact giving rise to Eqn. (3.2). Again Singh (1997) reported that Eqn. (3.2) can best be used to determine the strength of gear design having considered the dynamic load, the endurance limit of the material and the wear load. Therefore, Eqn. (3.2) is used in the design of gear and strongly considered in developing the Computer – Aided Design for Spur Gears Software (CADGEAR '2003) under review.

$F_t \quad = \delta_0 b y \pi m \, C_V$ ..... (3.2)

Where :

b = Face width, mm

$\delta_0 = \dfrac{\text{Permissible stress}}{\text{factor of safety}}$ N/mm^2

C_V = Velocity factor

3.3 SPUR GEAR DESIGN VALUES

3.3.1 LEWIS FORM FACTOR, y

The values of Lewis form factor 'y' may be obtained from the following relations:

$y = 0.124 - 0.684/z$ for 14½°involute full depth ..... (3.3)

$\;\; = 0.154 - 0.912/z$ for 20° involutes full depth ..... (3.4)

Where:

z = number of teeth of gear

From Eqn. (3.3) and (3.4), it is required that the values of $\delta_1 y_1$ and $\delta_2 y_2$ for both the driver and driven gear respectively are computed. The weaker gear will then be used in the design for strength, toughness and wear. If $\delta_1 y_1$ is less than $\delta_2 y_2$, it implies that the values of δ_1 and y_1 are used in the design, otherwise δ_2 and y_2. It should be noted that the amount of force that can be transmitted to a gear tooth is a function of the "δy" product. For two mating gears, the weaker will have the smaller value.

3.3.2 SELECTION OF MODULE, m

Hall et al (1961) stated that the smallest possible module will provide the most economical design. Therefore, the module selected should be as small as possible in order to obtain the best economy. Thus:

$d_1 \quad = mz_1$ ..... (3.5)

$d_2 \quad = mz_2$ ..... (3.6)

where:

d_1 = Driver pitch diameter, mm

d_2 =Driven pitch diameter, mm

z_1 = Driver number of teeth

z_2 = Driven number of teeth

Since the design procedure is one of a trial and error because the size, tooth form and dimensions of the gear must be known before the actual loads and stresses can be determined, it is therefore imperative that the module be varied until the required is chosen.

3.3.3 PITCH LINE VELOCITY, V_m

According to Singh (1997) the pitch line velocity V_m is given as

$V_m \quad = \pi dn/(60x1000)$ ..... (3.7)

Where:

n = rev. / min, rpm

d = Pitch diameter, mm

V_m = Pitch line velocity, m/s

The pitch line velocity can be used to determine the minimum quality of the gear pair. See Table 3.2

Table 3.2: Recommended Speeds of Gear and their Quality

Minimum Quality	*Peripheral Speed of Gears, v, m/s*
5 – 6	15 – 30
6 – 7	7.5 – 15
7 – 8	5 – 7.5
8 – 9	2.5 – 5
10 – 12	below 2.5

Source: *Singh (1997)*

3.3.4 TANGENTIAL FORCE, F_t

The tangential load F_t at the pitch line may be obtained from the power being transmitted. This equation is modified to account for service conditions. Thereby

$F_t = 1000 \times P/(V_m \times K_s)$ ..... (3.8)

Where:

P = Power transmitted, kw

K_s = Service factors

Table 3.3: Service Factor K_S for Spur Gears

TYPE OF LOAD	TYPE OF SERVICE		
	8-10hper day	24h per day	Intermittent 3h/day
Steady	1.00	0.80	1.25
Light Shock	0.80	0.65	1.00
Medium Shock	0.65	0.55	0.80
Heavy Shock	0.55	0.50	0.65

Source: *Singh (1997)*

3.3.5 VELOCITY FACTOR, C_V

Slight accuracies in the tooth profile and tooth spacing, teeth being not absolutely rigid, variations in the applied load and repetitions of the loading cause impact and fatigue stresses that become more severe as the pitch line velocity increases. So the velocity factor C_V allow for additional stresses. This factor according to Singh (1997) is given by:

$$C_V = \frac{3}{3+v_m}$$ for ordinary industrial gas operating at velocity up to 10m/s.

$V_m < 10$m/s. ..... (3.9)

$$C_V = \frac{6.1}{6.1+v_m}$$ for accurately cut gears operating at velocities up to 20m/s.

$10 \le V_m \le 20$m/s ..... (3.10)

$$C_V = \frac{5.56}{5.56+\sqrt{v_m}}$$ for precision gears cut with a high degree of accuracy and operating at velocities of 20m/s and over. $V_m > 20$m/s ....(3.11)

Where: V_m = Pitch line velocity, m/s

3.4 DESIGNS FOR TOOTH DYNAMIC LOADS

Inaccuracies of the tooth profiles, and the deflection of the teeth under load, causes periods of acceleration, inertia forces and impact loads on the teeth with an effect similar to that of a variable load superimposed on a steady load. According to Singh (1997), the maximum instantaneous load (dynamic load) on the tooth, is given by,

$$F_d = F_t + \frac{10Vm(bC + Ft)}{10Vm + 0.474\sqrt{bC + Ft}} \quad ..... (3.12)$$

Where:

F_d = Dynamic load, N

F_t = Tangential force (load), N

b = Face width, mm

C = a constant in N/mm, which depends on the tooth form, material, and the degree of accuracy with which the tooth is cut.

Table 3.6, gives the proper value of C, knowing the maximum error for the various classes of gear cutting. The maximum error that will permit reasonably quiet operation at different pitch-line velocities is given in Table 3.5. Knowing the class of gear cutting required, the probable error can be selected in Table 3.4, and C from Table 3.6 by interpolation.

Table 3.4: Maximum Errors in Action between Gears (mm)

Module, mm	*Class 1, Industrial*	*Class 2, accurate*	*Class 3, precision*
20	0.1219	0.0609	0.0305
12	0.1016	0.0508	0.0254
8	0.0813	0.0406	0.0203
6	0.0660	0.0330	0.0165
5	0.0559	0.0274	0.0139
4 and less	0.0508	0.0254	0.0127

Source: *Singh (1997)*

Table 3.5: Maximum Allowable Errors in Action between Gears for Quiet Operation

V_m, *m/s*	*Error, mm max*	V_m, *m/s*	*Error, mm max*
1.25	0.0925	12.50	0.0300
2.50	0.0800	13.75	0.0250
3.75	0.0700	15.00	0.0225
5.00	0.0600	16.25	0.0200
6.25	0.0525	17025	0.0175
7.50	0.0475	20.00	0.0150
8.75	0.0425	22.50	0.0140
10.00	0.0375	25 & over	0.0125
11.25	0.0325		

Source: *Singh (1997)*

Table 3.6: Values of the Dynamic Factor C in N/mm

Materials	Tooth form	Errors in gears, mm					
		0.0125	*0.0250*	*0.0500*	*0.0750*	*0.1000*	*0.1250*
Cast iron & cast iron	14½°full depth	69.85	139.70	279.40	419.10	558.80	698.80
Cast iron & steel	14½°full depth	96.04	192.08	384.16	576.34	768.32	960.40
Steel & steel	14½°full depth	139.70	279.40	558.80	838.20	1117.60	1397.00
Cast iron & cast iron	20° full depth	72.50	145.00	290.00	435.00	580.00	726.00
Cast iron & steel	20° full depth	99.57	199.14	398.28	597.42	796.56	995.70
Steel & steel	20° full depth	145.00	290.00	580.00	870.00	1116.00	1450.00
Cast iron & cast iron	20° stub	75.05	150.10	300.20	450.30	600.40	750.00
Cast iron & steel	20° stub	103.01	206.02	412.04	618.06	824.08	1030.10
Steel & steel	20° stub	150.10	300.20	600.40	900.60	1200.80	1501.00

Source: *Singh (1997)*

3.5 DESIGNS FOR WEAR TOOTH LOADS

The load limit for wear is determined by the surface endurance limit of the material, the curvature of the surface, and the relative hardness of the surfaces. The pinion should always be harder to allow for work-hardening of the gear, to preserve the involute profile, to allow for greater abrasive wear on the pinion, and to decrease the possibility of seizing. To insure the durability of a gear pair, Singh (1997) argued that the tooth profile must not have excessive Contact Stress as determined by the wear load F_w.

$$F_w = d_1 bQK$$

$$= \pi \delta_{es}^2 b\sin\alpha / 2[d_1 d_2/(d_1+d_2)][(1-\nu_1^2)/E_1 + (1-\nu_2^2)/E_2] \quad \text{..... (3.13)}$$

But $v_p = v_g = 0.3$ for most metal gears. Therefore:

$$1 - v^2_p = 1 - v^2_g = 1 - (0.3)^2 = 0.91$$

$$F_w = \delta_{es}^2 \, b\sin\alpha/1.4[2d_1d_2/(d_1+d_2)][1/E_1 + 1/E_2] \quad \text{..... (3.14)}$$

$$K = \delta_{es}^2 \sin\alpha/1.4[1/E_1 + 1/E_2]$$

$$Q = 2d_2/(d_1+d_2) = 2z_2/(z_1+z_2)$$

$$b = 3\pi m \text{ to } 4\pi m$$

where:

α = pressure angle deg.

b = face width of gear, mm

δ_{es} = surface endurance limit of gear pairs, N/mm^2

d_1 = pitch diameter of smaller (pinion) gear, mm

z_2 = number of teeth on gear (driven)

z_1 = number of teeth on pinion (driver)

E_1 = modulus of elasticity on the pinion material, N/mm^2

E_2 = modulus of elasticity on the gear material, N/mm^2

The modulus of elasticity and poisson's ratio of the materials can be found in Table 3.7.

Table 3.7: Modulus of Elasticity and Poisson's Ratio

Material	*Modulus of Elasticity MPa (N/mm^2)*	*Poisson's Ratio*
Steel	205000	0.3
Cast steel	202000	0.3
Cast iron	115000	0.3
Wrought iron	205000	0.3
Cast tin bronze	103000	0.3
Tin bronze	113000	0.3
Grey cast iron	118000	0.3

Source: *Bureau of India Standards, BIS (1995)*

For steel gears, the appropriate value of δ_{es} is given by

$$\delta es \quad = [2.76(HB) - 68.96] \text{ N/mm}^2. \qquad \text{..... (3.15)}$$

Where:

HB = Brinell hardness.

It has been observed that the value of F_w must not be less than the value of F_d. if otherwise, then the hardness of the designed gear is increased by equating $F_w = F_d$, to find the desired value of δ_{es} and HB.

3.6 DESIGN TO AVOID INTERFERENCE

Under certain conditions involute profiles overlap or cut into the mating teeth. This interface can be avoided if the maximum addendum radius r_a for each gear is equal or less than "μ"

$$\mu \quad = \quad \sqrt{r_b^2 + a^2(\sin\alpha)^2} \qquad \text{......(3.16)}$$

where:

a = center distance, mm

r_b = radius of base circle, mm

α = pressure angle deg.

Interference will occur when the actual addendum circle radius exceeds the value as calculated by Eqn. (3.16).

CHAPTER FOUR

4.0 SOFTWARE DEVELOPMENT AND RESULTS OF CASE STUDIES

4.1 CADGEAR '2003 SOFTWARE SYSTEM DESIGN

A number of clearly defined and identifiable steps that are always involved in software programming process and provide a convenient framework for studying these processes are considered in developing the Computer – Aided Design for Spur Gears Software (CADGEAR '2003). These steps are to:

- Define the problem,
- Plan a solution,
- Implement the solution, and
- Maintain the program.

4.1.1 PROBLEM DEFINITION

The problem at hand was carefully and thoroughly analyzed. A skeletal layout was carried out and later modified and optimized which resulted in the development of a finished design program used to compute data for gear system.

Design Procedure

The following procedure usually give good results:

1. The required power, revolutions per minute, velocity ratio and centre distance are used to obtain values for the gear diameters, tangential force, pitch line velocity and the class of gear.

   (i) Calculate F_t from the Eqn. (3.8) and service factor from Table 3.3.

(ii) Pitch-line Velocity V_m from Eqn. (3.7). See Table 3.2 for recommended speed.

2. The dynamic effect on gear teeth, due to such factors as inaccurately cut teeth, improper tooth spacing, improper mounting deflections due to elasticity of the gears and shaft and irregular load requirements must be taken into account in this preliminary stage.

(i) Calculate the face width from Eqn. (3.2) by accounting for velocity factor Cv from Eqn. (3.9), (3.10), or (3.11). For permissible stress, see Table 2.4. The weaker pinion (Driver) or gear (Driven) shall have lower value of δy.

(ii) Calculate dynamic load F_d from Eqn. (3.12).

(iii) Calculate wear load F_w from Eqn. (3.14).

(iv) Check wear load $F_w \geq F_d$, otherwise increase the hardness of the pinion or Driver.

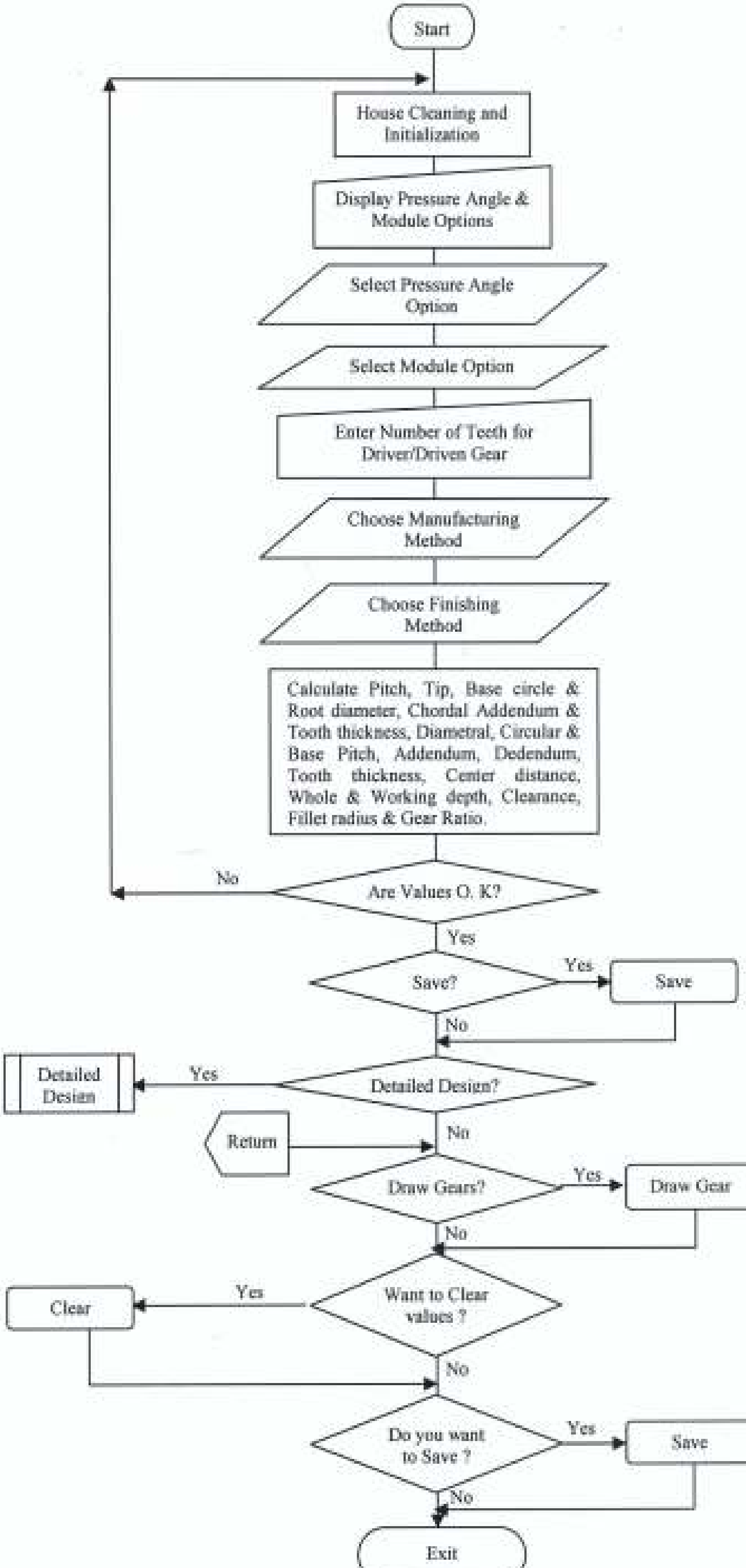
3. Face width should lie between 3πm to 4πm.

