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A SOFTWARE DEVELOPMENT IN GEAR DESIGN

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ABSTRACT: *Power or energy production is improbable everywhere due to various factors. For assorted applications, people depending source of power.This shows the need of transmission of power. Considering power transmission of mechanical drives, mesh type of drives are largely used to maintain the velocity ratio. Among mesh type, gears transmitting the power by means of successive engagement of their teeth. Design of gears either by manually or using computers has become a highly convoluted and comprehensive subject. Therefore, this study present a new method of how the gears can be designed and detailed with computer, previously, highlighting the design process which involves prolong time. A reliable software package developed with a help of Visual Basic 6.0 (VB) provides significant saving time reduces its convolution.*

Keywords- *Power transmission, Design, Gear, Package, VB.*

1. INTRODUCTION

Gears are the drives which transmit power between the shafts by means of successive engagement of teeth. Among mesh type drive, gears are preferable when a constant speed ratio that is velocity ratio is desired and the distance between the shafts is comparatively small. Gears operate in pairs the smaller of the pair being called the pinion and the larger one the gear. Usually the pinion drives the gear and then it can act either as a speed reducer or speed accelerator and a torque converter. Generally gears are designed either by considering gear life or beam strength which is based on American Gear Manufactures Association (AGMA).

Nordiana et al presented a new method of spur gear design detailed with computer aided design [1]. The presenters developed a package namely "Cadgear (2007)" which enhances the analytical and logical power of the designer of gear system. Varatharajulu and Rajendran developed a visual basic package to do the design of coupling and knuckle joint, which has the ability to reduce the burden of designer [2]. Researcher concluded that, the design of machine elements, transmission systems and jigs and fixture is possible by visual basic.

This attempt concentrates on design of spur, helical, bevel and worm gear design based on two conventional techniques, with a help of computer aided design. A machine language is needed to make the computer to understand. Here coding written in visual basic, the computer processes these statements into visual basic language.

1.1 Software Development

Visual Basic project explorer window has the tool box. From the tool box the label, text box and command box were dragged and then dropped in the appropriate position. Then code was written in the respective page according to the design parameters. Properties window helps to make the changes.

