Catia customization for Design and Modeling of Two stage spur Gearbox

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1. Introduction

Current scenario of the market is competitive. To sustain in the market for company product time to the market have to be minimum. Companies existing product demands from the customer are to be provided quickly as soon as possible. Existing product requirement has same parametric features of components for different specification. Design and modeling time of the product is generally 60-70% of overall time of the product development. Design phase has lot of potential where time can be saved. Parametric modeling can be used for saving the modeling time. Knowledge based approach can be useful for saving the design time. Lot of repetitive calculations can be saving for avoiding tedious work. CATIA software is selected having strong parameterization. Mechanical product selected is gearbox. Nowadays best of the best innovations are coming into picture, in these, researchers have made one way to reduce maximum design time by doing design automation concept which means integration of GUI developed with the help of computer programming language and market available CAD packages. Graphical User Interface (GUI) is the only way for users to communicate with the system.

But no specific software is available for the design of a specific product. So by this dissertation approach it is very important to make one tailor-made software which will be useful for complete design of a specific component and output of the software should easily be integrated with other modeling software. In this with use of Macro which means program written for specific task. For developing advanced macros for special needs Catia V5 is an open system. Macros may be useful for creating, analyzing, measuring, modifying. Translating, optimizing surfaces, solids, wireframes and more. Macros are useful for part operation, assembly operation and all multidisciplinary applications.
2. Literature Review

Many research attempts have been made in the area of parametric modeling.

Ruchik D. Trivedi et al [1] discussed about integrating the commercially available package Pro/E with Microsoft Excel spreadsheet for 3D parametric modeling. Various product variants of the inner ring of spherical roller bearing have been executed by parametric designing concept in Pro/Engineer Wildfire.

Umesh Bedse et al [2] discussed about developed GUI is made for the case study of design of CI engine parts like cylinder head, cylinder block, piston and crankshaft. CI engine is having many numbers of mechanical components, but parts named above are the most important parts of any CI engine. So design of these parts is useful to take into account to develop a GUI. And creo software is used for modeling.

Indrajitsinh J. Jadeja et al [3] discussed about the work reviews the procedural steps involved in the design of couplings and the development of the software package using visual basic as a tool for the design. This system is carried out on the case study of flange coupling and standard design equation being carried out together with the use of programming software and use CREO as modeling software.

Dhaval b. shah et al [4] discussed about the 3D models for flange type coupling and related dimension database in Microsoft Excel have been prepared. This Excel sheet has been linked with Autodesk Inventor to transfer data and relate to respective features of the part. User can update the model just by modifying the sheet. This takes comparatively very less time to generate complex part models with respect to generating them individually. This automation can further be proceeded by exporting models to the analysis or CAM package.

L.Karikalan et al [5] discussed about the the main purpose of this assignment is to provide a gear box with Low reduction ratio, low weight and efficient for engine up to 500cc. It should also be used in “All Terrain” vehicles.

CATIA V5

CATIA (Computer Aided Three Dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by French company Dassault Systems and it is marketed world-wide by IBM. Catia is the world’s leading CAD/CAM/CAE software. For developing advanced macros for special needs Catia V5 is open system. A macro is a series of functions, written in a scripting language, that you group in a single command to perform the requested task automatically. These macros may be useful for creating, analyzing, measuring, modifying, Translating, optimizing surfaces, solids, wireframes and more. Macros are used to save time, reduce the possibility of human error by automating repetitive processes, standardization, improving efficiency, expanding Catia’s capabilities, and for streamlining tasks. For creating basic structure and basic flow of program we require inputs, outputs, and supporting data from the user. Catia provides customization capability. In Catia the part Objects, which are used for developing part model i.e. three dimensional object are structured under a automation tree.

CATIA V5 MACROS

A macro is a series of functions, written in a scripting language, that you group in a single command to perform the requested task automatically. In simple it is a piece of code written in certain programming language which groups a set of operation that defines a certain task. For each task separate code is written and assembled together by using forms.

CATIA Customization/Automation Objects

In CATIA the part objects, which are used for developing part model i.e. three dimensional object are structured under a tree as shown in the following figure. As and when needed the part object can be extracted with the macro programming for customization or automation of CATIA V5 The Part Document object aggregates, or includes, the part tree structure starting with the Part object located at the top of the part specification tree. These Part Document objects are: Origin Element, Geometric...
Elements, Bodies and Part objects are: Constraints, Relations, Parameters, and Factory3D, Shape Factory (Sketches, Geometric Elements, and Shapes).