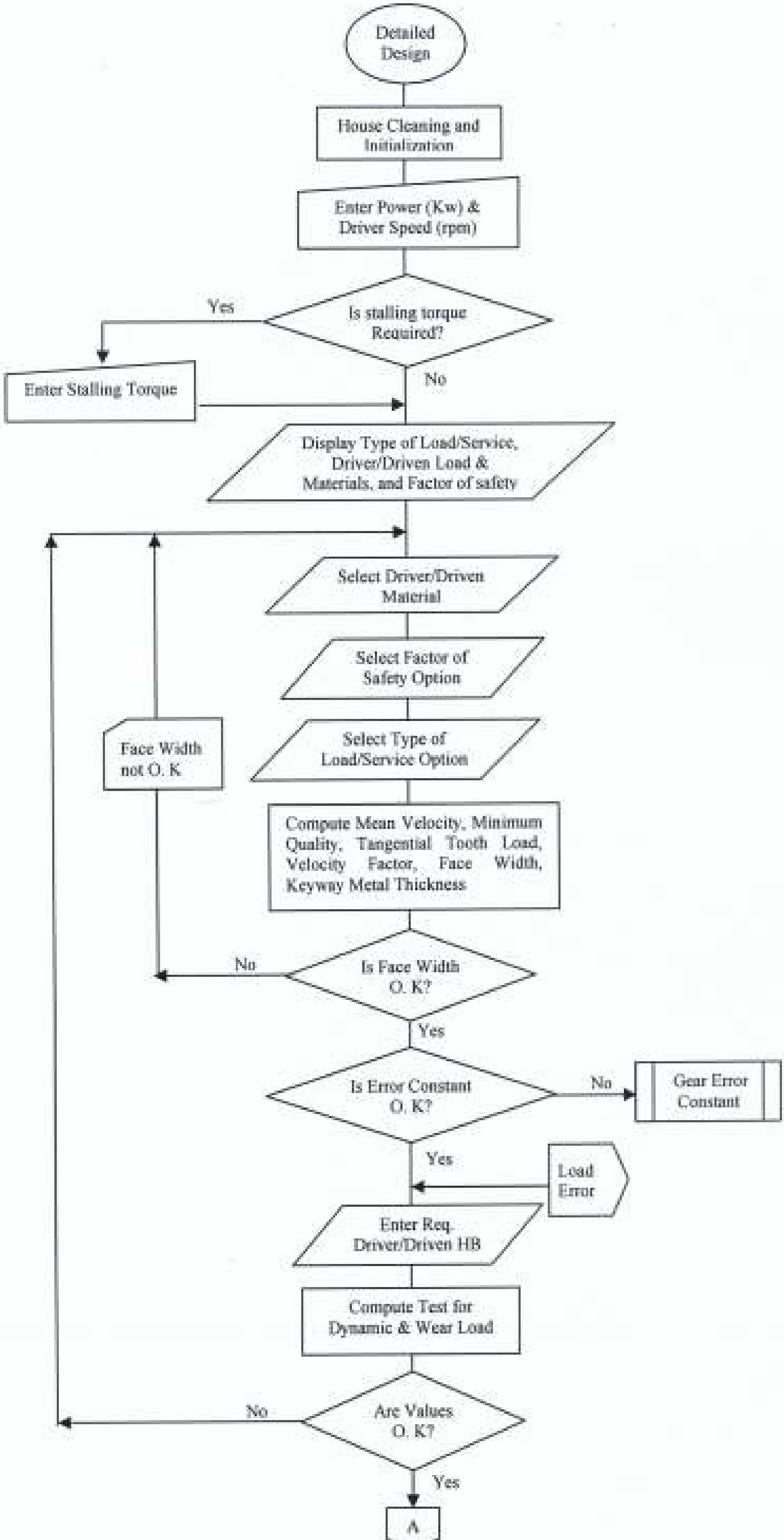
4. The minimum number of teeth for standard gears is usually taken as 18, although for high loads, as few as 14 may be permitted.

5. Calculate gear dimensions.

4.1.2 PLANNING AND DEVELOPMENT OF FLOWCHART

Planning is a more detailed step. A detailed set of specifications were developed resulting into the establishment of a program. Thus, the planning was subdivided into a number of separate rules; known as algorithm for computing gear system. This algorithm was later developed into a graphical representation known as flowchart.


Start
House Cleaning and Initialization
Display Pressure Angle & Module Options
Select Pressure Angle Option
Select Module Option
Enter Number of Teeth for Driver/Driven Gear
Choose Manufacturing Method
Choose Finishing Method
Calculate Pitch, Tip, Base circle & Root diameter, Chordal Addendum & Tooth thickness, Diametral, Circular & Base Pitch, Addendum, Dedendum, Tooth thickness, Center distance, Whole & Working depth, Clearance, Fillet radius & Gear Ratio.
No
Are Values O. K?
Yes
Save?
Yes
Save
No
Detailed Design
Yes
Detailed Design?
Return
No
Draw Gears?
Yes
Draw Gear
No
Clear
Yes
Want to Clear values ?
No
Do you want to Save ?
Yes
Save
No
Exit



Detailed Design
House Cleaning and Initialization
Enter Power (Kw) & Driver Speed (rpm)
Is stalling torque Required?
Yes
No
Enter Stalling Torque
Display Type of Load/Service, Driver/Driven Load & Materials, and Factor of safety
Select Driver/Driven Material
Select Factor of Safety Option
Select Type of Load/Service Option
Face Width not O. K
Compute Mean Velocity, Minimum Quality, Tangential Tooth Load, Velocity Factor, Face Width, Keyway Metal Thickness
Is Face Width O. K?
No
Yes
Is Error Constant O. K?
No
Gear Error Constant
Yes
Load Error
Enter Req. Driver/Driven HB
Compute Test for Dynamic & Wear Load
Are Values O. K?
No
Yes
A

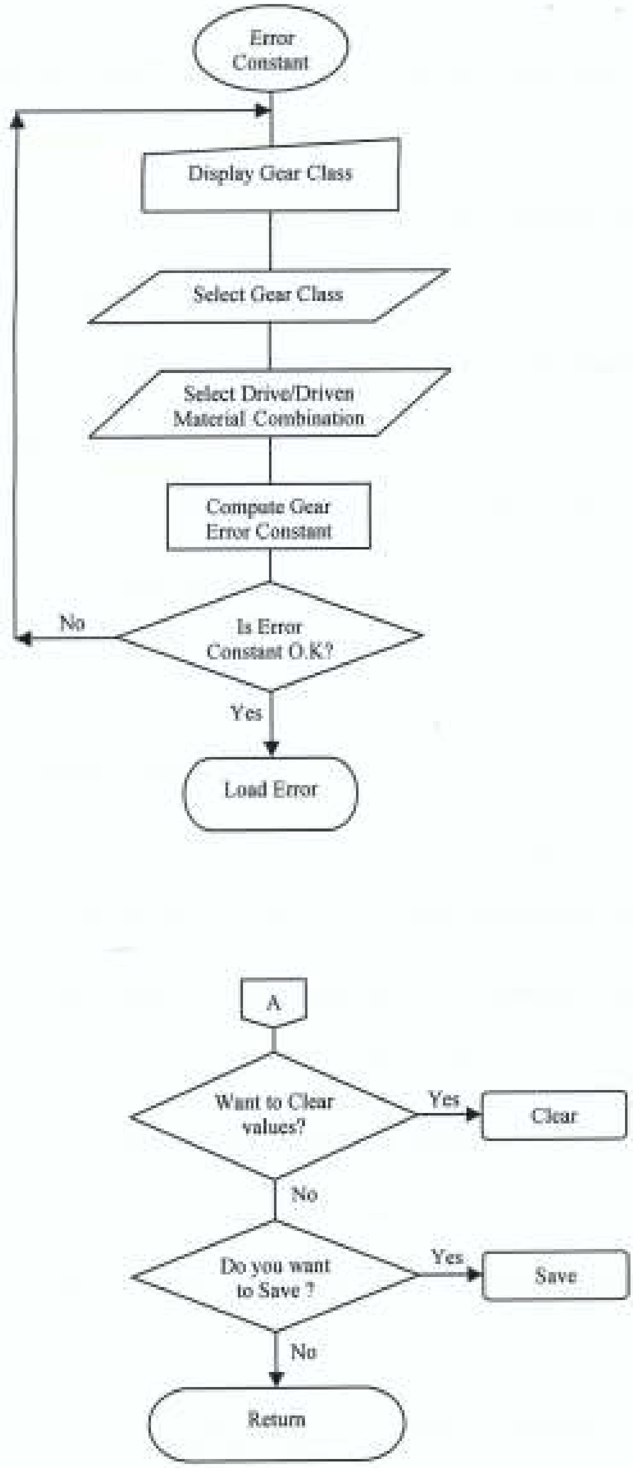


Fig 4.1: Flowchart Showing the Algorithm of Spur Gear Design

4.1.3 IMPLEMENTATION AND CHOICE OF PROGRAMMING LANGUAGE

(a) Implementation

The Implementation involves the execution of the planned program earlier developed. This was achieved by:

- Writing a computer program in an acceptable High Level Programming Language which is *user-friendly* and *menu-driven*.
- Using all available input medium like the mouse and keyboard in activating menus, command buttons, and selections.
- Executing the program.

(b) Choice of programming Language

In developing this project software, a particular high level programming language was carefully considered (Visual Basic Programming Language) based on the following:

(a) It is a very powerful language, versatile enough to be useful to a broad range of programmers – from beginner to seasoned professional.

(b) It is very effective; it brings a high degree of automatic programming to ones finger tips. Thus, you can do a lot with less coding.

(c) You can exploit the labour-saving nature of Visual Basic to implement a program quickly.

(d) Visual Basic Programming Language been an Object – Oriented Language (OOL) is easy to learn.

(e) The program allows the use and development of scientific functions.

(f) The compiler to compile the source code into an executable program is readily available and this will allow the developed program to run on its own.

4.1.4 MAINTENANCE OF PROGRAM

The maintenance of the designed program was realized by checking logic, securing, modifying and reviewing the program. A creative judgment was used in evaluating the results.

4.2 SOFTWARE DEVELOPMENT

4.2.1 DESIGN OF CADGEAR '2003

CADGEAR '2003 is an ellipsis for Computer-Aided Design for Spur Gear developed during the time of this project. The design of CADGEAR '2003 was prepared in two phases.

Phase 1: This involves the development of a flowchart taking into consideration all theories, tasks, processes and activities related to gear design and drafting. The flowchart showing the graphical representation of the algorithm developed is revealed in Fig. 4.1.

Phase 2: This involves the coding of the flowchart into a programming language which will enable the user to perform repetitive spur gear design task. The coded program is used to determine the planned gear parameters and drawings. This was achieved by creating a user interface, setting object properties and writing of codes. The set of instructions written, allow the software to accept variety of inputs. This program is found in Appendix A.

These inputs consist of parameters like *module, driver/driven teeth number, gear material, pressure angle, power, driver speed,* etc. The software accepts the input, process it, and display the output on the screen. The result can be stored in a file or database depending on the spur gear designer (end-user).

4.2.2 CADGEAR '2003 SOFTWARE

The CD – ROM accompanying this project includes the CADGEAR '2003 Software. It can be found in Appendix B. This software can better evaluate the CADGEAR '2003 software environment. However, it cannot create executable files (.exe) without permission from the research.

4.2.3 CADGEAR '2003 CD – ROM Installation

Windows 95/98/2000/XP Professional Installation Instructions

- Insert the CD – ROM disc into your CD – ROM drive.
- From the Windows 95/98/2000/XP Professional desktop, double-click on the 'My Computer' icon.
- Double-click on the icon representing your CD – ROM drive.
- Double-click on the icon titled START.EXE or CADGEAR '2003 to run the CD – ROM interface.

Alternatively,

- Insert the CD – ROM disc into your CD – ROM drive.
- Click the Start button on your desktop.
- Click on the run program to open a program, folder or document.
- Click the BROWSE button to select CADGEAR '2003 program.
- Click OK to commence installation.

Note: *If Windows 95/98/2000 or XP Professional is installed on your computer and you have the AutoPlay feature enable, the* START.EXE or CADGEAR '2003 program *starts automatically whenever you insert the disc into your* CD – ROM *drive.*

4.3 CASE STUDIES

4.3.1 MANUAL PROBLEM SOLVING METHOD

Case One

It is desired to determine the proportions of a spur gear drive to transmit 8kw from a shaft rotating at 1200rpm to a low speed shaft, with a reduction of 3:1. Assume that the teeth are 20 degree full depth involute, with 24 teeth on the driver (pinion). The driver is to be of 40C8 normalized steel and driven (gear) of 30C8 normalized steel. Assume that the stalling torque is 130 percent of the rated torque.

Source: *Singh (1997)*

Solution

- From Table 2.4, we get

Material	Condition (finished gear)	Minimum Tensile Strength δ (N/mm^2)	Brinell Hardness (HB)	Basic Surface Stress Factor S_c	Basic Bending Stress Factor S_b
Driver 40C8	N	568.8	152	1.125	14.05
Driven 30C8	N	490.3	143	0.985	11.95

Number of Teeth

Since the shaft reduction is 3:1, let

z_1 = 24

z_2 = 24 x 3 = 72

δ_1 = 568.8 N/mm^2

δ_2 = 490.3 N/mm^2

Lewis Form Factor

Using Eqn. 3.4;

y = 0.154 – 0.912/z   for 20° involute full depth,

$y_1 \quad = 0.154 - (0.912/24) = 0.116$

$y_2 \quad = 0.154 - (0.912/72) = 0.141$

$\delta_1 y_1 \quad = 568.8 \times 0.116 = 65.98$

$\delta_2 y_2 \quad = 490.3 \times 0.141 = 69.13$

As $\delta_1 y_1 < \delta_2 y_2$ Therefore, driver is the weaker and hence will be the basis for the design.

Selection of Module m

Let us assume module, m = 3mm. Then from Eqn. 3.5 and 3.6;

$d_1 \quad = mz_1 = 3 \times 24 = 72mm$

$d_2 \quad = mz_2 = 3 \times 72 = 216mm$

Pitch Line Velocity, V_m

From Eqn. 3.7;

$V_m \quad = \pi d_1 n_1/(60 \times 1000)$

$= \pi \times 72 \times 1200/(60 \times 1000)$

$= 4.52m/s$

From Table 3.2, we find that for peripheral speed lying between 2.5 to 5 m/s, the minimum quality of gear pair is 8 to 9.

Tangential Force, F_t

Assuming 8-10hrs service per day and steady load, the service factor K_s = 1.00 from Table 3.3. The stalling torque is also 130%. Therefore from Eqn. 3.8,

$F_t \quad = 1000 \times P/(V_m \times K_s)$

$= 1000 \times 8 \times 1.3/(4.52 \times 1)$

$= 2300.88N$

Velocity Factor, Cv

From Eqn. 3.9,

$C_V \quad = 3/(3+V_m)$ for ordinary industrial gas operating at velocity up to 10m/s.

$V_m < 10m/s.$

=3/(3+4.52)

=0.399

Face Width, b

Using a factor of safety of 3, From Eqn. 3.2;

F_t = $\delta_o by\pi m\ C_V$

2300.88=(568.8/3) x b x π x 0.116 x 3 x 0.399

b =27.82mm

≅28mm

Face width should lie between 9m = 27mm and 13m = 39mm. Hence the face width is satisfactory.

Dynamic Load, F_d

From Eqn. 3.12;

$$F_d = F_t + \frac{10Vm(bC + Ft)}{10Vm + 0.474\sqrt{bC + Ft}}$$

For m=3, the error in action Table 3.4, for Class 2 accurate gears is 0.0254mm. The value of C from Table 3.6, for steel and steel and 20° full depth tooth profile by interpolation is 294.64 N/mm. Therefore;

$$F_d = 2300.88 + \frac{10x4.52(28x294.64 + 2300.88)}{10x4.52 + 0.474\sqrt{28x294.64 + 2300.88}}$$

= 7380.30N

Wear Load, F_w

From Eqn. 3.14

F_w = δ_{es}^2 bsinα/1.4[$2d_1d_2/(d_1+d_2)$][$1/E_1 + 1/E_2$]

δ_{es} = 2.76HB – 68.96

= (2.76 x 152) – 68.96

= 350.56 N/mm^2

From Table 3.7;

E_1 = E_2 = 2.05 x 10^5 N/mm^2

F_w $= (350.56)^2 \times 28 \times \sin 20^0/1.4\ [(2\text{x}72\text{x}216)/(72+216)][2/2.05 \times 10^5]$

$=885.74$N

As $F_w < F_d$, therefore equating $F_w = F_d$, we find that the desired value of

δ_{cr} $=1011.92$ N/mm^2

HB $= 391.62$

The hardness of the driver shall have to be increased to approximately 400HB.

Geometric Values of Spur tooth

Addendum. From Eqn. 2.5

λ_a $= m = 3$mm

Dedendum. From Eqn.2.7

λ_f $= 1.25$m for 20° full depth involutes

$= 1.25 \times 3$

$= 3.75$mm

Tooth Thickness. From Eqn. 2.10

s $= \pi m/ 2$

$= \pi \times 3/2$

$= 4.71$mm

Center distance. From Eqn. 2.11

a $= {}^1/_2\, m\, (z_1+z_2)$

$= {}^1/_2 \times 3\text{x}\ (24 + 72)$

$= 144$mm

Fillet radius. From Eqn. 2.23

r $= 0.375$m

$= 0.375 \times 3$

$= 1.125$mm

Clearance. From Eqn. 2.15

c $= 0.25$m for 20° full depth involutes

$= 0.25 \times 3$

$= 0.75$mm

Working depth. From Eqn. 2.14

$h' = 2m$

$= 2 \times 3$

$= 6mm$

Whole depth. From Eqn. 2.12

$\lambda_p = 2.25m$ for 20° full depth involutes

$= 2.25 \times 3$

$= 6.75mm$

Tip diameter. From Eqn. 2.8

$d_{a1} = m(z_1 + 2)$

$= 3(24 + 2)$

$= 78mm$

$d_{a2} = m(z_2 + 2)$

$= 3(72 + 2)$

$= 222mm$

Root diameter. From Eqn. 2.9

$d_{f1} = m(z_1 - 2.5)$

$= 3 \times (24 - 2.5)$

$= 64.5mm$

$d_{f2} = m(z_2 - 2.5)$

$= 3 \times (72 - 2.5)$

$= 208.5mm$

Pitch diameter. From Eqn. 2.2

$d_1 = z_1 m$

$= 24 \times 3$

$= 72mm$

$d_2 = z_2 m$

$= 72 \times 3$

$= 216mm$

Case Two

A pair of gears is to be designed to transmit 30kw for a driver (pinion) speed of 1000 rpm and a speed ratio of 1:5. Design the gear pair assuming that the teeth are 20 degree full depth involute, with 18 teeth on the driver (pinion).

Source: *Singh (1997)*

Solution

- The speed of rotation of the pinion is less than 3600 rpm, therefore, we select spur gears for the drive.
- The speed ratio is less than 4, therefore, from Table 2.3, a possible combination of materials for driver (pinion) and driven (gear) may be 40 Cr 4 and 55C respectively.
- From Table 2.4, we get

Material	Condition (finished gear)	Minimum Tensile Strength δ (N/mm^2)	Brinell Hardness (HB)	Basic Surface Stress Factor S_c	Basic Bending Stress Factor S_b
Driver 40Cr 8	H + T	784.5	229 min	1.90	19.70
Driven 55C	-	784.5	248	2.11	19.70

- From Table 2.2, we find that for driven (gear) hardness of 245, the driver (pinion) hardness must not be less than 285.