1.2. Sample source code

With the help of Visual Basic authors, developed the software which will reduce the complication in gear design. Sample source code given, for reader's reference.

```
Public dbcon As New ADODB.Connection
Public rs As New ADODB.Recordset
Dim pi As Integer
Dim p As Double
Dim i As Double
Dim n1 As Double
Dim n2 As Double
Dim s1 As Double
Dim s2 As Double
Dim s3 As Double
Dim s4 As Double
Dim e1 As Double
Dim e2 As Double
Dim e As Double
Dim m1 As Double
Dim m2 As Double
Dim sai As Double
Dim saim As Double
Dim m As Double
Dim m3 As Double
Dim y As Double
Private Sub Combo3_Click()
If Combo3.Text = "Speed ratio, Pinion speed" Then
Label2.Visible = True
Label3.Visible = True
Label13.Visible = True
Text2.Visible = True
Text3.Visible = True
Label47.Visible = False
Text8.Visible = False
Label51.Visible = False
End If
If Combo3.Text = "Speed ratio, Gear speed" Then
Label2.Visible = True
Label47.Visible = True
Label51.Visible = True
Text2.Visible = True
Text8.Visible = True
Label3.Visible = False
Text3.Visible = False
Label13.Visible = False
```

```
End If
If Combo3.Text = "Pinion speed, Gear speed" Then
Label47.Visible = True
Text8.Visible = True
Label13.Visible = True
Label3.Visible = True
Text3.Visible = True
Label51.Visible = True
Text2.Visible = False
Label2.Visible = False
End If
End Sub
Private Sub Command3_Click()
Form17.Show
Me.Hide
End Sub
Private Sub Command_Click()
Me.PrintForm
End Sub
Private Sub Command4_Click()
Me.Hide
Form2.Show
End Sub
Private Sub Command5_Click()
End
End Sub
Private Sub Form_Load()
dbcon.ConnectionString = "Provider=Microsoft.Jet.OLEDB.4.0;Data Source=" + App.Path +
"\Database.mdb"
dbcon.Open
End Sub
Private Sub Combo1_Click()
rs.Open "select * from Table6 where Material = '" & Combo1.Text & "' ", dbcon, adOpenDynamic,
adLockOptimistic, -1
Text5.Text = rs.Fields(2)
Text6.Text = rs.Fields(1)
Text7.Text = rs.Fields(3)
rs.Close
End Sub
Private Sub Combo2_Click()
rs.Open "select * from Table6 where Material = '" & Combo2.Text & "' ", dbcon, adOpenDynamic,
adLockOptimistic, -1
Text9.Text = rs.Fields(2)
Text10.Text = rs.Fields(1)
```

```
Text11.Text = rs.Fields(3)
rs.Close
End Sub
Private Sub Command1_Click()
p = Val(Text1.Text)
If Combo3.Text = "Speed ratio, Pinion speed" Then
i = Val(Text2.Text)
n1 = Val(Text3.Text)
n2 = n1 / i
End If
If Combo3.Text = "Speed ratio, Gear speed" Then
i = Val(Text2.Text)
n2 = Val(Text8.Text)
n1 = i * n2
End If
If Combo3.Text = "Pinion speed, Gear speed" Then
n1 = Val(Text3.Text)
n2 = Val(Text8.Text)
i = n1 / n2
End If
s1 = Val(Text5.Text)
s2 = Val(Text6.Text)
s3 = Val(Text9.Text)
s4 = Val(Text10.Text)
e1 = Val(Text7.Text)
e2 = Val(Text11.Text)
Text12.Text = (60 * p * 10 ^ 3) / (2 * 3.14159265358979 * n1)
Text12.Text = Round(Val(Text12.Text), 5)
m1 = Val(Text12.Text)
Text13.Text = m1 * 1.3
Text13.Text = Round(Val(Text13.Text), 5)
m2 = Val(Text13.Text)
Text14.Text = (2 * Val(Text7.Text) * Val(Text11.Text)) / (Val(Text7.Text) + Val(Text11.Text))
e = Val(Text14.Text)
Text15.Text = (i + 1) * ((0.74 / s3) ^ 2 * e * m2 * 10 ^ 3 / (i * 0.3)) ^ (1 / 3)
Text15.Text = Round(Val(Text15.Text), 0)