Figure 1. Part Modeling Object Tree

3. Methodology

1. First user need to give input parameters of gearbox to GUI form
   The input parameters are as follows
   - Power (P) in KW
   - No. of teeth on gear 1 (Z1)
   - Service factor
   - RPM of Gear 1 (N1)
   - No. of teeth on gear 3 (Z3)
   - Factor of safety
   - RPM of Gear 4 (N4)
   - Surface hardness (BH2)
   - Ultimate stress for gear material Sut – N/mm²

2. As the input parameters are given from calculate module we get the value which is best suitable according to design procedure of gearbox

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3. As user fill that value into the input module value the design is getting checked
4. And gear dimensions are generated and model is generated.

![Developed GUI](image-url)

**Figure 3. Developed GUI**

![Spur gear with formula](image-url)

**Figure 4. Spur gear with formula**

### 4. Result and Discussion

Design calculations

| Notation     | Value | Unit                |
|--------------|-------|---------------------|
| Power to be transmitted | P     | 10                  |
| RPM of Input Shaft (Gear 1) | N1    | 1440                |
| RPM of Output Shaft (Gear 4) | N4    | 90                  |
| Minimum number of teeth for Gear 1 | Z1    | 18                  |
| Lewis form Factor for Gear 1 | Y1    | 0.308               |
| UTS of Gear material | Sut   | 600                 |
| Surface Hardness for Gears | BHN   | 340                 |

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### Assumptions

- Gear teeth pressure angle $\alpha$: 20
- Pitch line velocity $v$: 5 m/s
- Ratio $b/m$: 10
- Material for all gears is considered the same, the pinion is weaker than gear. Hence it is necessary to design for Pinion i.e. Gear 1

### Module Based on Beam Strength

| Step | Formula | Value |
|------|---------|-------|
| 1    | $\text{Velocity Factor} = \frac{3}{3 + v}$ | 0.375 |
| 2    | $\text{Permissible bending stress for gear teeth} = \frac{200}{3} \text{N/mm}^2$ | 66305.9622 N/mm |
| 3    | $\text{Torque transmitted by Gear 1} = \frac{60 \times 10^6}{3.142} \times \frac{P}{N1}$ | 19096117 Nmm |
| 4    | $\text{Module step-1} = \frac{22.5}{7} \times P \times Cs \times Fs$ | 5987520.00 |
| 5    | $\text{Module step-2} = \frac{71.760}{22.5} \times \text{Module step-1}$ | 71.760 |
| 6    | $\text{Module Based on Beam Strength} = \text{Cubertoot(step-4)}$ | 4.16 |

### Module Based on Beam Strength

| Selection of Module & FOS For Beam Strength & Wear Strength | Formula | Value |
|-----------------------------------------------------------|---------|-------|
| Standardized Module | $\text{stdm} = 5$ | |
| Pitch Circle diameter for Gear 1 | $\text{dp1} = 90 \text{mm}$ | $m \times Z1$ |

### B1 Considering Dynamic load

- Tangential force due to rated torque $\text{Pt} = 1473.46582 \text{N}$
- Actual Pitch line velocity $\text{Va} = 6.78672 \text{m/s}$
- Velocity Factor $\text{Cv} = 0.30654$
- Effective load $\text{Peff} = 7210.1987 \text{N}$
- Beam Strength $\text{Sb} = 15400.000 \text{N}$
- FOS Considering Dynamic load $\text{Fsb} = 2.1359$

### B2 Total transmission ratio

- $i = 16 \times \frac{N1}{N4}$
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Figure 4. model for assembly of gearbox

D  Shaft Selection

Shaft 1
Center Distance between Gear 1 & Gear 2  C1  225 mm  \((dp1+dp2)/2\)
Center Distance between Gear 3 & Gear 4  C2  225 mm  \((dp3+dp4)/2\)