Number of Teeth

Since the speed ratio is 1:5, let

$z_1 \quad = 18$

$z_2 \quad = 18 \times 5 = 90$

$\delta_1 \quad = \delta_2 \quad = 784.5 \text{ N/mm}^2$

Lewis Form Factor

Using Eqn. 3.4;

$y \quad = 0.154 - 0.912/z$ for 20° involute full depth,

$y_1 \quad = 0.154 - (0.912/18) = 0.103$

$y_2 \quad = 0.154 - (0.912/90) = 0.144$

$\delta_1 y_1 \quad = 784.5 \times 0.103 = 80.80$

$\delta_2 y_2 \quad = 784.5 \times 0.144 = 112.97$

As $\delta_1 y_1 < \delta_2 y_2$ Therefore, driver is the weaker and hence will be the basis for the design.

Selection of Module m

Module should be as small as possible in order to obtain the best economy. Let us assume module, m = 5mm. Then from Eqn. 3.5 and 3.6;

$d_1 \quad = mz_1 = 5 \times 18 = 90mm$

$d_2 \quad = mz_2 = 5 \times 90 = 450mm$

Pitch Line Velocity, V_m

From Eqn. 3.7;

$V_m \quad = \pi d_1 n_1/(60 \times 1000)$

$= \pi \times 90 \times 1000/(60 \times 1000)$

$= 4.71m/s$

From Table 3.2, we find that for peripheral speed laying between to 5 m/s, the minimum quality of gear pair is 8 to 9.

Tangential Force, F_t

Assuming 8-10hrs service per day and light shock load, the service factor $K_s = 0.80$ from Table 3.3. Therefore from Eqn. 3.8,

$F_t \quad = 1000 \times P/(V_m \times K_s)$

$= 1000 \times 30/(4.71 \times 0.8)$

$= 7961.78N$

$\cong 7962N$

Velocity Factor, Cv

From Eqn. 3.9,

$Cv \quad = 3/(3+V_m)$ for ordinary industrial gas operating at velocity up to 10m/s.

$V_m < 10m/s$.

$=3/(3+4.71)$

$=0.389$

Face Width, b

Factor of safety for steady load on a single pair is 3. From Eqn. 3.2;

$F_t \quad = \delta_o b y \pi m\, C_V$

$7962 \quad =(784.5/3) \times b \times \pi \times 0.103 \times 5 \times 0.389$

$b \quad =48.38mm$

$\cong 48mm$

The Face width should lie between 9m = 45mm and 13m = 65mm. Hence the face width is satisfactory.

Dynamic Load, F_d

From Eqn. 3.12;

$$F_d = F_t + \frac{10Vm(bC + Ft)}{10Vm + 0.474\sqrt{bC + Ft}}$$

For m=5, the error in action Table 3.4, for Class 1 industrial gears is 0.0559mm. The value of C from Table 3.6, for steel and steel and 20° full depth tooth profile by interpolation is 648.44 N/mm. Therefore;

$$F_d = 7962 + \frac{10x4.71(48x648.44 + 7962)}{10x4.71 + 0.474\sqrt{48x468.44 + 7962}}$$

$= 21036.19N$

Wear Load, F_w

From Eqn. 3.14,

$F_w \quad = \delta_{es}^2\, b\sin\alpha/1.4[2d_1d_2/(d_1+d_2)][1/E_1 + 1/E_2]$

$\delta_{es} \quad = 2.76HB - 68.96$

$= (2.76 \times 290) - 68.96$

$= 731.44\ N/mm^2$

From Table 3.7;

$E_1 \quad = E_2 = 2.05 \times 10^5\ N/mm^2$

F_w $= (731.44)^2 \times 48 \times \sin 20^0/1.4\ [(2x90x450)/(90+450)][2/2.05 \times 10^5]$

$=9180.99N$

As $F_w < F_d$, therefore equating $F_w = F_d$, we find that the desired value of

δ_{es} $=1095.82\ N/mm^2$

HB $= 423.$

The hardness of the driver shall have to be increased to approximately 423HB.

Geometric Values of Spur tooth

Addendum. From Eqn. 2.5

λ_a $= m = 5mm$

Dedendum. From Eqn. 2.7

λ_f $= 1.25m$ for 20° full depth involutes

$= 1.25 \times 5$

$= 6.25mm$

Tooth Thickness. From Eqn. 2.10

s $= \pi m/ 2$

$= \pi \times 5/2$

$= 7.85mm$

Center Distance. From Eqn. 2.11

a $= {}^1/_2\ m\ (z_1+z_2)$

$= {}^1/_2 \times 5 \times (18 + 90)$

$= 270mm$

Fillet radius. From Eqn. 2.23

r $= 0.375m$

$= 0.375 \times 5$

$= 1.875mm$

Clearance. From Eqn. 2.15

c $= 0.25m$ for 20° full depth involutes

$= 0.25 \times 5$

$= 1.25mm$

Working depth. From Eqn. 2.14

h' $= 2m$

$= 2 \times 5$

$= 10mm$

Whole depth. From Eqn. 2.12

λ_p $= 2.25m$ for 20° full depth involutes

$= 2.25 \times 5$

$= 11.25mm$

Tip diameter. From Eqn. 2.8

d_{a1} $= m(z_1 + 2)$

$= 5(18 + 2)$

$= 100mm$

d_{a2} $= m(z_2 + 2)$

$= 5(90 + 2)$

$= 460mm$

Root diameter. From Eqn. 2.9

d_{f1} $= m(z_1 - 2.5)$

$= 5 \times (18 - 2.5)$

$= 77.5mm$

d_{f2} $= m(z_2 - 2.5)$

$= 5 \times (90 - 2.5)$

$= 437.5mm$

Pitch diameter. From Eqn. 2.2

d_1 $= z_1m$

$= 18 \times 5$

$= 90mm$

d_2 $= z_2m$

$= 90 \times 5$

$= 450mm$

4.3.2 CADGEAR '2003 APPLICATION TO PROBLEM

CADGEAR' 2003 can precisely determine the following results generated for spur gear geometric parameters and detailed design and save them in the hard disk as shown in Tables 4.1, 4.2, 4.3 and 4.4 respectively. The software automatically draws a 2D driver and driven gear. Reference should be made to Chart 4.1 through Chart 4.8, for details.

Table 4.1: Case One Spur Gears Geometric Parameters

Date =Tuesday,September05,2006 Time =04:31:35AM

This is the result of Designed Driver/Driven

ITEMS	Driver	Driven
Pitch Diameter	72 . mm	216 . mm
Teeth Number	24	72
Tip Diameter	78 . mm	222 . mm
Base Circle Diameter	67 .66 mm	202 .97 mm
Root Diameter	64 .5 mm	208 .5 mm
Chordal Addendum	3 .08 mm	3 .03 mm
Chordal Tooth Thickness	4 .71 mm	4 .71 mm

	Driver/Driven General Data 1
Diametral Pitch	.33 mm
Circular Pitch	9 .42 mm
Base Pitch	8 .86 mm
Addendum	3 . mm
Dedendum	3 .75 mm
Tooth Thickness	4 .71 mm
Center Distance	144 . mm
Whole Depth	6 .75 mm
Working Depth	6 . mm
Clearance	.75 mm
Fillet Radius	1 .13 mm
Gear Ratio	3 .
Module	3mm
Pressure Angle	20deg
Manufacturing Method	Generating Hob
Finishing Method	Grinding

Table 4.2: Case One Detailed Design for Spur Gears

Date =Tuesday,September05,2006 Time =04:31:16AM

This is the result of Detailed Driver/Driven Gear

ITEMS	Driver	Driven
Materials	40C8	30C8
Min. Tensile Strength	568.8MPa	490.3MPa
Brinell Hardness,HB	152	143
HB Condition		
Modulus of Elasticity	205000MPa	205000MPa
Finished Condition	N	N
Surface Stress Factor	1.125	0.985
Bending Stress Factor	14.05	11.95

	Driver/Driven General Data 2
Power,P	8kw
Pinion Speed,n1	1200rev./min
Service Factor,Ks	1.00
Factor of Safety	3
Stalling Torque	130%
Dynamic Factor,C	294 .64 N/mm
Mean Velocity	4 .52 m/s
Tangential Tooth Load	2,298.91 N
Keyway Metal Thickness	6.57 mm
Minimum Quality	8 - 9
Velocity factor	.399
Face width	28 mm
Required HB	391.61
Dynamic Load	7,379.89 N
Wear Load	885.74 N

H -Hardened, T -Tempered, N -Normalized

Chart 4.1: Case One Screen Output for Spur Gear Geometric Parameters

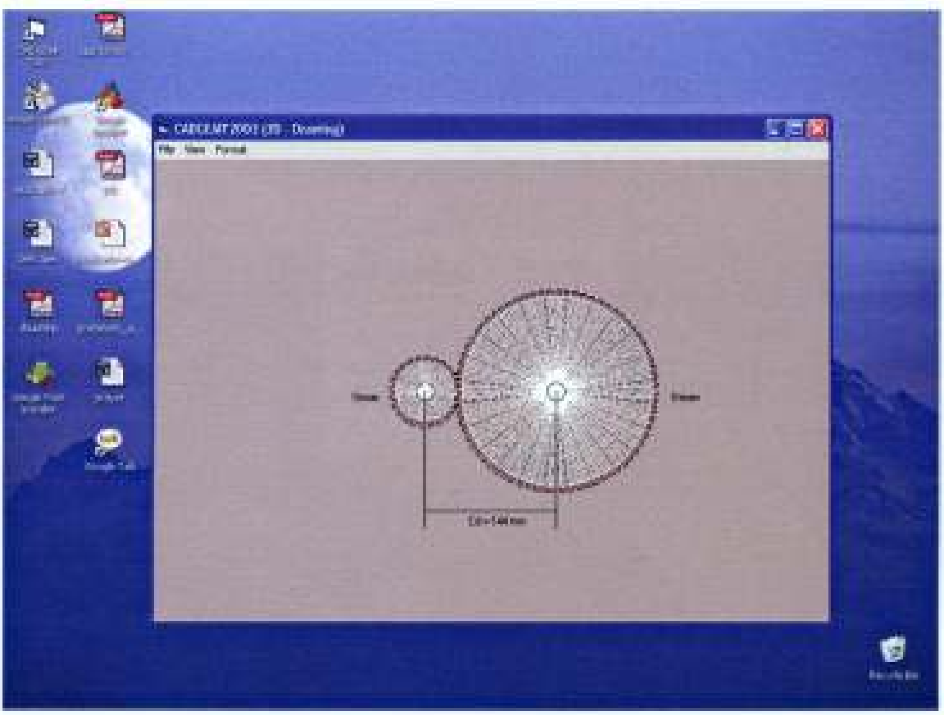


Chart 4.2: Case One "2D – Drawing" of the Driver/Driven Spur Gear Screen

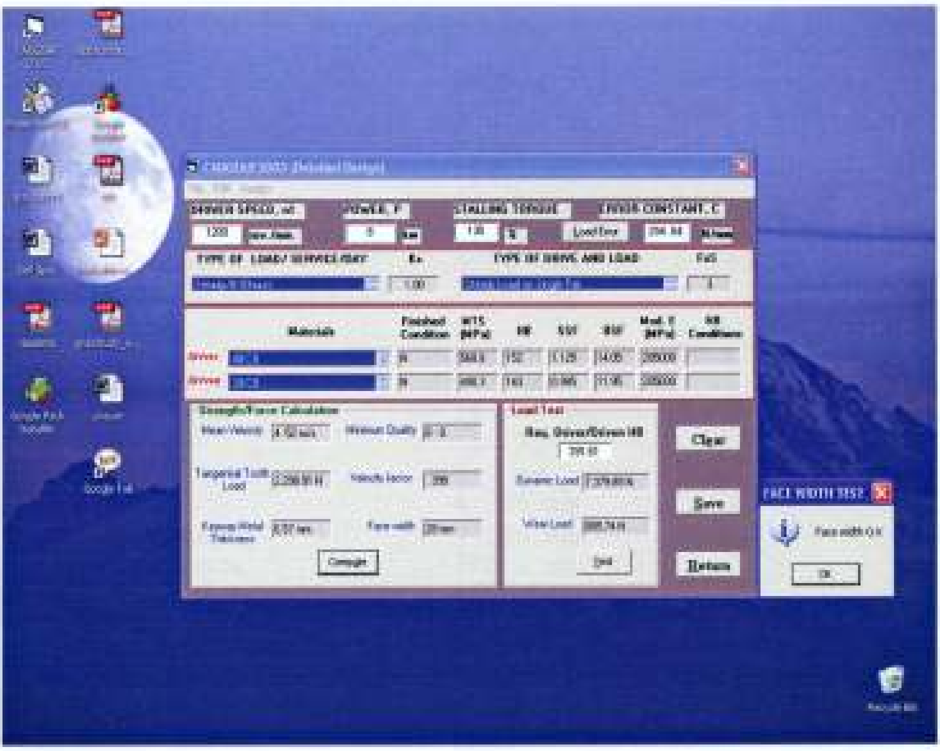


Chart 4.3: Case One Screen Output for Detailed Design

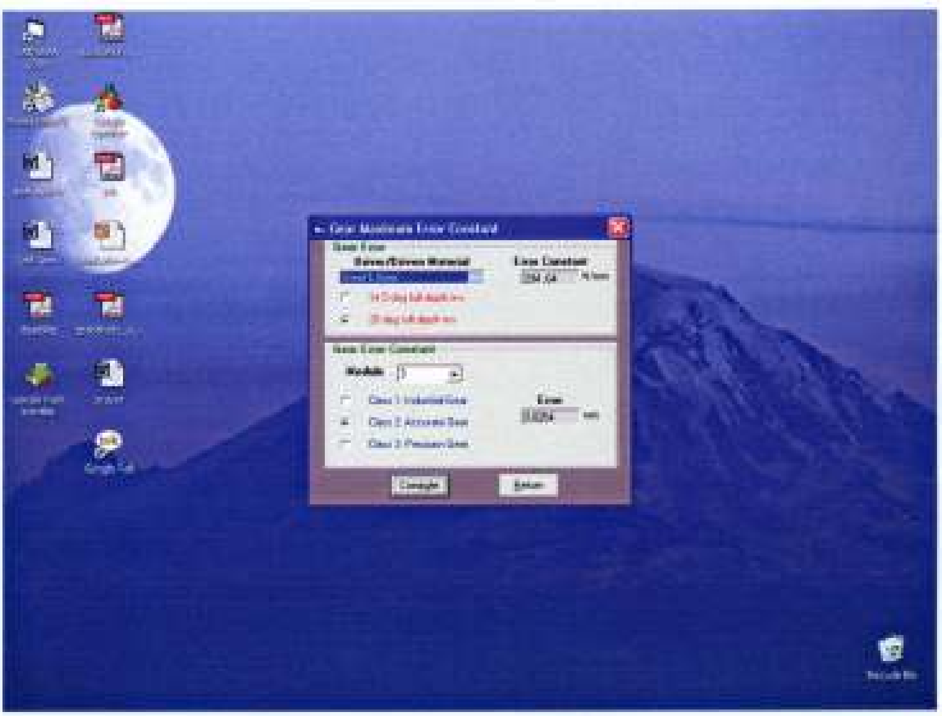


Chart 4.4: Case One Screen Out for Error Constant Generated

Table 4.3: Case Two Spur Gears Geometric Parameters

Date =Tuesday,September12,2006 Time =08:34:47AM

This is the result of Designed Driver/Driven

ITEMS	Driver	Driven
Pitch Diameter	90 . mm	450 . mm
Teeth Number	18	90
Tip Diameter	100 . mm	460 . mm
Base Circle Diameter	84 .57 mm	422 .86 mm
Root Diameter	77 .5 mm	437 .5 mm
Chordal Addendum	5 .17 mm	5 .03 mm
Chordal Tooth Thickness	7 .84 mm	7 .85 mm

	Driver/Driven General Data 1
Diametral Pitch	.2 mm
Circular Pitch	15 .71 mm
Base Pitch	14 .76 mm
Addendum	5 . mm
Dedendum	6 .25 mm
Tooth Thickness	7 .85 mm
Center Distance	270 . mm
Whole Depth	11 .25 mm
Working Depth	10 . mm
Clearance	1 .25 mm
Fillet Radius	1 .88 mm
Gear Ratio	5 .
Module	5mm
Pressure Angle	20deg
Manufacturing Method	Generating Hob
Finishing Method	Lapping

Table 4.4: Case Two Detailed Design for Spur Gears

Date =Tuesday,September12,2006 Time =08:34:40AM

This is the result of Detailed Driver/Driven Gear

ITEMS	Driver	Driven
Materials	40Cr4	55C
Min. Tensile Strength	784.5MPa	784.5MPa
Brinell Hardness,HB	229	248
HB Condition	min	
Modulus of Elasticity	205000MPa	205000MPa
Finished Condition	H+T	None
Surface Stress Factor	1.9	2.11
Bending Stress Factor	19.7	19.7
	Driver/Driven General Data 2	
Power,P	30kw	
Pinion Speed,n1	1000rev./min	
Service Factor,Ks	0.80	
Factor of Safety	3	
Stalling Torque	%	
Dynamic Factor,C	648 .44 N/mm	
Mean Velocity	4 .71 m/s	
Tangential Tooth Load	7,957.75 N	
Keyway Metal Thickness	9.49 mm	
Minimum Quality	8 - 9	
Velocity factor	.389	
Face width	48 mm	
Required HB	426.13	
Dynamic Load	21,035.41 N	
Wear Load	6,501.55 N	