m = (1.26) * (m2 * 10 ^ 3 / (0.389 * s4 * 10 * 20)) ^ (1 / 3)
Text16.Text = Round(m, 2)
 Text28.Text = Val(Text16.Text)
 m4 = Val(Text28.Text)
If Round(m4, o) - m4 < 0 Then
Text28.Text = Round((m4 + 1), 0)
Else
Text28.Text = Round(m4, 0)
```

```
End If
rs.Open "select * from Table5 where FIRST = '" & Text28.Text & "' ", dbcon, adOpenDynamic, adLockOptimistic, -1
Text17.Text = rs.Fields(1)
rs.Close
sai = 0.3
saim = 10
Text18.Text = ((2 * Val(Text15.Text)) / (Val(Text17.Text) * (i + 1)))
Text18.Text = Round((Text18.Text), 0)
rs.Open "select * from Table7 where pinion = '" & Text18.Text & "' ", dbcon, adOpenDynamic, adLockOptimistic, -1
Text4.Text = rs.Fields(1)
y = rs.Fields(2)
rs.Close
Text19.Text = i * Val(Text4.Text)
Text20.Text = Val(Text17.Text) * Val(Text4.Text)
Text20.Text = Round((Text20.Text), 3)
Text21.Text = Val(Text17.Text) * Val(Text19.Text)
Text21.Text = Round((Text21.Text), 3)
Text22.Text = (Val(Text20.Text) + Val(Text21.Text)) / 2
b = sai * Val(Text22.Text)
b1 = saim * Val(Text17.Text)
If b > b1 Then
Text23.Text = b
Else
Text23.Text = b1
End If
Text25.Text = Val(Text12.Text) * 1.47
Text25.Text = Round(Val(Text25.Text), 3)
Text29.Text = ((i + 1) * Val(Text25.Text) * 10 ^ 3) / (Val(Text22.Text) * Val(Text17.Text) * Val(Text23.Text) * y)
Text29.Text = Round(Val(Text29.Text), 3)
If Val(Text29.Text) < Val(Text6.Text) Then
Text26.Text = "Design is safe"
Else
Text26.Text = "Design is not safe"
End If
Text24.Text = 0.74 * ((i + 1) / Val(Text22.Text)) * ((i + 1) * Val(Text14.Text) * Val(Text25.Text) * 1000 / (i * Val(Text23.Text))) ^ (1 / 2)
Text24.Text = Round(Val(Text24.Text), 3)
If Val(Text24.Text) < Val(Text5.Text) Then
Text27.Text = "Desing is safe"
Else
Text27.Text = "Design is not safe"
```

```
End If
End Sub
Private Sub Command2_Click()
Text18.Text = ((2 * Val(Text15.Text)) / (Val(Text17.Text) * (i + 1)))
Text18.Text = Round((Text18.Text), 0)
rs.Open "select * from Table7 where pinion = '" & Text18.Text & "' ", dbcon, adOpenDynamic,
adLockOptimistic, -1
Text4.Text = rs.Fields(1)
y = rs.Fields(2)
rs.Close
Text19.Text = i * Val(Text4.Text)
Text20.Text = Val(Text17.Text) * Val(Text4.Text)
Text20.Text = Round((Text20.Text), 3)
Text21.Text = Val(Text17.Text) * Val(Text19.Text)
Text21.Text = Round((Text21.Text), 3)
Text22.Text = (Val(Text20.Text) + Val(Text21.Text)) / 2
b = sai * Val(Text22.Text)
b1 = saim * Val(Text17.Text)
If b > b1 Then
Text23.Text = b
Else
Text23.Text = b1
End If
Text25.Text = Val(Text12.Text) * 1.47
Text25.Text = Round(Val(Text25.Text), 3)
Text29.Text = ((i + 1) * Val(Text25.Text) * 10 ^ 3) / (Val(Text22.Text) * Val(Text17.Text) *
Val(Text23.Text) * y)
Text29.Text = Round(Val(Text29.Text), 3)
If Val(Text29.Text) < Val(Text6.Text) Then
Text26.Text = "Design is safe"
Else
Text26.Text = "Design is not safe"
End If
Text24.Text = 0.74 * ((i + 1) / Val(Text22.Text)) * ((i + 1) * Val(Text14.Text) * Val(Text25.Text) *
1000 / (i * Val(Text23.Text))) ^ (1 / 2)
Text24.Text = Round(Val(Text24.Text), 3)
If Val(Text24.Text) < Val(Text5.Text) Then
Text27.Text = "Desing is safe"
Else
Text27.Text = "Design is not safe"
End If
End Sub
```