H -Hardened, T -Tempered, N -Normalized

Chart 4.5: Case Two Screen Output for Spur Gear Geometric Parameters

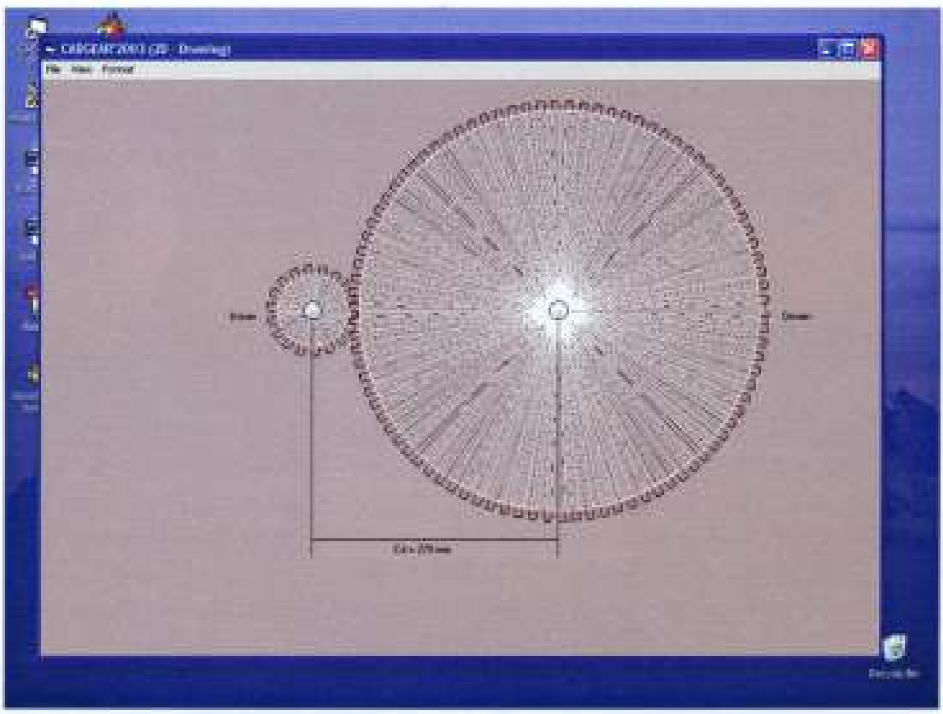


Chart 4.6: Case Two "2D – Drawing" of the Driver/Driven Spur Gear Screen

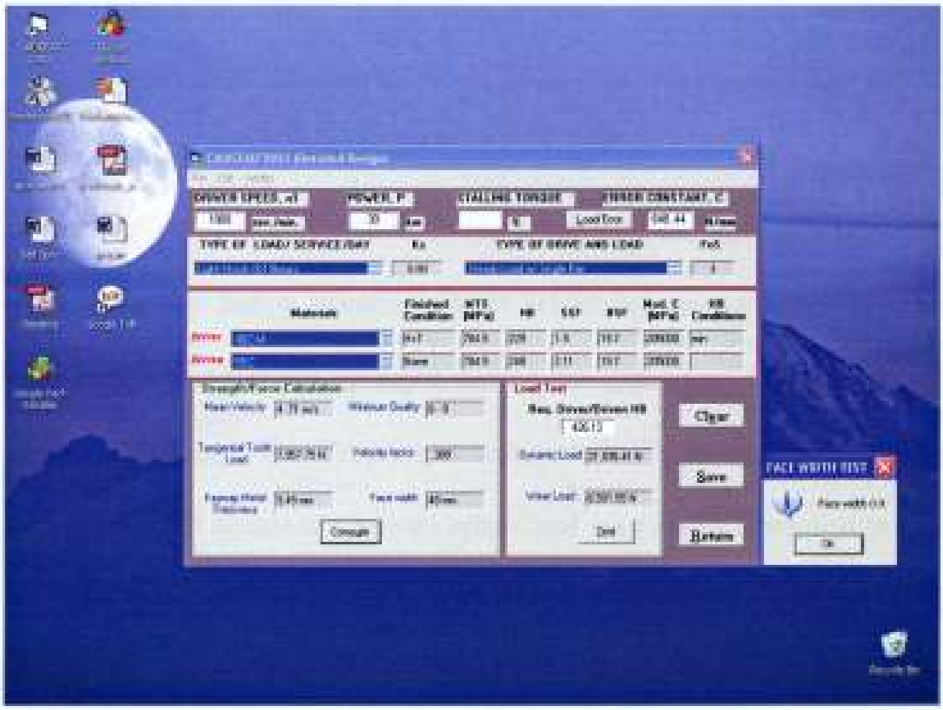


Chart 4.7: Case Two Screen Output for Detailed Design

Chart 4.8: Case Two Screen Out for Error Constant Generated

4.4 DISCUSSION

Based on some of the output from this research work, it is apparent that CADGEAR '2003 software has been developed. This application can work conveniently with various standard Microsoft windows having Interactive Computer Graphics (ICG) interface. The software is *event-driven* (code remains idle until called upon to respond to some event by button pressing, menu selection), *user-friendly*, and support the use of *mouse* as a supplementary input device for activating menus, command buttons and making selections. This Proprietary software facilitates the design of spur gears, validates users input and eliminates human errors that may result from design process. It generates accurate data used in design process; performs repetitive and routine tasks involved in spur gear design. It also produces precise and efficient 2D (*two dimensional*) design drawings of the gears and stores the information for use in manufacturing and future design activities in the hard disk.

Some of the advantages of this user software over other software include lower cost and proprietary nature of the software. The introduction of this software to the society will in no small way increase productivity and the reliability of spur gear design in Nigeria as it assist in tackling factors influencing spur gear design in Nigeria. It will also help reduce the direct cost of production.

4.5 LIMITATIONS OF THE STUDY

There are some limitations accompanying the CADGEAR '2003 software. They are highlighted as follows:

- CADGEAR '2003 can only be employed to design a single pair of spur gear used in power transmission or other type of machines.

- The maximum required driver/driven gear number of teeth is 100 while the minimum required number of teeth is 18.
- The general range of application is:

Module:	m	1.5 to 25 mm
Pitch Circle:	d	25 to 3200 mm
Pitch-line Velocity:	v	less than 25 m/s
Driver Rotating Speed:	n_1	less than 3600 rpm

If the Pitch-line Velocity (Mean Velocity) exceeds 25m/s or the Rotational Speed of the Driver exceeds 3600 rpm, it is recommended that helical gears should be used for the operation.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

During the cause of this research work an interactive user-friendly and menu-driven computer software system that enhances the analytical and logical power of the designer was developed. This system facilitates the design of spur gears, validate users input and eliminate human errors that may result from manual design process. It generates accurate data used in design process; perform repetitive and routine tasks involved in spur gear design. The software was able to produce 2D (*two dimensional*) design drawings of the gears. It also store information for used in manufacture and future design activities.

Conclusively, it was observed that the system developed will successfully increase productivity over other means used for gear design and drafting.

5.2 RECOMMENDATIONS

Having realized the stated goals and objectives of this research, the following recommendations can be implemented:

(i) The resulting software is recommended for commercialization so that responses from end-users of the system can be used to improve on it.

(ii) Research efforts should be concentrated on developing prototype spur gear using this software.

(iii) The developed proprietary software should be encouraged in small scale industries and research institutes to facilitate the design of gears.

(iv) Engineers should intensify efforts to ensure they learn at list a particular high-level programming language which can be used in developing suitable software for their utilization.

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APPENDIX A

CADGEAR '2003 Program

```
'Initial Design of Spur Gear
Option Explicit
Public Z1 As Single, Z2 As Single, M As Single, a As Double
Dim pi As Double, b As Double, Res As Long, Mytime As Variant
Private Sub cboModule_Change()     'Index Module as zero at starting
cboModule.ListIndex = 0
End Sub
Private Sub cmdCalculate_Click()   'Calculate the parameters of spur gear driver&
driven
M = cboModule
Z1 = Val(txtPin.Text)            'driver number of teeth
Z2 = Val(txtGear.Text)           'driven number of teeth
If Z1 * Z2 <> 0 Then
pi = 3.14159265
b = (90 * pi) / 180
If Opt1.Value = True Then        'If pressure angle is 14.5 deg. full depth involute
a = (14.5 * pi) / 180
Text16.Text = Format((M), "## .## ") & "mm"        'Addendum
Text17.Text = Format((1.157 * M), "## .## ") & "mm" 'Dedendum
Text20.Text = Format((2.157 * M), "## .## ") & "mm" 'Whole depth
Text22.Text = Format((0.157 * M), "## .## ") & "mm" 'Clearance
Else
a = (20 * pi) / 180
Text16.Text = Format((M), "## .## ") & "mm"        'Addendum
Text17.Text = Format((1.25 * M), "## .## ") & "mm"  'Dedendum
Text20.Text = Format((2.25 * M), "## .## ") & "mm"  'Whole depth
Text22.Text = Format((0.25 * M), "## .## ") & "mm"  'Clearance
End If
Text1.Text = Format((Z1 * M), "## .## ") & "mm"    'Driver Pitch diameter
Text2.Text = Format((Z2 * M), "## .## ") & "mm"    'Driven Pitch diameter
Text3.Text = Format((M * (Z1 + 2)), "## .## ") & "mm"   'Driver Tip diameter
Text4.Text = Format((M * (Z2 + 2)), "## .## ") & "mm"   'Driven Tip diameter
Text5.Text = Format((Z1 * M * Cos(a)), "## .## ") & "mm"   'Driver Base Circle
diameter
Text6.Text = Format((Z2 * M * Cos(a)), "## .## ") & "mm"   'Driven Base Circle
diameter
Text7.Text = Format((M * (Z1 - 2.5)), "## .## ") & "mm"    'Driver Root diameter
Text8.Text = Format((M * (Z2 - 2.5)), "## .## ") & "mm"    'Driven Root diameter
Text9.Text = Format((M + (Z1 * M / 2) * (1 - Cos(b / Z1))), "## .## ") & "mm"
'Driver Chordal Addendum
Text10.Text = Format((M + (Z2 * M / 2) * (1 - Cos(b / Z2))), "## .## ") & "mm"
'Driven Chordal Addendum
Text11.Text = Format((Z1 * M * Sin(b / Z1)), "## .## ") & "mm"    'Driver Chordal
tooth thickness
Text12.Text = Format((Z2 * M * Sin(b / Z2)), "## .## ") & "mm"    'Driven Chordal
tooth thickness
```

```
Text13.Text = Format((1 / M), "## .## ") & "mm"     'Diametral pitch
Text14.Text = Format((pi * M), "## .## ") & "mm"    'Circular pitch
Text15.Text = Format((pi * M * Cos(a)), "## .## ") & "mm"   'Base pitch
Text18.Text = Format((pi * M / 2), "## .## ") & "mm"       'Tooth thickness
Text19.Text = Format(((M / 2) * (Z1 + Z2)), "## .## ") & "mm"   'Center distance
Text21.Text = Format((2 * M), "## .## ") & "mm"       'Working depth
Text23.Text = Format((0.375 * M), "## .## ") & "mm"     'Fillet radius
Text24.Text = Format((Z2 / Z1), "## .## ")      'Gear ratio
Else
MsgBox "Enter value for Z1 and Z2", vbExclamation, "DRIVER AND DRIVEN
TEETH"
If txtPin.Text = "" Then
txtPin.SetFocus                'To enter number of teeth for driver
ElseIf txtGear.Text = "" Then
txtGear.SetFocus               'To enter number of teeth for driven
End If
End If
End Sub
Private Sub cmdExit_Click()     'To exit CADGEAR '2003 Screen
If MsgBox("Are you sure you want to exit?", vbQuestion + vbYesNo, "EXIT
SCREEN") = vbYes Then
Unload Me
Form5.Show
Else
Load Me
End If
End Sub
Private Sub Command1_Click()    'Allow you to compute detailed design.
If MsgBox("Are You Sure?", vbQuestion + vbYesNo, "DETAILED DESIGN") =
vbYes Then
Z1 = Val(txtPin.Text)      'Driver number of teeth
Z2 = Val(txtGear.Text)      'Driven number of teeth
If Z1 * Z2 <> 0 Then
If Val(Text1.Text) <> 0 Then
   Form1.Hide
   fmrgear.Show 1
Else
   MsgBox "Compute Values", vbInformation, "DETAILED DESIGN"
   cmdCalculate.SetFocus
End If
Else
MsgBox "Enter value for Z1 and Z2", vbExclamation, "DETAILED DESIGN"
If txtPin.Text = "" Then
txtPin.SetFocus
ElseIf txtGear.Text = "" Then
txtGear.SetFocus
End If
End If
Else
Exit Sub
```

```
End If
End Sub
Public Sub Command2_Click()    'Condition for computation.
If Text1.Text = "" Then
   MsgBox "Compute Geometry Parameters", vbExclamation, "DRIVER AND
DRIVEN COMPUTATION"
   cmdCalculate.SetFocus
   Exit Sub
End If
If MsgBox("Are you sure? ", vbYesNo + vbQuestion, "SAVE SCREEN") = vbYes
Then
Z1 = Val(txtPin.Text)
Z2 = Val(txtGear.Text)
If Z1 * Z2 <> 0 Then
Mytime = Now
Open "F:\dayo\result.txt" For Append As #1
Write #1,
Print #1, "Date ="; Format(Date, "dddd,mmmmdd,yyyy"), "", "Time =";
Format(Mytime, "hh:mm:ssAM/PM")
Print #1, "This is the result of Designed Driver/Driven"
Print #1,
Print #1, "ITEMS", "", "Driver", "Driven"
Print #1, "Pitch Diameter", Text1.Text, Text2.Text
Print #1, "Teeth Number", "", txtPin.Text, txtGear.Text
Print #1, "Tip Diameter", "", Text3.Text, Text4.Text
Print #1, "Base Circle Diameter", Text5.Text, Text6.Text
Print #1, "Root Diameter", "", Text7.Text, Text8.Text
Print #1, "Chordal Addendum", Text9.Text, Text10.Text
Print #1, "Chordal Tooth Thickness", Text11.Text, Text12.Text
Print #1,
Print #1, "", "", "Driver/Driven General Data 1"
Print #1, "Diametral Pitch", Text13.Text
Print #1, "Circular Pitch", Text14.Text
Print #1, "Base Pitch", "", Text15.Text
Print #1, "Addendum", "", Text16.Text
Print #1, "Dedendum", "", Text17.Text
Print #1, "Tooth Thickness", Text18.Text
Print #1, "Center Distance", Text19.Text
Print #1, "Whole Depth", "", Text20.Text
Print #1, "Working Depth", "", Text21.Text
Print #1, "Clearance", "", Text22.Text
Print #1, "Fillet Radius", "", Text23.Text
Print #1, "Gear Ratio", "", Text24.Text
Print #1, "Module", "", cboModule.Text; "mm"
If Opt1.Value = True Then
Print #1, "Pressure Angle", "14.5deg"
Else
Print #1, "Pressure Angle", "20deg"
End If
Print #1, "Manufacturing Method", List1.Text
```

```
Print #1, "Finishing Method", List2.Text
Close
MsgBox "Your design is saved", vbOKOnly, "SAVE SCREEN"
Else
MsgBox "Enter value for Z1 and Z2", vbExclamation, "DETAILED DESIGN"
If txtPin.Text = "" Then
txtPin.SetFocus
ElseIf txtGear.Text = "" Then
txtGear.SetFocus
End If
End If
Else
Exit Sub
End If
End Sub
Private Sub Command3_Click()    'Gives a 2D configuration of spur gear
Dim rpd1 As Single, rpd2 As Single, rtd1 As Single, rtd2 As Single
Dim rrd1 As Single, rrd2 As Single, Cx As Single
Dim Cy As Single, Cx1 As Single, Cy1 As Single, Cd As Single
Dim t As Single, k As Single, i As Integer, Cz As Single
Dim Ca As Single, Cx2 As Single, D1 As Single, D2 As Single

If MsgBox("Are You Ready for Drawing?", vbQuestion + vbYesNo, "DRAW
GEAR") = vbYes Then
If Val(Text1.Text) <> 0 Then
Form1.Hide
Form2.Show
Form2.ScaleMode = 3  ' set scale to pixels.
Cx = Form2.ScaleWidth / 2 ' set coordinate for driver
Cy = Form2.ScaleHeight / 2    ' set coordinate for driver
rpd1 = M / 2 * Z1
rpd2 = M / 2 * Z2
rtd1 = M / 2 * (Z1 + 2)
rtd2 = M / 2 * (Z2 + 2)
rrd1 = M / 2 * (Z1 - 2.5)
rrd2 = M / 2 * (Z2 - 2.5)
Cd = M / 2 * (Z1 + Z2)
Cy1 = Cy 'set coordinate for driven
Cx1 = Cx + Cd 'set coordinate for driven
   Form2.PSet (Cx, Cy)
   Form2.PSet (Cx1, Cy1)
   t = pi / Z1
   Form2.Circle (Cx, Cy), rpd1, vbRed
   Form2.Circle (Cx, Cy), rtd1, RGB(0, 0, 0)
   For i = 0 To Z1 * 2 - 1
   Form2.Circle (Cx, Cy), rtd1, RGB(0, 0, 0), -i * t, -i * t
   Next i
   For i = 0 To Z1 * 2 - 1 Step 2
   Form2.Circle (Cx, Cy), rtd1, RGB(255, 255, 255), i * t, (i + 1) * t
   Next i
```

```
Form2.Circle (Cx, Cy), rrd1, RGB(0, 0, 0)
For i = 0 To Z1 * 2 - 1
Form2.Circle (Cx, Cy), rrd1, RGB(255, 255, 255), -i * t, -i * t
Next i
For i = 1 To Z1 * 2 - 2 Step 2
Form2.Circle (Cx, Cy), rrd1, RGB(255, 255, 255), i * t, (i + 1) * t
Next i
Form2.Circle (Cx, Cy), 10, vbBlack

k = pi / Z2
Form2.Circle (Cx1, Cy1), rpd2, vbRed
Form2.Circle (Cx1, Cy1), rtd2, RGB(0, 0, 0)
For i = 0 To Z2 * 2 - 1
Form2.Circle (Cx1, Cy1), rtd2, RGB(0, 0, 0), -i * k, -i * k
Next i
For i = 0 To Z2 * 2 - 1 Step 2
Form2.Circle (Cx1, Cy1), rtd2, RGB(255, 255, 255), i * k, (i + 1) * k
Next i
Form2.Circle (Cx1, Cy1), rrd2, RGB(0, 0, 0)
For i = 0 To Z2 * 2 - 1
Form2.Circle (Cx1, Cy1), rrd2, RGB(255, 255, 255), -i * k, -i * k
Next i
For i = 1 To Z2 * 2 - 2 Step 2
Form2.Circle (Cx1, Cy1), rrd2, RGB(255, 255, 255), i * k, (i + 1) * k
Next i
Form2.Circle (Cx1, Cy1), 10, vbBlack

If rtd1 > rtd2 Then
Cz = Cy + rtd1 + 40
Ca = Cy + rtd1 + 20
D2 = Cy + rtd1 + 25
Else
Cz = Cy + rtd2 + 40
Ca = Cy + rtd2 + 20
D2 = Cy + rtd2 + 25
End If
Form2.Line (Cx, Cy)-(Cx, Cz), vbBlack
Form2.Line (Cx1, Cy1)-(Cx1, Cz), vbBlack
Form2.Line (Cx, Ca)-(Cx1, Ca), vbBlack
Form2.CurrentX = Cx - rtd1 - 40
Form2.CurrentY = Cy
Form2.Print "Driver"
Form2.CurrentX = Cx1 + rtd2 + 15
Form2.CurrentY = Cy
Form2.Print "Driven"
Cx2 = Cd / 3
D1 = Cx + Cx2
Form2.CurrentX = D1
Form2.CurrentY = D2
Form2.Print "Cd ="; Cd; "mm"
```

```
Else
   MsgBox "Compute Geometry Parameters", vbExclamation, "DRAW GEAR"
   cmdCalculate.SetFocus
If txtPin.Text = "" Then
txtPin.SetFocus
ElseIf txtGear.Text = "" Then
txtGear.SetFocus
End If
End If
Exit Sub
End If
End Sub
Public Sub Command4_Click()     'Clear values in CADGEAR '2003 Screen.
If txtPin.Text = "" Or txtGear.Text = "" Then
   MsgBox "Your Result is Cleared Already!", vbOKOnly, "CLEAR SCREEN"
End If
If MsgBox("Do you want to save changes?", vbQuestion + vbYesNo, "SAVE
CHANGES") = vbNo Then
txtPin.Text = ""    'Clear driver number of teeth
txtGear.Text = ""   'Clear driven number of teeth
Text1.Text = ""     'Clear driver pitch diameter
Text2.Text = ""     'Clear driven pitch diameter
Text3.Text = ""     'Clear driver tip diameter
Text4.Text = ""     'Clear driven tip diameter
Text5.Text = ""     'Clear driver base circle diameter
Text6.Text = ""     'Clear driven base circle diameter
Text7.Text = ""     'Clear driver root diameter
Text8.Text = ""     'Clear driven root diameter
Text9.Text = ""     'Clear driver chordal addendum
Text10.Text = ""    'Clear driven chordal addendum
Text11.Text = ""    'Clear driver chordal tooth thickness
Text12.Text = ""    'Clear driven chordal tooth thickness
Text13.Text = ""    'Clear diametral pitch
Text14.Text = ""    'Clear Circular pitch
Text15.Text = ""    'Clear base pitch
Text16.Text = ""    'Clear Addendum
Text17.Text = ""    'Clear Dedendum
Text18.Text = ""    'Clear tooth thickness
Text19.Text = ""    'Clear center distance
Text20.Text = ""    'Clear whole depth
Text21.Text = ""    'Clear working depth
Text22.Text = ""    'Clear clearance
Text23.Text = ""    'Clear fillet Radius
Text24.Text = ""    'Clear Gear ratio
Else
Z1 = Val(txtPin.Text)
Z2 = Val(txtGear.Text)
If Z1 * Z2 <> 0 Then
If Val(Text1.Text) <> 0 Then
Mytime = Now
```

```
Open "D:\dayo\result.txt" For Append As #1
Write #1,
Print #1, "Date ="; Format(Date, "dddd,mmmmdd,yyyy"), "", "Time =";
Format(Mytime, "hh:mm:ssAM/PM")
Print #1, "This is the result of Designed Driver/Driven"
Print #1,
Print #1, "ITEMS", "", "Driver", "Driven"
Print #1, "Pitch Diameter", Text1.Text, Text2.Text
Print #1, "Teeth Number", "", txtPin.Text, txtGear.Text
Print #1, "Tip Diameter", "", Text3.Text, Text4.Text
Print #1, "Base Circle Diameter", Text5.Text, Text6.Text
Print #1, "Root Diameter", "", Text7.Text, Text8.Text
Print #1, "Chordal Addendum", Text9.Text, Text10.Text
Print #1, "Chordal Tooth Thickness", Text11.Text, Text12.Text
Print #1,
Print #1, "", "", "Driver/Driven General Data 1"
Print #1, "Diametral Pitch", Text13.Text
Print #1, "Circular Pitch", Text14.Text
Print #1, "Base Pitch", "", Text15.Text
Print #1, "Addendum", "", Text16.Text
Print #1, "Dedendum", "", Text17.Text
Print #1, "Tooth Thickness", Text18.Text
Print #1, "Center Distance", Text19.Text
Print #1, "Whole Depth", "", Text20.Text
Print #1, "Working Depth", "", Text21.Text
Print #1, "Clearance", "", Text22.Text
Print #1, "Fillet Radius", "", Text23.Text
Print #1, "Gear Ratio", "", Text24.Text
Print #1, "Module", "", cboModule.Text; "mm"
If Opt1.Value = True Then
Print #1, "Pressure Angle", "14.5deg"
Else
Print #1, "Pressure Angle", "20deg"
End If
Print #1, "Manufacturing Method", List1.Text
Print #1, "Finishing Method", List2.Text
Close
Else
   MsgBox "Compute Values", vbInformation, "DESIGN SCREEN"
   cmdCalculate.SetFocus
   Exit Sub
End If
   MsgBox "Your design is saved", vbOKOnly, "SAVE SCREEN"
Else
   MsgBox "Enter values for Z1 and Z2", vbExclamation, "DETAILED DESIGN"
   txtPin.SetFocus
   Exit Sub
If txtPin.Text = "" Then
txtPin.SetFocus
ElseIf txtGear.Text = "" Then
```

```
txtGear.SetFocus
End If
End If
txtPin.Text = ""   'Clear driver number of teeth
txtGear.Text = ""   'Clear driven number of teeth
Text1.Text = ""    'Clear driver pitch diameter
Text2.Text = ""    'Clear driven pitch diameter
Text3.Text = ""    'Clear driver tip diameter
Text4.Text = ""    'Clear driven tip diameter
Text5.Text = ""    'Clear driver base circle diameter
Text6.Text = ""    'Clear driven base circle diameter
Text7.Text = ""    'Clear driver root diameter
Text8.Text = ""    'Clear driven root diameter
Text9.Text = ""    'Clear driver chordal addendum
Text10.Text = ""    'Clear driven chordal addendum
Text11.Text = ""    'Clear driver chordal tooth thickness
Text12.Text = ""    'Clear driven chordal tooth thickness
Text13.Text = ""    'Clear diametral pitch
Text14.Text = ""    'Clear Circular pitch
Text15.Text = ""    'Clear base pitch
Text16.Text = ""    'Clear Addendum
Text17.Text = ""    'Clear Dedendum
Text18.Text = ""    'Clear tooth thickness
Text19.Text = ""    'Clear center distance
Text20.Text = ""    'Clear whole depth
Text21.Text = ""    'Clear working depth
Text22.Text = ""    'Clear clearance
Text23.Text = ""    'Clear fillet Radius
Text24.Text = ""    'Clear Gear ratio
End If
MsgBox "Your Result is Cleared", vbOKOnly, "CLEAR SCREEN"
End Sub

Private Sub Form_Load()
'Add Module types to third combo box
cboModule.AddItem "1"
cboModule.AddItem "1.125"
cboModule.AddItem "1.25"
cboModule.AddItem "1.375"
cboModule.AddItem "1.5"
cboModule.AddItem "1.75"
cboModule.AddItem "2"
cboModule.AddItem "2.25"
cboModule.AddItem "2.5"
cboModule.AddItem "2.75"
cboModule.AddItem "3"
cboModule.AddItem "3.25"
cboModule.AddItem "3.5"
cboModule.AddItem "3.75"
cboModule.AddItem "4"
```

```
cboModule.AddItem "4.5"
cboModule.AddItem "5"
cboModule.AddItem "5.5"
cboModule.AddItem "6"
cboModule.AddItem "6.5"
cboModule.AddItem "7"
cboModule.AddItem "8"
cboModule.AddItem "9"
cboModule.AddItem "10"
cboModule.AddItem "11"
cboModule.AddItem "12"
cboModule.AddItem "14"
cboModule.AddItem "16"
cboModule.AddItem "18"
cboModule.AddItem "20"
cboModule.ListIndex = 0
Opt1.Value = True

'Add Manufacturing Methods to List1 box
List1.AddItem "Choose Me"
List1.AddItem "Drawing"
List1.AddItem "Milling"
List1.AddItem "Extruding"
List1.AddItem "Generating Hob"
List1.AddItem "Stamping"
List1.AddItem "Die Casting"
List1.AddItem "Sintering"
List1.AddItem "Injection Moulding"
List1.AddItem "Generating Rack"
List1.AddItem "Generating Shaper"
List1.ListIndex = 0

'Add Finishing Methods to List2 box
List2.AddItem "Choose Me"
List2.AddItem "Grinding"
List2.AddItem "Burning"
List2.AddItem "Lapping"
List2.AddItem "Honing"
List2.ListIndex = 0
End Sub
Private Sub Form_Unload(Cancel As Integer)
MsgBox "Want to Exit?", vbOKOnly + vbExclamation, "EXIT"
Form5.Show
End Sub
Private Sub mnuCalculate_Click()
Call cmdCalculate_Click
End Sub
Private Sub mnuclear_Click()
Call Command4_Click
End Sub
```

```
Private Sub mnuDetailedDesign_Click()
Call Command1_Click
End Sub
Private Sub mnuDrawGear_Click()
Call Command3_Click
End Sub

Private Sub mnuDesignCalculate_Click()
Call cmdCalculate_Click
End Sub

Private Sub mnuDesignDetailedDesign_Click()
Call Command1_Click
End Sub

Private Sub mnuDesignDrawGear_Click()
Call Command3_Click
End Sub

Private Sub mnuEditClear_Click()
Call Command4_Click
End Sub

Private Sub mnuFileExit_Click()
Call cmdExit_Click
End Sub

Private Sub mnuSave_Click()
Call Command2_Click
End Sub

Private Sub mnufileSave_Click()
Call Command2_Click
End Sub

Private Sub mnuHelpAboutCadGear_Click()
Form7.Show
End Sub

Private Sub mnuHelpAboutSpurGearDesign_Click()
MsgBox "The Content Collection does not exist. please reinstall Content", vbCritical
+ vbOKOnly, "Help System"
End Sub

Private Sub mnuHelpContent_Click()