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2. SOFTWARE DEVELOPMENT

2.1. Execution of the Software

The software consists of the following pages. First page has the classification of gears. Selection of gear using, the combo box lead to next page. The task in the first page is shown in figure 1. From clicking the command box 'Click Here' will bring the next page.

Fig. 1. Very first page of the software having the combo box, to select the needed design

Fig. 2. Respective design page, having its classification in the combo box.

Selection of required gear design either based on gear life or based on beam strength is in the second page. The tasks in the second page are shown in figure 2. From clicking the command box 'Click Here' will bring the next page.

2.2. *Justification*

Justification is the very significant portion in the software development. Software developer has to validate, whether the software will give the appropriate design or not. With the help of the manual calculation alone validate possible while the package is in developing stage. Preprocessing work, that is manual calculation of various gear design made to formulate the coding. Here, an example calculation presented to highlight the tediousness of design process and to justify the software.

*2.1.1. Justification (***Spur gear design based on gear life)**

$$a \geq (i \pm 1)\sqrt[3]{\left(\frac{0.74}{[\sigma_c]}\right)^2 \frac{E\,[M_t]}{i\,\psi}} \qquad \text{PSGDD 8.13}$$

I	=	4		Given
$[\sigma_c]$	=	500	N/mm^2	*Minimum value among pinion and gear*
E	=	2.15×10^5	N/mm^2	PSGDD 8.14
Ψ	=	$\frac{b}{a} = 0.3$ (initially assume)		PSGDD 8.1, 8.14
$[M_t]$	=	$M_t \times k \times k_d$		PSGDD 8.15

$$P = \frac{2 \times \pi \times n \times Mt}{60}$$

$$M_t = \frac{60 \times P}{2 \times \pi \times n}$$

$$= \frac{60 \times 20 \times 10^3}{2 \times \pi \times 1400}$$

	=	136.418	N-m	
K. K_d	=	1.3 (initially assume)		PSGDD 8.15
$[M_t]$	=	136.418×1.3		
	=	177.343	N-m	
	=	177.343×10^3	N-mm	

$$a = (4+1)\sqrt[3]{\left(\frac{0.74}{[\sigma_c]}\right)^2 \frac{2.15 \times 10^6 \times 177.343 \times 1}{4 \times 0.3}}$$

a = 205.669 ≈ 206 Mm

Design a pair of spur gear to transmit 20kW at pinion speed is 1400 rpm, transmission ratio is 4. Assume suitable material and stresses [3-7].

Given

P = 20 kW = 20×10^3 W, n = 1400, rpm; i = 4

1. Material selection

	Material	$[\sigma_b]$	$[\sigma_c]$
		N/mm²	
Pinion	*15Ni2Cr1Mo15*	*320*	*950*
Gear	*C45*	*140*	*500*

From PSG Design data book: 1.40, 8.4 & 8.5

2. Minimum centre distance

$$a \geq (i \pm 1)\sqrt[3]{\left(\frac{0.74}{[\sigma_c]}\right)^2 \frac{E\,[M_t]}{i\,\psi}} \qquad \text{PSGDD 8.13}$$

I	=	4		Given
$[\sigma_c]$	=	500	N/mm²	*Minimum value among pinion and gear*
E	=	2.15×10^5	N/mm²	PSGDD 8.14
Ψ	=	$\frac{b}{a}$ = 0.3 (initially assume)		PSGDD 8.1, 8.14
$[M_t]$	=	$M_t \times k \times k_d$		PSGDD 8.15

$$P = \frac{2 \times \pi \times n \times Mt}{60}$$

$$M_t = \frac{60 \times P}{2 \times \pi \times n}$$

$$= \frac{60 \times 20 \times 10^3}{2 \times \pi \times 1400}$$

	=	136.418	N-m	
K. K_d	=	1.3 (initially assume)		PSGDD 8.15
$[M_t]$	=	136.418×1.3		

= 177.343 N-m

= 177.343×10^3 N-mm

$$a = (4+1)\sqrt[3]{\left(\frac{0.74}{[\sigma_c]}\right)^2 \frac{2.15 \times 10^6 \times 177.343 \times 10^3}{4 \times 0.3}}$$

a = 205.669 ≈ 206 Mm

3. Minimum module

$$m \geq 1.26\sqrt[3]{\frac{[M_t]}{y[\sigma_b]\Psi_m Z_1}}$$ PSGDD 8.13A

$[M_t]$ = 177.343×10^3 N-mm

Y = 0.389 (assume Z_1 = 20 and X = 0) PSGDD 8.18

$[\sigma_b]$ = 140 N/mm^2 *Minimum value among pinion and gear*

Ψ_m = $\frac{b}{m}$ = 10 (initially assume) PSGDD 8.14

Z_1 = 20 (initially assume) PSGDD 8.18

$$m = 1.26\sqrt[3]{\frac{177.343 \times 10^3}{0.389 \times 140 \times 10 \times 20}}$$ *Minimum centre distance value rounded off from recommended series available in design data*

m = 3.194 ≈ 4 Mm PSGDD 8.2

4. Calculation of number of teeth

$$Z_1 = \frac{2a}{m(i+1)}$$ PSGDD 8.22

$$= \frac{2 \times 206}{4 \times (4+1)}$$

= 20.6 ≈ 22 (Rounded off from table 18 in design data) PSGDD 8.18

Z_2 = i Z_1

= 4×22 = 88

5. Calculation of pitch circle diameter

d_1 = mZ_1 = 4×22 = 88 Mm PSGDD 8.22

d_2 = mZ_2 = 4×88 = 352 Mm PSGDD 8.22

6. Correction of center distance

$$a = \frac{(d_1+d_2)}{2} = \frac{(88+352)}{2} = 220\ mm > 206\ mm$$

Calculated center distance is greater than the early calculated one. Hence the design is safe.

7. Calculation of face width

$\Psi = \frac{b}{a}$ $\Psi_m = \frac{b}{m}$

$0.3 = \frac{b}{220}$ $10 = \frac{b}{4}$

$b = 66$ $B = 40$

Consider the larger among the above values. Therefore face width b = 66 mm

8. Revision of design torque

$[M_t] = M_t \times k \times k_d$ PSGDD 8.15

k - Load concentration factor for steel gears of quality IS 8 having HB > 350 (assume bearings close to gears and symmetrical)

$$\Psi_p = \frac{b}{d_1} = \frac{66}{88} = 0.75$$

If $\Psi_p = 0.6$, k = 1.03

PSGDD 8.15

If $\Psi_p = 0.8$, k = 1.06, therefore k calculated based on interpolation

$$\frac{0.75 - 0.6}{0.8 - 0.6} = \frac{k - 1.03}{1.06 - 1.03}$$

k = 1.0525

k_d - Dynamic load factor (assumption IS 8 quality cylindrical gear)

$$v = \frac{\pi d_1 n_1}{60000} = \frac{\pi \times 88 \times 1400}{60000} = 6.451\ m/s$$

If v = 3 m/s, $k_d = 1.3$

PSGDD 8.16

If v = 8 m/s, $k_d = 1.6$, therefore k_d calculated based on interpolation

$$\frac{6.451 - 3}{8 - 3} = \frac{k_d - 1.3}{1.6 - 1.3}$$

$k_d = 1.369$

$[M_t] = 136.418 \times 1.0525 \times 1.369$

$= 200.585$ N-m

$= 200.585 \times 10^3$ N-mm

9. Checking of bending stress

$\sigma_b = \frac{i+1}{amby}[M_t] \leq [\sigma_b]$ PSGDD 8.13A

I	=	4			
A	=	220	Mm		
M	=	4	Mm		
B	=	66	Mm		
Y	=	0.402 (Z_1 = 22 and X = 0)		PSGDD	8.18
$[M_t]$	=	196.563×10^3	N-mm		

$$\sigma_b = \frac{(4+1)}{220 \times 4 \times 66 \times 0.402} \times 196.563 \times 10^3$$

$= 42.944 \leq 140$ N/mm^2

Calculated bending stress is less than the design bending stress. Hence, Design is safe.

10. Checking for compressive stress

$$\sigma_c = 0.74 \frac{(i+1)}{a} \sqrt{\frac{(i+1)}{ib} E[M_t]} \leq [\sigma_c]$$ PSGDD 8.13

E	=	2.15×10^5	N/mm^2
B	=	66	Mm
$[M_t]$	=	196.563×10^3	N-mm

$$\sigma_c = 0.74 \times \frac{(4+1)}{220} \sqrt{\frac{(4+1)}{4 \times 66} \times 2 \times 10^5 \times 196.563 \times 10^3}$$

$= 480.592 \leq 500$ N/mm^2

Calculated compressive stress is less than the design compressive stress. Hence, Design is safe.

11. Checking for compressive stress

$$\sigma_c = 0.74 \frac{(i+1)}{a} \sqrt{\frac{(i+1)}{ib} E[M_t]} \leq [\sigma_c]$$ PSGDD 8.13

E	=	2.15×10^5	N/mm^2
B	=	66	Mm
$[M_t]$	=	196.563×10^3	N-mm

$$\sigma_c = 0.74 \times \frac{(4+1)}{220} \sqrt{\frac{(4+1)}{4 \times 66} \times 2 \times 10^5 \times 196.563 \times 10^3}$$

$= 480.592 \leq 500$ N/mm^2

Calculated compressive stress is less than the design compressive stress. Hence, Design is safe.