MsgBox "The Content Collection does not exist. please reinstall Content", vbCritical
+ vbOKOnly, "Help System"
End Sub

Private Sub mnuViewGearDrawings_Click()
```

```
Call Command3_Click
End Sub

Private Sub txtGear_Change()
If Val(txtGear) > 100 Then
txtGear = ""
MsgBox " Teeth number must be less than 100", vbInformation, "TEETH NUMBER"
 ElseIf Not IsNumeric(txtGear) Then
txtGear = ""
txtGear.SetFocus
End If
End Sub
Private Sub txtPin_Change()
If Val(txtPin) > 100 Then
txtPin = ""
MsgBox " Teeth number must be less than 100", vbInformation, "TEETH NUMBER"
ElseIf Not IsNumeric(txtPin) Then
txtPin = ""
txtPin.SetFocus
End If
End Sub

'Detailed Design for Spur Gear
Option Explicit
Dim t As Long, ges As Double, e1 As Single, e2 As Single, ZZ1 As Single
Dim ZZ2 As Single, MM As Single, AA As Double, a As Single, p As Double
Dim q As Double, fw As Double, pi As Double, y1 As Double, y2 As Double
Dim J1 As Double, J2 As Double, g As Single, g0 As Single, Y As Single
Dim HB As Double, HBX As Double, D1 As Double, D2 As Double, n1 As Single
Dim Vm As Double, ft As Single, ft1 As Single, st As Single, KW As Single
Dim Ks As Single, fos As Integer, Cv As Single, b As Long, low As Single
Dim high As Single, fb As Single, fta As Single, f1 As Single, f2 As Single
Dim fi As Single, fd As Single, C As Single, g1 As Single, g2 As Single
Dim tm As Double, HB1 As Double, HB2 As Double, HBR As Double
Dim Mytime As Variant
Private Sub Command1_Click()
KW = Val(Text16.Text)      'Power
Ks = Val(Text28.Text)      'Type of Load/service/day constant
fos = Val(Text29.Text)     'Type of drive and load constant
n1 = Val(Text15.Text)      'Driver speed

If n1 <> 0 Then
If KW <> 0 Then

'Lewis form factor Calculation
If Form1.Opt1.Value = True Then
AA = (14.5 * pi) / 180
y1 = 0.124 - 0.684 / ZZ1
y2 = 0.124 - 0.684 / ZZ2
Else
```

```
AA = (20 * pi) / 180
y1 = 0.154 - 0.912 / ZZ1
y2 = 0.154 - 0.912 / ZZ2
End If

'Pinion or gear design decisions
g1 = Val(Text2.Text)
g2 = Val(Text9.Text)
HB1 = Val(Text3.Text)
HB2 = Val(Text10.Text)
J1 = g1 * y1
J2 = g2 * y2
If J1 > J2 Then

'Design for driven
MsgBox "Design for Driven", vbOKOnly + vbInformation, "DRIVER/DRIVEN
DESIGN DECISIONS"
g = g2
Y = y2
HB = HB2
tm = MM * Sqr(ZZ2 / 5)
Text22.Text = Format(tm, "###.## ") & "mm"
Else

'Design for driver
MsgBox "Design for Driver", vbOKOnly + vbInformation, "DRIVER/DRIVEN
DESIGN DECISIONS"
g = g1
Y = y1
HB = HB1
tm = MM * Sqr(ZZ1 / 5)
Text22.Text = Format(tm, "###.## ") & "mm"
End If
If g <> 0 Then

'pitch diameter computation
D1 = MM * ZZ1
D2 = MM * ZZ2

'mean velocity computation
Vm = (pi * D1 * n1) / 60000
Text18.Text = Format(Vm, "### .## ") & "m/s"    'Mean velocity value

'Minimum Quality decision
If Vm > 30 Then
Text19.Text = "No Value"
ElseIf Vm >= 15 And Vm <= 30 Then
Text19.Text = "5 - 6"
ElseIf Vm >= 7.5 And Vm < 15 Then
Text19.Text = "6 - 7"
```

```
ElseIf Vm >= 5 And Vm < 7.5 Then
Text19.Text = "7 - 8"
ElseIf Vm >= 2.5 And Vm < 5 Then
Text19.Text = "8 - 9"
ElseIf Vm < 2.5 Then
Text19.Text = "10 - 12"
Else
End If

'tangential tooth load computation
st = Val(Text23.Text)
ft1 = 1000 * KW / (Vm * Ks)
If st <> 0 Then
ft = ft1 * st / 100
Text21.Text = Format(ft, "###,###.## ") & "N"
Else
ft = ft1
Text21.Text = Format(ft, "###,###.## ") & "N"
End If

'velocity factors computation
If Vm <= 10 Then
Cv = 3 / (3 + Vm)
Text20.Text = Format(Cv, "## .### ")
Else
If Vm > 10 And Vm < 20 Then
Cv = 6.1 / (6.1 + Vm)
Text20.Text = Format(Cv, "## .### ")
Else
Cv = 5.56 / (5.56 + Sqr(Vm))
Text20.Text = Format(Cv, "## .###")
End If
End If

'face width computation
g0 = g / fos
b = ft / (g0 * pi * Y * MM * Cv)
Text24.Text = Format(b, "## ") & "mm"
low = 9 * MM
high = 13 * MM
If low <= b And b <= high Then
MsgBox "Face width O.K", vbOKOnly + vbInformation, "FACE WIDTH TEST"
ElseIf b < low Or b > high Then
MsgBox "Face width NOT O.K", vbOKOnly + vbInformation, "FACE WIDTH
TEST"
MsgBox "Select Material", vbInformation, "MATERIALS"
Text2.SetFocus
Else
End If
ElseIf g = Val(Text2.Text) Then
```

```
MsgBox "Select Driver Material", vbInformation, "MATERIALS"
Text2.SetFocus
Else
MsgBox "Select Driven Material", vbInformation, "MATERIALS"
Text9.SetFocus
End If
Else
MsgBox "Enter value for KW", vbExclamation, "POWER REQUIRED"
Text16.SetFocus
End If
Else
MsgBox "Enter value for n1", vbExclamation, "RPM REQUIRED"
Text15.SetFocus
End If
t = Val(Text15.Text)
If t > 3600 Then
Text15.Text = ""
Else
End If
End Sub
Private Sub Command2_Click()
If Text15.Text = "" Or Text15.Text = "" Then
   MsgBox "Your Result is Cleared Already!", vbOKOnly, "CLEAR SCREEN"
End If
If MsgBox("Do you want to Save changes?", vbYesNo + vbQuestion, "GEAR
DESIGN DETAILS") = vbNo Then
Text15.Text = ""   'Clear Pinion Speed
Text16.Text = ""   'Clear Power
Text17.Text = ""   'Clear Dynamic factor
Text18.Text = ""   'Clear Mean Velocity
Text19.Text = ""   'Clear Minimum Quality
Text20.Text = ""   'Clear Velocity factor
Text21.Text = ""   'Clear Tangential tooth load
Text22.Text = ""   'Clear Keyway Metal Thickness
Text23.Text = ""   'Clear Stalling torque %
Text24.Text = ""   'Clear face width
Text25.Text = ""   'Clear Dynamic load
Text26.Text = ""   'Clear wear load
Text27.Text = ""   'Clear Required HB
Else
If n1 * KW <> 0 Then
If Val(Text18.Text) <> 0 Then
Mytime = Now
Open "D:\dayo\Detailed Design.txt" For Append As #2
Write #2,
Print #2, "Date ="; Format(Date, "dddd,mmmmdd,yyyy"), "", "Time =";
Format(Mytime, "hh:mm:ssAM/PM")
Print #2, "This is the result of Detailed Driver/Driven Gear"
Print #2,
Print #2, "ITEMS", "", "Driver", "Driven"
```

```
Print #2, "Materials", "", List1.Text, List2.Text
Print #2, "Min. Tensile Strength", Text2.Text; "MPa", Text9.Text; "MPa"
Print #2, "Brinell Hardness,HB", Text3.Text, Text10.Text
Print #2, "HB Condition", "", Text7.Text, Text14.Text
Print #2, "Modulus of Elasticity", Text6.Text; "MPa", Text13.Text; "MPa"
Print #2, "Finished Condition", Text1.Text, Text8.Text
Print #2, "Surface Stress Factor", Text4.Text, Text11.Text
Print #2, "Bending Stress Factor", Text5.Text, Text12.Text
Print #2,
Print #2, "", "", "Driver/Driven General Data 2"
Print #2, "Power,P", "", Text16.Text; "kw"
Print #2, "Pinion Speed,n1", Text15.Text; "rev./min"
Print #2, "Service Factor,Ks", Text28.Text
Print #2, "Factor of Safety", Text29.Text
Print #2, "Stalling Torque", Text23.Text; "%"
Print #2, "Dynamic Factor,C", Text17.Text; "N/mm"
Print #2, "Mean Velocity", "", Text18.Text
Print #2, "Tangential Tooth Load", Text21.Text
Print #2, "Keyway Metal Thickness", Text22.Text
Print #2, "Minimum Quality", Text19.Text
Print #2, "Velocity factor", Text20.Text
Print #2, "Face width", "", Text24.Text
Print #2, "Required HB", "", Text27.Text
Print #2, "Dynamic Load", "", Text25.Text
Print #2, "Wear Load", "", Text26.Text
Print #2,
Print #2,
Print #2, "H -Hardened,", "T -Tempered,", "N -Normalized"
Close
Else
   MsgBox "Compute Strength/Force Parameters", vbExclamation, "DETAILED
DESIGN COMPUTATION"
   Command1.SetFocus
   Exit Sub
End If
   MsgBox "Your design is saved", vbOKOnly, "SAVE SCREEN"
Else
   MsgBox "Enter values for n1 and KW", vbExclamation, "DETAILED DESIGN"
   Text15.SetFocus
   Exit Sub
If Text15.Text = "" Then
Text15.SetFocus
ElseIf Text16.Text = "" Then
Text16.SetFocus
End If
End If
Text15.Text = ""   'Clear Pinion Speed
Text16.Text = ""   'Clear Power
Text17.Text = ""   'Clear Dynamic factor
Text18.Text = ""   'Clear Mean Velocity
```

```
Text19.Text = ""   'Clear Minimum Quality
Text20.Text = ""   'Clear Velocity factor
Text21.Text = ""   'Clear Tangential tooth load
Text22.Text = ""   'Clear Keyway Metal Thickness
Text23.Text = ""   'Clear Stalling torque %
Text24.Text = ""   'Clear face width
Text25.Text = ""   'Clear Dynamic load
Text26.Text = ""   'Clear wear load
Text27.Text = ""   'Clear Required HB
End If
MsgBox "Your Result is Cleared", vbOKOnly, "CLEAR SCREEN"
End Sub

Private Sub Command4_Click()
'dynamic load computation
If Val(Text18.Text) <> 0 Then
st = Val(Text23.Text)   'stalling torque
e1 = Val(Text6.Text)
e2 = Val(Text13.Text)
HB1 = Val(Text3.Text)
HB2 = Val(Text10.Text)
C = Val(Text17.Text)    'Error constant interpolated
If C <> 0 Then
g0 = g / fos
b = ft / (g0 * pi * Y * MM * Cv)
Vm = (pi * D1 * n1) / 60000
ft1 = 1000 * KW / (Vm * Ks)
If st <> 0 Then
ft = ft1 * st / 100
Else
ft = ft1
End If
f1 = 10 * Vm * (b * C + ft)
f2 = 10 * Vm + 0.474 * Sqr(b * C + ft)
fi = f1 / f2
fd = ft + fi
Text25.Text = Format(fd, "###,###.## ") & "N"   'dynamic load

'wear load computation
If HB1 > HB2 Then
HB = HB1
Else
HB = HB2
End If
ges = 2.76 * HB - 68.96
p = Sin(AA) * (1 / 1.4) * (1 / e1 + 1 / e2)
q = 2 * D1 * D2 / (D1 + D2)
fw = ges ^ 2 * p * q * b
Text26.Text = Format(fw, "###,###.## ") & "N"
HBR = (68.96 + Sqr(fd / (p * q * b))) / 2.76
```

```
Text27.Text = Format(HBR, "###.## ")
Else
MsgBox "Enter Constant, C", vbInformation, "LOAD TEST CONDITION"
Text17.SetFocus
End If
Else
MsgBox "Compute Strength/Force Values!", vbExclamation + vbOKOnly, "LOAD
TEST CONDITION"
Exit Sub
End If
End Sub

Private Sub Command5_Click()
If Text18.Text = "" Then
   MsgBox "Compute Strength/Force Parameters", vbExclamation, "DETAILED
DESIGN COMPUTATION"
   Command1.SetFocus
   Exit Sub
End If
If MsgBox("Are you sure? ", vbYesNo + vbInformation, "SAVE SCREEN") = vbYes
Then
If Val(Text15.Text) * Val(Text16.Text) <> 0 Then
Mytime = Now
Open "F:\dayo\Detailed Design.txt" For Append As #2
Write #2,
Print #2, "Date ="; Format(Date, "dddd,mmmmdd,yyyy"), "", "Time =";
Format(Mytime, "hh:mm:ssAM/PM")
Print #2, "This is the result of Detailed Driver/Driven Gear"
Print #2,
Print #2, "ITEMS", "", "Driver", "Driven"
Print #2, "Materials", "", List1.Text, List2.Text
Print #2, "Min. Tensile Strength", Text2.Text; "MPa", Text9.Text; "MPa"
Print #2, "Brinell Hardness,HB", Text3.Text, Text10.Text
Print #2, "HB Condition", "", Text7.Text, Text14.Text
Print #2, "Modulus of Elasticity", Text6.Text; "MPa", Text13.Text; "MPa"
Print #2, "Finished Condition", Text1.Text, Text8.Text
Print #2, "Surface Stress Factor", Text4.Text, Text11.Text
Print #2, "Bending Stress Factor", Text5.Text, Text12.Text
Print #2,
Print #2, "", "", "Driver/Driven General Data 2"
Print #2, "Power,P", "", Text16.Text; "kw"
Print #2, "Pinion Speed,n1", Text15.Text; "rev./min"
Print #2, "Service Factor,Ks", Text28.Text
Print #2, "Factor of Safety", Text29.Text
Print #2, "Stalling Torque", Text23.Text; "%"
Print #2, "Dynamic Factor,C", Text17.Text; "N/mm"
Print #2, "Mean Velocity", "", Text18.Text
Print #2, "Tangential Tooth Load", Text21.Text
Print #2, "Keyway Metal Thickness", Text22.Text
Print #2, "Minimum Quality", Text19.Text
```

```
Print #2, "Velocity factor", Text20.Text
Print #2, "Face width", "", Text24.Text
Print #2, "Required HB", "", Text27.Text
Print #2, "Dynamic Load", "", Text25.Text
Print #2, "Wear Load", "", Text26.Text
Print #2,
Print #2,
Print #2, "H -Hardened,", "T -Tempered,", "N -Normalized"
Close
MsgBox "Your design is saved", vbOKOnly, "SAVE SCREEN"
Else
MsgBox "Enter values for n1 and RPM", vbExclamation, "DETAILED DESIGN"
If Text15.Text = "" Then
Text15.SetFocus
ElseIf Text16.Text = "" Then
Text16.SetFocus
End If
End If
Else
Exit Sub
End If
End Sub
Private Sub Command6_Click()
If MsgBox("Are you sure you want to exit?", vbYesNo, "EXIT SCREEN") = vbYes
Then
If MsgBox("Do you want to Save Changes?", vbYesNo, "SAVE SCREEN") = vbNo
Then
   Unload Me
   Form1.Show
Else
Mytime = Now
Open "F:\dayo\Detailed Design.txt" For Append As #2
Write #2,
Print #2, "Date ="; Format(Date, "dddd,mmmmdd,yyyy"), "", "Time =";
Format(Mytime, "hh:mm:ssAM/PM")
Print #2, "This is the result of Detailed Driver/Driven Gear"
Print #2,
Print #2, "ITEMS", "", "Driver", "Driven"
Print #2, "Materials", "", List1.Text, List2.Text
Print #2, "Min. Tensile Strength", Text2.Text; "MPa", Text9.Text; "MPa"
Print #2, "Brinell Hardness,HB", Text3.Text, Text10.Text
Print #2, "HB Condition", "", Text7.Text, Text14.Text
Print #2, "Modulus of Elasticity", Text6.Text; "MPa", Text13.Text; "MPa"
Print #2, "Finished Condition", Text1.Text, Text8.Text
Print #2, "Surface Stress Factor", Text4.Text, Text11.Text
Print #2, "Bending Stress Factor", Text5.Text, Text12.Text
Print #2,
Print #2, "", "", "Driver/Driven General Data 2"
Print #2, "Power,P", "", Text16.Text; "kw"
Print #2, "Pinion Speed,n1", Text15.Text; "rev./min"
```

```
Print #2, "Service Factor,Ks", Text28.Text
Print #2, "Factor of Safety", Text29.Text
Print #2, "Stalling Torque", Text23.Text; "%"
Print #2, "Dynamic Factor,C", Text17.Text; "N/mm"
Print #2, "Mean Velocity", "", Text18.Text
Print #2, "Tangential Tooth Load", Text21.Text
Print #2, "Keyway Metal Thickness", Text22.Text
Print #2, "Minimum Quality", Text19.Text
Print #2, "Velocity factor", Text20.Text
Print #2, "Face width", "", Text24.Text
Print #2, "Required HB", "", Text27.Text
Print #2, "Dynamic Load", "", Text25.Text
Print #2, "Wear Load", "", Text26.Text
Print #2,
Print #2,
Print #2, "H -Hardened,", "T -Tempered,", "N -Normalized"
Close
MsgBox "Your design is saved", vbOKOnly, "SAVE SCREEN"
fmrgear.Hide
Form1.Show
End If
ElseIf vbNo Then
Load Me
Else
Unload Me
End If
End Sub
Private Sub Command7_Click()
If Val(Text17.Text) <> 0 Then
   If MsgBox("Error Constant is Already Computed, Do You want to Replace?",
vbInformation + vbYesNo, "GEAR ERROR CONSTANT") = vbYes Then
      Form3.Show
   Else
   End If
 Else
    Me.Hide
    Form3.Show
End If
End Sub
Private Sub Form_Load()
pi = 3.14159265
' Driver choice of material
List1.AddItem "Grade27-54"
List1.AddItem "Grade1"
List1.AddItem "Grade1"
List1.AddItem "Grade1"
List1.AddItem "30C8"
List1.AddItem "30C8"
List1.AddItem "40C8"
List1.AddItem "40C8"
```

```
List1.AddItem "55C"
List1.AddItem "55C"
List1.AddItem "55C"
List1.AddItem "55Cr3"
List1.AddItem "55Cr3"
List1.AddItem "40Cr4"
List1.AddItem "40Cr4Mo3"
List1.AddItem "40Cr4Mo3"
List1.AddItem "40Cr4Mo3"
List1.AddItem "40Cr4Mo3"
List1.AddItem "40Cr5Mo6"
List1.AddItem "40Cr5Mo6"
List1.AddItem "40Ni6Cr4Mo6"
List1.AddItem "40Ni6Cr4Mo6"
List1.AddItem "31Ni10Cr3Mo6"
List1.AddItem "31Ni10Cr3Mo6"
List1.AddItem "31Ni10Cr3Mo6"
List1.AddItem "40Ni10Cr3Mo6"
List1.AddItem "40Ni10Cr3Mo6"
List1.AddItem "40Ni10Cr3Mo6"
List1.AddItem "40C8"
List1.AddItem "55C6"
List1.AddItem "55C3"
List1.AddItem "40Cr4"
List1.ListIndex = 0

' Driven choice of material
List2.AddItem "Grade27-54"
List2.AddItem "Grade1"
List2.AddItem "Grade1"
List2.AddItem "Grade1"
List2.AddItem "30C8"
List2.AddItem "30C8"
List2.AddItem "40C8"
List2.AddItem "40C8"
List2.AddItem "55C"
List2.AddItem "55C"
List2.AddItem "55C"
List2.AddItem "55Cr3"
List2.AddItem "55Cr3"
List2.AddItem "40Cr4"
List2.AddItem "40Cr4Mo3"
List2.AddItem "40Cr4Mo3"
List2.AddItem "40Cr4Mo3"
List2.AddItem "40Cr4Mo3"
List2.AddItem "40Cr5Mo6"
List2.AddItem "40Cr5Mo6"
List2.AddItem "40Ni6Cr4Mo6"
List2.AddItem "40Ni6Cr4Mo6"
List2.AddItem "31Ni10Cr3Mo6"
```

```
List2.AddItem "31Ni10Cr3Mo6"
List2.AddItem "31Ni10Cr3Mo6"
List2.AddItem "40Ni10Cr3Mo6"
List2.AddItem "40Ni10Cr3Mo6"
List2.AddItem "40Ni10Cr3Mo6"
List2.AddItem "40C8"
List2.AddItem "55C6"
List2.AddItem "55C3"
List2.AddItem "40Cr4"
List2.ListIndex = 0

' Select pressure angle
ZZ1 = Val(Form1.txtPin)     'Driver teeth number
ZZ2 = Val(Form1.txtGear)    'Driven teeth number
MM = Val(Form1.cboModule)   'Module
If Form1.Opt1.Value = True Then
AA = (14.5 * pi) / 180
Else
AA = (20 * pi) / 180
End If

'Type of load and service per day
List3.AddItem "Steady/8-10hours"
List3.AddItem "Light Shock/8-10hours"
List3.AddItem "Medium Shock/8-10hours"
List3.AddItem "Heavy Shock/8-10hours"
List3.AddItem "Steady/24hours"
List3.AddItem "Light Shock/24hours"
List3.AddItem "Medium Shock/24hours"
List3.AddItem "Heavy Shock/24hours"
List3.AddItem "Steady/Intermittent 3hours"
List3.AddItem "Light Shock/Intermittent 3hours"
List3.AddItem "Medium Shock/Intermittent 3hours"
List3.AddItem "Heavy Shock/Intermittent 3hours"
List3.ListIndex = 0

'Type of Drive and Load
List4.AddItem "Steady Load on Single Pair"
List4.AddItem "Sudden Load on Single Pair"
List4.AddItem "Steady Load on Gear Train"
List4.AddItem "Sudden Load on Gear Train"
List4.ListIndex = 0
End Sub

Private Sub Form_Unload(Cancel As Integer)
MsgBox "Exit Detailed Design Window!", vbOKOnly + vbExclamation, "EXIT"