12. Other parameters

f_0 =1 and c = 0.25 — PSGDD 8.1

h_a	=	$f_0 m$	=	1×4	=	4	Mm	PSGDD	8.22
h_f	=	(f_0+c) m	=	1.25×4	=	5	Mm	PSGDD	8.22
d_{a1}	=	d_1+2h_a	=	88+2×4	=	96	Mm	PSGDD	8.24
d_{a2}	=	d_2+2h_a	=	352+2×4	=	360	Mm	PSGDD	8.24
d_{f1}	=	d_1-2h_f	=	88-2×5	=	78	Mm	PSGDD	8.24
d_{f2}	=	d_2-2h_f	=	352-2×5	=	342	Mm	PSGDD	8.24

Table 1 –Specification

Sl. No.	Description	Pinion	Gear
1	Material	15Ni2Cr1Mo15	C45
2	Number of teeth	22	88
3	Pitch circle diameter	88 mm	352 mm
4	Tip circle diameter	96 mm	360 mm
5	Root circle diameter	78 mm	342 mm
6	Centre distance	220 mm	
7	Face width	66 mm	
8	Torque	196.563×10^3 N – mm	
9	Module	4 mm	
10	Addendum	4 mm	
11	Dedendum	5 mm	
12	Height factor	1 mm	
13	Bottom clearance	0.25 mm	
14	Tooth depth	9 mm	

Earlier two tasks, brings the respective design input page. Here, sample page i.e., design of spur gear based on gear life illustrating the inputs like power, speed ratio, material for pinion and gear, etc.

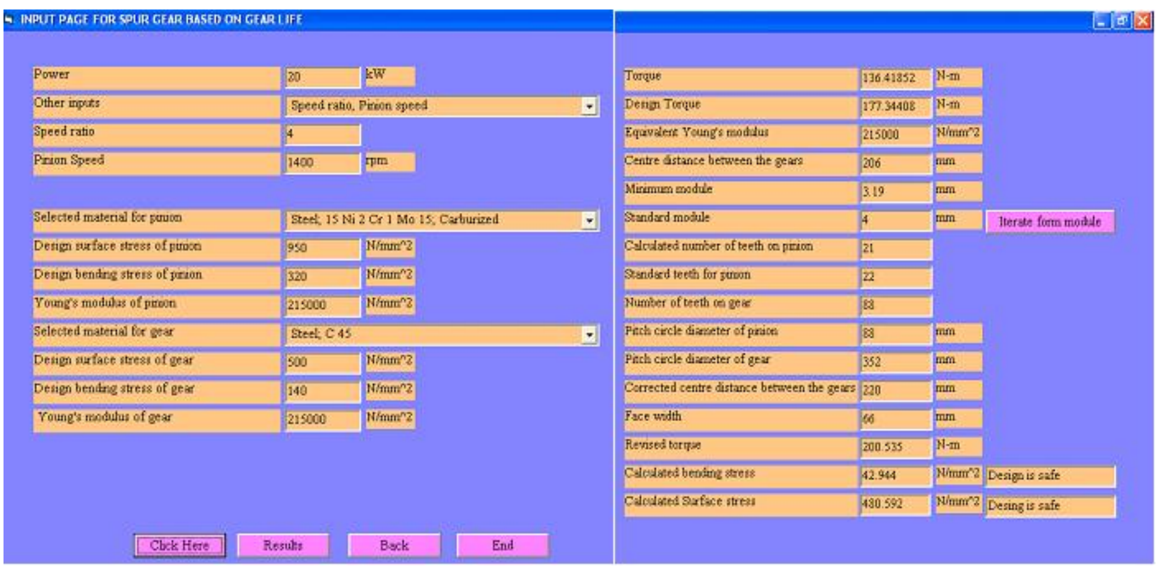

Fig. 3 Spur gear design based on gear life, calculation page

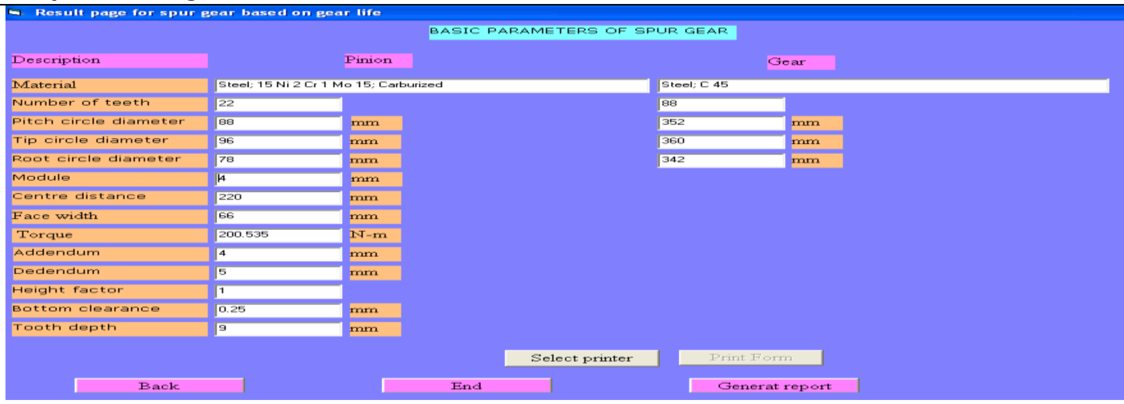

Fig. 4 Final specification page

Adopt all the primary inputs in the text box and then command box 'Click Here' will lead to get the calculated data's in the right side column in the same page which was consisting mean torque, design torque, equivalent young's modulus, module, number of teeth, pitch circle diameter and etc as illustrated in figure 3. The same page has the design status, whether calculated bending and surface stress is in safe zone of not so. If, the design is not safe, iteration is possible form the module dimensions. By means of many ways that is by changing the gear material or by changing the pinion material or increasing the centre distance or increasing module lead to safe design. Here, one can change their input of preliminary calculated values accordingly they can make safest design. After the verification of the calculated data's, the command box 'Result' leads to the next page i.e., final specification page. A database (Microsoft office access), recall the data's with respect to the input and adapt for the further calculation.

The figure 4 has shown the final specification page for the spur gear. Design is an iterative process, aiming at reaching the best possible result. If the first design is not satisfactory, further modifications are to be carried out till the best performance is obtained. The software gives such a nice feasibility to the users.

Table 2-*Justification of Results*

Description	***Symbol***	***Manual Calculation***	***Software Result***	***Unit***
Number of teeth on pinion	z_1	*21*	*21*	
Number of teeth on gear	z_2	*88*	*88*	
Pitch circle diameter of pinion	d_1	*88*	*88*	*mm*
Pitch circle diameter of gear	d_2	*352*	*352*	*mm*
Tip circle diameter of pinion	da_1	*96*	*96*	*mm*
Tip circle diameter of gear	da_2	*360*	*360*	*mm*
Root circle diameter of pinion	df_1	*78*	*78*	*mm*
Root circle diameter of gear	df_2	*342*	*342*	*mm*
Calculated bending stress	σ_b	*42.949*	*42.949*	N/mm^2
Calculated surface stress	σ_c	*480.592*	*480.592*	N/mm^2
Face width	B	*66*	*66*	*mm*
Torque	M_t	*200.535*	*200.535*	*N-m*
Center distance	A	*220*	*220*	*mm*

Module	*M*	*4*	*4*	*mm*
Addendum	h_a	*4*	*4*	*mm*
Dedendum	h_f	*5*	*5*	*mm*
Height factor	f_o	*1*	*1*	*mm*
Bottom clearance	*C*	*0.25*	*0.25*	*mm*
Tooth depth	*H*	*9*	*9*	*mm*

Comparing (table 2) the manual calculation with the software results shows good agreement among results. Similar validation of each and every page i.e. helical, bevel and worm gear design based on gear life as well as beam strength, carried out to give fullness to the package.

2.3. *Features*

- Within a short span one can do the design without manual error.
- Even a semi skilled operator enough to do the design.
- User can do the optimum design, by changing the numerical in the respective design calculation pages.

2.4. Future development

At present the software includes the design of various gears. It is planned to include the other design such as machine elements, transmission system and jigs and fixture, etc. Integration of modeling software can generate graphical output. Further studies needed to incorporate those things.

3. CONCLUSION

This study presents a new method of gear design and detailed with computer. Developed system provides the user to perform repetitive and routine tasks involved in gear design, also provides a flexibility to optimize the design process which will improve the productivity by means of reducing manufacturing cost. It was evident that the developed system will successfully increase productivity by roughly twenty times over manual gear design at reduced cost, provides significant saving time reduces its convolution.

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