   fmrgear.Hide
   Form1.Show
End Sub
```

```
Private Sub List1_Click()
Dim k As Integer
k = Val(List1.ListIndex)    'Driver choice of material
Select Case k       'Select material
Case 0  'Grade 27-54 cast steel material with no heat treatment
    Text1.Text = "None"         'finished condition
    Text2.Text = 540            'Minimum tensile strength
    Text3.Text = 145            'Brinell hardness
    Text4.Text = 1.125          'Basic Surface stress factor
    Text5.Text = 13.38          'Basic Bending stress factor
    Text6.Text = 202000         'Modulus of Elasticity
    Text7.Text = ""             'HB condition
Case 1  'Grade 1 Annealed cast steel material
    Text1.Text = "Annealed"
    Text2.Text = 620
    Text3.Text = 182
    Text4.Text = 1.47
    Text5.Text = 15.3
    Text6.Text = 202000
    Text7.Text = "min"
Case 2  'Grade 1 hardened & tempered cast steel material
    Text1.Text = "H+T"
    Text2.Text = 790
    Text3.Text = 229
    Text4.Text = 1.9
    Text5.Text = 19.7
    Text6.Text = 202000
    Text7.Text = "min"
Case 3  'Grade 1 Surface hardened cast steel material
    Text1.Text = "Surface"
    Text2.Text = 620
    Text3.Text = 460
    Text4.Text = 1.97
    Text5.Text = 13.36
    Text6.Text = 202000
    Text7.Text = "(Case)min"
Case 4  '30C8 Normalized forged carbon steel material
    Text1.Text = "N"
    Text2.Text = 490.3
    Text3.Text = 143
    Text4.Text = 0.985
    Text5.Text = 11.95
    Text6.Text = "205000"
    Text7.Text = ""
Case 5  '30C8 hardened & tempered forged carbon steel material
    Text1.Text = "H+T"
    Text2.Text = 588.4
    Text3.Text = 152
    Text4.Text = 1.125
    Text5.Text = 14.8
```

```
    Text6.Text = "205000"
    Text7.Text = ""
Case 6 '40C8 Normalized forged carbon steel material
    Text1.Text = "N"
    Text2.Text = 568.8
    Text3.Text = 152
    Text4.Text = 1.125
    Text5.Text = 14.05
    Text6.Text = "205000"
    Text7.Text = ""
Case 7 '40C8 hardened & tempered forged carbon steel material
    Text1.Text = "H+T"
    Text2.Text = 588.4
    Text3.Text = 179
    Text4.Text = 1.44
    Text5.Text = 14.8
    Text6.Text = "205000"
    Text7.Text = ""
Case 8 '55C Normalized forged carbon steel material
    Text1.Text = "N"
    Text2.Text = 706.1
    Text3.Text = 201
    Text4.Text = 1.69
    Text5.Text = 17.6
    Text6.Text = "205000"
    Text7.Text = ""
Case 9 '55C hardened & tempered forged carbon steel material
    Text1.Text = "H+T"
    Text2.Text = 686.5
    Text3.Text = 223
    Text4.Text = 1.83
    Text5.Text = 16.9
    Text6.Text = "205000"
    Text7.Text = ""
Case 10 '55C forged carbon steel material with no heat treatment
    Text1.Text = "None"
    Text2.Text = 784.5
    Text3.Text = 248
    Text4.Text = 2.11
    Text5.Text = 19.7
    Text6.Text = "205000"
    Text7.Text = ""
Case 11 '55Cr3 hardened & tempered forged carbon chromium steel material
    Text1.Text = "H+T"
    Text2.Text = 882.6
    Text3.Text = 225
    Text4.Text = 2.105
    Text5.Text = 22.2
    Text6.Text = "205000"
    Text7.Text = "min"
```

```
Case 12 '55Cr3 hardened & tempered forged carbon chromium steel material with diff.Min.Tensile Strength
    Text1.Text = "H+T"
    Text2.Text = 980.7
    Text3.Text = 285
    Text4.Text = 2.47
    Text5.Text = 24.6
    Text6.Text = "205000"
    Text7.Text = "min"
Case 13 '40Cr4 hardened & tempered forged carbon chromium steel material
    Text1.Text = "H+T"
    Text2.Text = 784.5
    Text3.Text = 229
    Text4.Text = 1.9
    Text5.Text = 19.7
    Text6.Text = "205000"
    Text7.Text = "min"
Case 14 '40Cr4Mo3 hardened & tempered forged chromium Molybdenum steel material
    Text1.Text = "H+T"
    Text2.Text = 686.5
    Text3.Text = 201
    Text4.Text = 1.69
    Text5.Text = 16.9
    Text6.Text = "205000"
    Text7.Text = "min"
Case 15 '40Cr4Mo3 hardened & tempered forged chromium Molybdenum steel material with diff.Min.Tensile Strength
    Text1.Text = "H+T"
    Text2.Text = 784.5
    Text3.Text = 229
    Text4.Text = 1.9
    Text5.Text = 19.7
    Text6.Text = "205000"
    Text7.Text = "min"
Case 16 '40Cr4Mo3 hardened & tempered forged chromium Molybdenum steel material with diff.Min.Tensile Strength
    Text1.Text = "H+T"
    Text2.Text = 882.6
    Text3.Text = 225
    Text4.Text = 2.105
    Text5.Text = 23.2
    Text6.Text = "205000"
    Text7.Text = "min"
Case 17 '40Cr4Mo3 hardened & tempered forged chromium Molybdenum steel material with diff.Min.Tensile Strength
    Text1.Text = "H+T"
    Text2.Text = 980.7
    Text3.Text = 285
    Text4.Text = 2.47
```

```
    Text5.Text = 24.6
    Text6.Text = "205000"
    Text7.Text = "min"
Case 18 '40Cr5Mo6 hardened & tempered forged chromium Molybdenum steel
material
    Text1.Text = "H+T"
    Text2.Text = 882.6
    Text3.Text = 248
    Text4.Text = 1.75
    Text5.Text = 23.2
    Text6.Text = "205000"
    Text7.Text = "min"
Case 19 '40Cr5Mo6 hardened & tempered forged chromium Molybdenum steel
material with diff. Min. Tensile Strength
    Text1.Text = "H+T"
    Text2.Text = 980.7
    Text3.Text = 293
    Text4.Text = 2.06
    Text5.Text = 24.6
    Text6.Text = "205000"
    Text7.Text = "min"
Case 20 '40Ni6Cr4Mo6 hardened & tempered forged Nickel,chromium Molybdenum
steel material
    Text1.Text = "H+T"
    Text2.Text = 882.6
    Text3.Text = 255
    Text4.Text = 2.11
    Text5.Text = 23.2
    Text6.Text = "205000"
    Text7.Text = "min"
Case 21 '40Ni6Cr4Mo6 hardened & tempered forged Nickel,chromium Molybdenum
steel material with diff. Min. Tensile Strength
    Text1.Text = "H+T"
    Text2.Text = 1520
    Text3.Text = 444
    Text4.Text = 3.87
    Text5.Text = 37.3
    Text6.Text = "205000"
    Text7.Text = "min"
Case 22 '31Ni10Cr3Mo6 hardened & tempered forged Nickel,chromium
Molybdenum steel material
    Text1.Text = "H+T"
    Text2.Text = 882.6
    Text3.Text = 255
    Text4.Text = 2.11
    Text5.Text = 23.3
    Text6.Text = "205000"
    Text7.Text = "min"
Case 23 '31Ni10Cr3Mo6 hardened & tempered forged Nickel,chromium
Molybdenum steel material with diff. Min. Tensile Strength
```

```
    Text1.Text = "H+T"
    Text2.Text = 1520
    Text3.Text = 444
    Text4.Text = 3.87
    Text5.Text = 36.6
    Text6.Text = "205000"
    Text7.Text = "min"
Case 24 '31Ni10Cr3Mo6 hardened & tempered forged Nickel,chromium
Molybdenum steel material with diff. Min. Tensile Strength
    Text1.Text = "H+T"
    Text2.Text = 1078.7
    Text3.Text = 311
    Text4.Text = 2.6
    Text5.Text = 26.7
    Text6.Text = "205000"
    Text7.Text = "min"
Case 25 '40Ni10Cr3Mo6 hardened & tempered forged Nickel,chromium
Molybdenum steel material
    Text1.Text = "H+T"
    Text2.Text = 980
    Text3.Text = 285
    Text4.Text = 2.47
    Text5.Text = 24.6
    Text6.Text = "205000"
    Text7.Text = "min"
Case 26 '40Ni10Cr3Mo6 hardened & tempered forged Nickel,chromium
Molybdenum steel material with diff. Min. Tensile Strength
    Text1.Text = "H+T"
    Text2.Text = 1520
    Text3.Text = 444
    Text4.Text = 3.81
    Text5.Text = 37.3
    Text6.Text = "205000"
    Text7.Text = "min"
Case 27 '40Ni10Cr3Mo6 hardened & tempered forged Nickel,chromium
Molybdenum steel material with diff. Min. Tensile Strength
    Text1.Text = "H+T"
    Text2.Text = 1176.8
    Text3.Text = 341
    Text4.Text = 3.82
    Text5.Text = 28.8
    Text6.Text = "205000"
    Text7.Text = "min"
Case 28 '40C8 Surface hardened Carbon steel with no heat treatment required
    Text1.Text = "None"
    Text2.Text = 540.6
    Text3.Text = 145
    Text4.Text = 1.97
    Text5.Text = 8.35
    Text6.Text = "206000"
```

```
    Text7.Text = "core"
Case 29 '55C6 Surface hardened Carbon steel with no heat treatment required
    Text1.Text = "None"
    Text2.Text = 694.9
    Text3.Text = 200
    Text4.Text = 2.8
    Text5.Text = 10.55
    Text6.Text = "206000"
    Text7.Text = "core"
Case 30 '55C6 Surface hardened Carbon Chromium steel with no heat treatment
required
    Text1.Text = "None"
    Text2.Text = 849.3
    Text3.Text = 250
    Text4.Text = 3.58
    Text5.Text = 12.91
    Text6.Text = "206000"
    Text7.Text = "core"
Case 31 '40Cr4 Surface hardened Carbon Chromium steel with no heat treatment
required
    Text1.Text = "None"
    Text2.Text = 694.9
    Text3.Text = 500
    Text4.Text = 2.8
    Text5.Text = 10.55
    Text6.Text = "206000"
    Text7.Text = "case"
Case Else
End Select
End Sub
Private Sub List2_Click()
Dim k As Integer
k = Val(List2.ListIndex)    'Driven choice of material
Select Case k       'Select Material
Case 0  'Grade 27-54 cast steel material with no heat treatment
    Text8.Text = "None"         'finished condition
    Text9.Text = 540            'Minimum tensile strength
    Text10.Text = 145           'Brinell hardness
    Text11.Text = 1.125         'Basic Surface stress factor
    Text12.Text = 13.38         'Basic Bending stress factor
    Text13.Text = 202000        'Modulus of Elasticity
    Text14.Text = ""            'HB condition
Case 1  'Grade 1 Annealed cast steel material
    Text8.Text = "Annealed"
    Text9.Text = 620
    Text10.Text = 182
    Text11.Text = 1.47
    Text12.Text = 15.3
    Text13.Text = 202000
    Text14.Text = "min"
```

```
Case 2  'Grade 1 hardened & tempered cast steel material
   Text8.Text = "H+T"
   Text9.Text = 790
   Text10.Text = 229
   Text11.Text = 1.9
   Text12.Text = 19.7
   Text13.Text = 202000
   Text14.Text = "min"
Case 3  'Grade 1 Surface hardened cast steel material
   Text8.Text = "Surface"
   Text9.Text = 620
   Text10.Text = 460
   Text11.Text = 1.97
   Text12.Text = 13.36
   Text13.Text = 202000
   Text14.Text = "(Case)min"
Case 4  '30C8 Normalized forged carbon steel material
   Text8.Text = "N"
   Text9.Text = 490.3
   Text10.Text = 143
   Text11.Text = 0.985
   Text12.Text = 11.95
   Text13.Text = "205000"
   Text14.Text = ""
Case 5  '30C8 hardened & tempered forged carbon steel material
   Text8.Text = "H+T"
   Text9.Text = 588.4
   Text10.Text = 152
   Text11.Text = 1.125
   Text12.Text = 14.8
   Text13.Text = "205000"
   Text14.Text = ""
Case 6  '40C8 Normalized forged carbon steel material
   Text8.Text = "N"
   Text9.Text = 568.8
   Text10.Text = 152
   Text11.Text = 1.125
   Text12.Text = 14.05
   Text13.Text = "205000"
   Text14.Text = ""
Case 7  '40C8 hardened & tempered forged carbon steel material
   Text8.Text = "H+T"
   Text9.Text = 588.4
   Text10.Text = 179
   Text11.Text = 1.44
   Text12.Text = 14.8
   Text13.Text = "205000"
   Text14.Text = ""
Case 8  '55C Normalized forged carbon steel material
   Text8.Text = "N"
```

```
    Text9.Text = 706.1
    Text10.Text = 201
    Text11.Text = 1.69
    Text12.Text = 17.6
    Text13.Text = "205000"
    Text14.Text = ""
Case 9  '55C hardened & tempered forged carbon steel material
    Text8.Text = "H+T"
    Text9.Text = 686.5
    Text10.Text = 223
    Text11.Text = 1.83
    Text12.Text = 16.9
    Text13.Text = "205000"
    Text14.Text = ""
Case 10 '55C forged carbon steel material with no heat treatment
    Text8.Text = "None"
    Text9.Text = 784.5
    Text10.Text = 248
    Text11.Text = 2.11
    Text12.Text = 19.7
    Text13.Text = "205000"
    Text14.Text = ""
Case 11 '55Cr3 hardened & tempered forged carbon chromium steel material
    Text8.Text = "H+T"
    Text9.Text = 882.6
    Text10.Text = 225
    Text11.Text = 2.105
    Text12.Text = 22.2
    Text13.Text = "205000"
    Text14.Text = "min"
Case 12 '55Cr3 hardened & tempered forged carbon chromium steel material with
diff.Min.Tensile Strength
    Text8.Text = "H+T"
    Text9.Text = 980.7
    Text10.Text = 285
    Text11.Text = 2.47
    Text12.Text = 24.6
    Text13.Text = "205000"
    Text14.Text = "min"
Case 13 '40Cr4 hardened & tempered forged carbon chromium steel material
    Text8.Text = "H+T"
    Text9.Text = 784.5
    Text10.Text = 229
    Text11.Text = 1.9
    Text12.Text = 19.7
    Text13.Text = "205000"
    Text14.Text = "min"
Case 14 '40Cr4Mo3 hardened & tempered forged chromium Molybdenum steel
material
    Text8.Text = "H+T"
```

```
    Text9.Text = 686.5
    Text10.Text = 201
    Text11.Text = 1.69
    Text12.Text = 16.9
    Text13.Text = "205000"
    Text14.Text = "min"
Case 15 '40Cr4Mo3 hardened & tempered forged chromium Molybdenum steel material with diff.Min.Tensile Strength
    Text8.Text = "H+T"
    Text9.Text = 784.5
    Text10.Text = 229
    Text11.Text = 1.9
    Text12.Text = 19.7
    Text13.Text = "205000"
    Text14.Text = "min"
Case 16 '40Cr4Mo3 hardened & tempered forged chromium Molybdenum steel material with diff.Min.Tensile Strength
    Text8.Text = "H+T"
    Text9.Text = 882.6
    Text10.Text = 225
    Text11.Text = 2.105
    Text12.Text = 23.2
    Text13.Text = "205000"
    Text14.Text = "min"
Case 17 '40Cr4Mo3 hardened & tempered forged chromium Molybdenum steel material with diff.Min.Tensile Strength
    Text8.Text = "H+T"
    Text9.Text = 980.7
    Text10.Text = 285
    Text11.Text = 2.47
    Text12.Text = 24.6
    Text13.Text = "205000"
    Text14.Text = "min"
Case 18 '40Cr5Mo6 hardened & tempered forged chromium Molybdenum steel material
    Text8.Text = "H+T"
    Text9.Text = 882.6
    Text10.Text = 248
    Text11.Text = 1.75
    Text12.Text = 23.2
    Text13.Text = "205000"
    Text14.Text = "min"
Case 19 '40Cr5Mo6 hardened & tempered forged chromium Molybdenum steel material with diff. Min. Tensile Strength
    Text8.Text = "H+T"
    Text9.Text = 980.7
    Text10.Text = 293
    Text11.Text = 2.06
    Text12.Text = 24.6
    Text13.Text = "205000"
```

```
    Text14.Text = "min"
Case 20 '40Ni6Cr4Mo6 hardened & tempered forged Nickel,chromium Molybdenum steel material
    Text8.Text = "H+T"
    Text9.Text = 882.6
    Text10.Text = 255
    Text11.Text = 2.11
    Text12.Text = 23.2
    Text13.Text = "205000"
    Text14.Text = "min"
Case 21 '40Ni6Cr4Mo6 hardened & tempered forged Nickel,chromium Molybdenum steel material with diff. Min. Tensile Strength
    Text8.Text = "H+T"
    Text9.Text = 1520
    Text10.Text = 444
    Text11.Text = 3.87
    Text12.Text = 37.3
    Text13.Text = "205000"
    Text14.Text = "min"
Case 22 '31Ni10Cr3Mo6 hardened & tempered forged Nickel,chromium Molybdenum steel material
    Text8.Text = "H+T"
    Text9.Text = 882.6
    Text10.Text = 255
    Text11.Text = 2.11
    Text12.Text = 23.3
    Text13.Text = "205000"
    Text14.Text = "min"
Case 23 '31Ni10Cr3Mo6 hardened & tempered forged Nickel,chromium Molybdenum steel material with diff. Min. Tensile Strength
    Text8.Text = "H+T"
    Text9.Text = 1520
    Text10.Text = 444
    Text11.Text = 3.87
    Text12.Text = 36.6
    Text13.Text = "205000"
    Text14.Text = "min"
Case 24 '31Ni10Cr3Mo6 hardened & tempered forged Nickel,chromium Molybdenum steel material with diff. Min. Tensile Strength
    Text8.Text = "H+T"
    Text9.Text = 1078.7
    Text10.Text = 311
    Text11.Text = 2.6
    Text12.Text = 26.7
    Text13.Text = "205000"
    Text14.Text = "min"
Case 25 '40Ni10Cr3Mo6 hardened & tempered forged Nickel,chromium Molybdenum steel material
    Text8.Text = "H+T"
    Text9.Text = 980
```

```
    Text10.Text = 285
    Text11.Text = 2.47
    Text12.Text = 24.6
    Text13.Text = "205000"
    Text14.Text = "min"
Case 26 '40Ni10Cr3Mo6 hardened & tempered forged Nickel,chromium
Molybdenum steel material with diff. Min. Tensile Strength
    Text8.Text = "H+T"
    Text9.Text = 1520
    Text10.Text = 444
    Text11.Text = 3.81
    Text12.Text = 37.3
    Text13.Text = "205000"
    Text14.Text = "min"
Case 27 '40Ni10Cr3Mo6 hardened & tempered forged Nickel,chromium
Molybdenum steel material with diff. Min. Tensile Strength
    Text8.Text = "H+T"
    Text9.Text = 1176.8
    Text10.Text = 341
    Text11.Text = 3.82
    Text12.Text = 28.8
    Text13.Text = "205000"
    Text14.Text = "min"
Case 28 '40C8 Surface hardened Carbon steel with no heat treatment required
    Text8.Text = "None"
    Text9.Text = 540.6
    Text10.Text = 145
    Text11.Text = 1.97
    Text12.Text = 8.35
    Text13.Text = "206000"
    Text14.Text = "core"
Case 29 '55C6 Surface hardened Carbon steel with no heat treatment required
    Text8.Text = "None"
    Text9.Text = 694.9
    Text10.Text = 200
    Text11.Text = 2.8
    Text12.Text = 10.55
    Text13.Text = "206000"
    Text14.Text = "core"
Case 30 '55C6 Surface hardened Carbon Chromium steel with no heat treatment
required
    Text8.Text = "None"
    Text9.Text = 849.3
    Text10.Text = 250
    Text11.Text = 3.58
    Text12.Text = 12.91
    Text13.Text = "206000"
    Text14.Text = "core"
Case 31 '40Cr4 Surface hardened Carbon Chromium steel with no heat treatment
required
```

```
   Text8.Text = "None"
   Text9.Text = 694.9
   Text10.Text = 500
   Text11.Text = 2.8
   Text12.Text = 10.55
   Text13.Text = "206000"
   Text14.Text = "case"
Case Else
End Select
End Sub
Private Sub List3_Click()
Dim k As Integer
k = Val(List3.ListIndex)    'type of load per service per day
Select Case k          'select type of load/service/day
' ks = Text28.Text which is Service factor
Case 0                 'Steady/8-10hrs
   Text28.Text = "1.00"
Case 1                 'Light shock/8-10hrs
   Text28.Text = "0.80"
Case 2                 'Medium shock/8-10hrs
   Text28.Text = "0.65"
Case 3                 'Heavy shock/8-10hrs
   Text28.Text = "0.55"
Case 4                 'Steady/24hrs
   Text28.Text = "0.80"
Case 5                 'Light shock/24hrs
   Text28.Text = "0.65"
Case 6                 'Medium shock/24hrs
   Text28.Text = "0.55"
Case 7                 'Heavy shock/24hrs
   Text28.Text = "0.50"
Case 8                 'Steady/Intermittent 3hrs
   Text28.Text = "1.25"
Case 9                 'Light shock/Intermittent 3hrs
   Text28.Text = "1.00"
Case 10                'Medium shock/Intermittent 3hrs
   Text28.Text = "0.80"
Case 11                'Heavy shock/Intermittent 3hrs
   Text28.Text = "0.65"
Case Else
End Select
End Sub
Private Sub List4_Click()
Dim k As Integer
k = Val(List4.ListIndex)    'Type of drive & Load
Select Case k
'FoS = Text29.Text which is the Factor of Safety
Case 0            'steady load on single pair
   Text29.Text = "3"
Case 1            'steady load on single pair
```

```
    Text29.Text = "4"
Case 2          'steady load on Gear Train
    Text29.Text = "5"
Case 3          'steady load on Gear Train
    Text29.Text = "6"
Case Else
End Select
End Sub


Private Sub mnuDesignDetailedCompute_Click()
Call Command1_Click
End Sub

Private Sub mnuDesignDetailedLoadError_Click()
Call Command7_Click
End Sub

Private Sub mnuDesignDetailedTest_Click()
Call Command4_Click
End Sub

Private Sub mnuEditClear_Click()
Call Command2_Click
End Sub

Private Sub mnuFileReturn_Click()
Call Command6_Click
End Sub

Private Sub mnufileSave_Click()
Call Command5_Click
End Sub

Private Sub mnuHelpAboutCadGear_Click()
fmrgear.Hide
Form7.Show
End Sub


Private Sub Text15_Change()
If Val(Text15) > 3600 Then
Text15 = ""
MsgBox " Driver Speed must be less than 3600", vbInformation, "DRIVER SPEED"
ElseIf Not IsNumeric(Text15) Then
Text15 = ""
Text15.SetFocus
End If
End Sub
```

```
Private Sub Text16_Change()
If Val(Text16) > 100 Then
Text16 = ""
MsgBox " Power must be less than 100", vbInformation, "POWER"
ElseIf Not IsNumeric(Text16) Then
Text16 = ""
Text16.SetFocus
End If
End Sub

Private Sub Text23_Change()
If Not IsNumeric(Text23) Then
Text23 = ""
Text23.SetFocus
End If
End Sub

Private Sub Text27_Change()
If Not IsNumeric(Text27) Then
Text27 = ""
Text27.SetFocus
End If
End Sub

'Gear Maximum Error Constant
Private Sub Combo1_Click()
   Dim i As Integer          'Module selection
   i = Val(Combo1.ListIndex)
If Option1.Value = True Then    'Class1: Industial Gear
  Select Case i              'Select module
   Case 0                    'initialized
      Text1.Text = ""
   Case 1 To 7               'module 1 to 4 selection option
      Text1.Text = "0.0508"
   Case 8                    'module 5 selected
     Text1.Text = "0.0559"
   Case 9                    'module 6 selected
      Text1.Text = "0.0660"
   Case 10                   'module 8 selected
      Text1.Text = "0.0813"
   Case 11                   'module 12 selected
     Text1.Text = "0.1016"
   Case 12                   'module 20 selected
     Text1.Text = "0.1219"
   Case Else
   End Select
ElseIf Option2.Value = True Then 'Class2: Accurate Gear
   Select Case i             'Select module
   Case 0                    'initialized
      Text1.Text = ""
```

```
    Case 1 To 7              'module 1 to 4 selection option
      Text1.Text = "0.0254"
    Case 8                  'module 5 selected
      Text1.Text = "0.0279"
    Case 9                  'module 6 selected
      Text1.Text = "0.0330"
    Case 10                  'module 8 selected
      Text1.Text = "0.0406"
    Case 11                  'module 12 selected
      Text1.Text = "0.0508"
    Case 12                  'module 20 selected
      Text1.Text = "0.0609"
    Case Else
    End Select
Else                        'Class3: Precision Gear
    Select Case i              'Select module
    Case 0                  'initialized
      Text1.Text = ""
    Case 1 To 7              'module 1 to 4 selection option
      Text1.Text = "0.0127"
   Case 8                   'module 5 selected
      Text1.Text = "0.0139"
    Case 9                  'module 6 selected
      Text1.Text = "0.0165"
    Case 10                  'module 8 selected
      Text1.Text = "0.0203"
    Case 11                  'module 12 selected
      Text1.Text = "0.0254"
    Case 12                  'module 20 selected
      Text1.Text = "0.0305"
    Case Else
    End Select
End If
End Sub

Private Sub Combo1_KeyDown(KeyCode As Integer, Shift As Integer)
    Dim i As Integer          'Module selection
    i = Val(Combo1.ListIndex)
If Option1.Value = True Then    'Class1: Industial Gear
  Select Case i               'Select module
    Case 0                  'initialized
      Text1.Text = ""
    Case 1 To 7              'module 1 to 4 selection option
      Text1.Text = "0.0508"
    Case 8                  'module 5 selected
      Text1.Text = "0.0559"
    Case 9                  'module 6 selected
      Text1.Text = "0.0660"
    Case 10                  'module 8 selected
      Text1.Text = "0.0813"
```

```
   Case 11                    'module 12 selected
     Text1.Text = "0.1016"
   Case 12                    'module 20 selected
     Text1.Text = "0.1219"
   Case Else
   End Select
ElseIf Option2.Value = True Then 'Class2: Accurate Gear
   Select Case i              'Select module
   Case 0                     'initialized
     Text1.Text = ""
   Case 1 To 7                'module 1 to 4 selection option
     Text1.Text = "0.0254"
   Case 8                     'module 5 selected
     Text1.Text = "0.0279"
   Case 9                     'module 6 selected
     Text1.Text = "0.0330"
   Case 10                    'module 8 selected
     Text1.Text = "0.0406"
   Case 11                    'module 12 selected
     Text1.Text = "0.0508"
   Case 12                    'module 20 selected
     Text1.Text = "0.0609"
   Case Else
   End Select
Else                          'Class3: Precision Gear
   Select Case i              'Select module
   Case 0                     'initialized
     Text1.Text = ""
   Case 1 To 7                'module 1 to 4 selection option
     Text1.Text = "0.0127"
   Case 8                     'module 5 selected
     Text1.Text = "0.0139"
   Case 9                     'module 6 selected
     Text1.Text = "0.0165"
   Case 10                    'module 8 selected
     Text1.Text = "0.0203"
   Case 11                    'module 12 selected
     Text1.Text = "0.0254"
   Case 12                    'module 20 selected
     Text1.Text = "0.0305"
   Case Else
   End Select
End If

End Sub

Private Sub Combo1_KeyUp(KeyCode As Integer, Shift As Integer)
    Dim i As Integer          'Module selection
   i = Val(Combo1.ListIndex)
If Option1.Value = True Then    'Class1: Industial Gear
```

```
  Select Case i           'Select module
   Case 0                 'initialized
     Text1.Text = ""
   Case 1 To 7            'module 1 to 4 selection option
     Text1.Text = "0.0508"
   Case 8                 'module 5 selected
    Text1.Text = "0.0559"
   Case 9                 'module 6 selected
     Text1.Text = "0.0660"
   Case 10                'module 8 selected
     Text1.Text = "0.0813"
   Case 11                'module 12 selected
    Text1.Text = "0.1016"
   Case 12                'module 20 selected
    Text1.Text = "0.1219"
   Case Else
   End Select
ElseIf Option2.Value = True Then 'Class2: Accurate Gear
   Select Case i           'Select module
   Case 0                 'initialized
     Text1.Text = ""
   Case 1 To 7            'module 1 to 4 selection option
     Text1.Text = "0.0254"
   Case 8                 'module 5 selected
     Text1.Text = "0.0279"
   Case 9                 'module 6 selected
     Text1.Text = "0.0330"
   Case 10                'module 8 selected
    Text1.Text = "0.0406"
   Case 11                'module 12 selected
     Text1.Text = "0.0508"
   Case 12                'module 20 selected
     Text1.Text = "0.0609"
   Case Else
   End Select
Else                      'Class3: Precision Gear
   Select Case i           'Select module
   Case 0                 'initialized
     Text1.Text = ""
   Case 1 To 7            'module 1 to 4 selection option
    Text1.Text = "0.0127"
  Case 8                  'module 5 selected
     Text1.Text = "0.0139"
   Case 9                 'module 6 selected
     Text1.Text = "0.0165"
   Case 10                'module 8 selected
     Text1.Text = "0.0203"
   Case 11                'module 12 selected
     Text1.Text = "0.0254"
   Case 12                'module 20 selected
```

```
        Text1.Text = "0.0305"
    Case Else
    End Select
End If

End Sub
Private Sub Command1_Click()
Dim i As Integer, X As Single, a As Double, e As Double
    a = 0.0125
    e = Val(Text1.Text)
    i = Val(List2.ListIndex)
If e <> 0 Then
If Option4.Value = True Then
    Select Case i              'Select Driver/Driven material
        Case 0                 'initialize
        Case 1                 'Cast Iron & cast iron Material selected
        X = 69.85
        If a = e Then
        Text2.Text = Format((X), "## .## ")
        fmrgear.Text17.Text = Format((X), "## .## ")
        ElseIf a < e <= 10 * a Then
        Text2.Text = Format((X + X * (e - a) / a), "## .## ")
        fmrgear.Text17.Text = Format((X + X * (e - a) / a), "## .## ")
        Else
        End If
    Case 2                     'Cast Iron & steel Material selected
        X = 96.04
        If e = a Then
        Text2.Text = Format((X), "## .## ")
        fmrgear.Text17.Text = Format((X), "## .## ")
        ElseIf a < e <= 10 * a Then
        Text2.Text = Format((X + X * (e - a) / a), "## .## ")
        fmrgear.Text17.Text = Format((X + X * (e - a) / a), "## .## ")
        Else
        End If
    Case 3                     'Steel & steel Material selected
        X = 139.7
        If e = a Then
        Text2.Text = Format((X), "## .## ")
        fmrgear.Text17.Text = Format((X), "## .## ")
        ElseIf a < e <= 10 * a Then
        Text2.Text = Format((X + X * (e - a) / a), "## .## ")
        fmrgear.Text17.Text = Format((X + X * (e - a) / a), "## .## ")
        Else
        End If
    Case Else
    End Select
ElseIf Option5.Value = True Then
    Select Case i
        Case 0            'initialize
```

```
    Case 1          'Cast Iron & cast iron Material selected
    X = 72.5
    If e = a Then
    Text2.Text = Format((X), "## .## ")
    fmrgear.Text17.Text = Format((X), "## .## ")
    ElseIf a < e <= 10 * a Then
    Text2.Text = Format((X + X * (e - a) / a), "## .## ")
    fmrgear.Text17.Text = Format((X + X * (e - a) / a), "## .## ")
    Else
    MsgBox "Compute Gear Error", vbInformation + vbOKOnly, "GEAR ERROR
CONSTANT"
    End If
  Case 2            'Cast Iron & steel Material selected
    X = 99.57
    If e = a Then
    Text2.Text = Format((X), "## .## ")
    fmrgear.Text17.Text = Format((X), "## .## ")
    ElseIf a < e <= 10 * a Then
    Text2.Text = Format((X + X * (e - a) / a), "## .## ")
    fmrgear.Text17.Text = Format((X + X * (e - a) / a), "## .## ")
    Else
    End If
  Case 3            'Steel & steel Material selected
    X = 145#
    If e = a Then
    Text2.Text = Format((X), "## .## ")
    fmrgear.Text17.Text = Format((X), "## .## ")
    ElseIf a < e <= 10 * a Then
    Text2.Text = Format((X + X * (e - a) / a), "## .## ")
    fmrgear.Text17.Text = Format((X + X * (e - a) / a), "## .## ")
    Else
    End If
  Case Else
  End Select
Else
MsgBox "Compute Gear Error", vbInformation + vbOKOnly, "GEAR ERROR
CONSTANT"
End If
Else
MsgBox "Compute Gear Error", vbInformation + vbOKOnly, "GEAR ERROR
CONSTANT"
End If
End Sub
Private Sub Command3_Click()
  Unload Form3
  fmrgear.Show
End Sub
Private Sub Form_Load()
'Add Items to Combo1
Combo1.AddItem "Module"
```

```
Combo1.AddItem "1"
Combo1.AddItem "1.25"
Combo1.AddItem "1.5"
Combo1.AddItem "2"
Combo1.AddItem "2.5"
Combo1.AddItem "3"
Combo1.AddItem "4"
Combo1.AddItem "5"
Combo1.AddItem "6"
Combo1.AddItem "8"
Combo1.AddItem "12"
Combo1.AddItem "20"
Combo1.ListIndex = 0
'Add Driver/Driven Material
List2.AddItem "Driver/Driven Material"
List2.AddItem "Cast Iron & Cast Iron"
List2.AddItem "Cast Iron & Steel"
List2.AddItem "Steel & Steel"
List2.ListIndex = 0
End Sub

Private Sub Form_Unload(Cancel As Integer)
   Unload Form3
   fmrgear.Show
End Sub

Private Sub Option1_Click()
Dim i As Integer
   i = Val(Combo1.ListIndex)
   Select Case i
   Case 0
      Text1.Text = ""
   Case 1 To 7
      Text1.Text = "0.0508"
   Case 8
      Text1.Text = "0.0559"
   Case 9
      Text1.Text = "0.0660"
   Case 10
      Text1.Text = "0.0813"
   Case 11
      Text1.Text = "0.1016"
   Case 12
      Text1.Text = "0.1219"
   Case Else
   End Select

End Sub
Private Sub Option1_GotFocus()
Dim i As Integer
```

```
  i = Val(Combo1.ListIndex)
  Select Case i
  Case 0
     Text1.Text = ""
  Case 1 To 7
     Text1.Text = "0.0508"
  Case 8
     Text1.Text = "0.0559"
  Case 9
     Text1.Text = "0.0660"
  Case 10
     Text1.Text = "0.0813"
  Case 11
     Text1.Text = "0.1016"
  Case 12
     Text1.Text = "0.1219"
  Case Else
  End Select

End Sub

Private Sub Option2_Click()
  Dim i As Integer
  i = Val(Combo1.ListIndex)
  Select Case i
  Case 0
    . Text1.Text = ""
  Case 1 To 7
     Text1.Text = "0.0254"
  Case 8
   . Text1.Text = "0.0279"
  Case 9
     Text1.Text = "0.0330"
  Case 10
     Text1.Text = "0.0406"
  Case 11
     Text1.Text = "0.0508"
  Case 12
    Text1.Text = "0.0609"
  Case Else
  End Select
End Sub

Private Sub Option2_GotFocus()
Dim i As Integer
  i = Val(Combo1.ListIndex)
  Select Case i
  Case 0
     Text1.Text = ""
  Case 1 To 7
```

```
        Text1.Text = "0.0254"
    Case 8
        Text1.Text = "0.0279"
    Case 9
        Text1.Text = "0.0330"
    Case 10
        Text1.Text = "0.0406"
    Case 11
        Text1.Text = "0.0508"
    Case 12
        Text1.Text = "0.0609"
    Case Else
    End Select
End Sub

Private Sub Option3_Click()
Dim i As Integer
    i = Val(Combo1.ListIndex)
Select Case i
    Case 0
        Text1.Text = ""
    Case 1 To 7
        Text1.Text = "0.0127"
    Case 8
        Text1.Text = "0.0139"
    Case 9
        Text1.Text = "0.0165"
    Case 10
        Text1.Text = "0.0203"
    Case 11
        Text1.Text = "0.0254"
    Case 12
        Text1.Text = "0.0305"
    Case Else
    End Select
End Sub

Private Sub Option3_GotFocus()
Dim i As Integer
    i = Val(Combo1.ListIndex)
Select Case i
    Case 0
        Text1.Text = ""
    Case 1 To 7
        Text1.Text = "0.0127"
    Case 8
        Text1.Text = "0.0139"
    Case 9
        Text1.Text = "0.0165"
    Case 10
```

```
        Text1.Text = "0.0203"
    Case 11
        Text1.Text = "0.0254"
    Case 12
        Text1.Text = "0.0305"
    Case Else
    End Select
End Sub

Private Sub Form_Unload(Cancel As Integer)
MsgBox "2D - Drawing!", vbOKOnly + vbExclamation, "EXIT"
    Form2.Hide
    Form1.Show
End Sub

Private Sub mnuFileExit_Click()
If MsgBox("Are you sure you want to exit program?", vbQuestion + vbYesNo, "EXIT
SCREEN") = vbYes Then
    Unload Me
    Form5.Show
Else
    Load Me
End If
End Sub

'2D-Drawings
Private Sub mnuFileReturn_Click()
If MsgBox("Back to Design?", vbQuestion + vbYesNo, "CONFIRMATION") =
vbYes Then
    Unload Me
    Form1.Show
Else
    Load Me
End If
End Sub
```