ASME code for Bending moment  kb  1.5
ASME code for torsional moment  kt  1

Assumptions
Factor of Safety for shaft 1  Fss  2
Distance Between Bearings on Shaft 1  L1  200 mm
Permissible Shear Stress  Ssy  108 N/mm²  \(0.18 \times S_{ut}\)
Gears are fixed on shaft by Keyways, Therefore  tmax  40.5 N/mm²  \(0.75 \times Ssy/Fss\)
Tangential Force at Gear 1 (C)  Ftc  1473.466 N  \(T_1 \times 2/dp1\)
Axial Force at Gear 1  Fac  536.298 N  \(Ftc \times \tan \theta\)
Resultant force at C  Fct  1568.030 N  \(Ftc / \cos \theta\)
Tangential Force at Gear 1 (C)  Ftc  1473.466 N  \(T_1 \times 2/dp1\)
Axial Force at Gear 1  Fac  536.298 N  \(Ftc \times \tan \theta\)
Resultant force at C  Fct  1568.030 N  \(Ftc / \cos \theta\)

Weight of Spur Gear 1  Ws1  24.499 N
Total Resultant Force at C  Fc  1592.528 N
Reactions at A  Ra  796.264 N  \(Fc \times (L_1/2)/L_1\)
Reactions at B  Rb  796.264 N  \(Fc - Ra\)
Maximum Bending moment at C  Mbc  79626.40518 Nmm  \(Fc \times L_1/4\)
Equivalent twisting moment  Te1  136610.0309  \(\sqrt{(K_b \times M_b)^2 + (K_t \times M_t)^2}\)
Shaft 1 Diameter cube  \(d_1^3\)  17176.76477  \(16/(3.142 \times t_{max}) \times T_{e}\)
Shaft 1 Diameter  d1  25.802 mm
Considering next standard value for Shaft Diameter  27.00 mm

Shaft 2
Distance Between Bearings on Shaft 2  L2  180 mm
Distance Between Bearing and Spur Gear 2  LEG  45 mm
Distance Between Gear 2 & 3  LGH  90 mm

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| Tangential Force at Gear 2 (G) | FtG | 368.366 | N | Mt/(dp2/2) |
| Weight of Gear 2 | Wg2 | 389.9790136 |
| Total force at Gear 2 | FG | 758.345 | N |
| Tangential Force at Gear 3 (H) | FtH | 1473.466 | N | Mt/(dp3/2) |
| Weight of Gear 3 | Wg3 | 24.37369 |
| Total force at Gear 3 | FH | 1497.840 |
| Taking moment at E, Force at F | RF | 1312.966004 | N | (FG*LEG+ (FH*(LEG+LGH)))/L2 |
| Force at E | RE | 943.219 | N | FG+FH-RF |
| Bending moment at G | MG | 42444.85418 | Nmm | RE*LEG |
| Bending moment at F | MH | 59083.4702 | Nmm | RE*LEH-FG*LGH |
| Maximum Bending moment | Mmax2 | 59083.4702 | Nmm |
| Equivalent Twisting moment | Te2 | 110683.8183 | Nmm | Sqrt((Kb*Mmax2)^2+(Kt*Mt)^2) |
| | d2 | 13916.91298 |
| | d2 | 24.05364907 |
| Considering next standard value for Shaft Diameter | d2 | 26 | mm |
| Shaft 3 | Distance Between Bearings on Shaft 3 | L3 | 240 | mm |
| Distance Between Bearing and Spur Gear 4 | LKJ | 150 | mm |
| | LIK | 90 |
| Tangential Force at Gear 4 (K) | FtK | 368.366 | N | Mt/(dp4/2) |
| Axial Force at Gear 14 | Fak | 134.074 | N | Ftk* tan20 |
| Resultant force at k | FrK | 392.007 | N | Ftk/ Cos20 |
| Weight of Gear 4 | Wg4 | 389.979 |
| Total Force at Gear 4 | Fk | 781.986 | N |
| Reaction at J | RJ | 293.245 | N | FK*LIK/L3 |
| Reaction at I | RI | 488.742 | N | FK-RJ |
| Maximum Bending moment at K | MbK | 43986.73551 | Nmm | RI * LIK |
| Equivalent twisting moment | Te3 | 93540.65777 | Nmm | sqrt((Kb*MbK)^2+(Kt*Mt)^2) |
| Shaft 3 Diameter cube | d3^3 | 11761.40482 | (16/(3.142*tmax))*Te |
| Shaft 3 Diameter | d3 | 22.742 | mm |
| Considering next std value for Shaft Dia | d3 | 30.00 | mm |

**E** Bearing Selection
- for Shaft-1 Diameter at bearings | 25 | mm |
- Selected Bearing Number | 6005 |
- Load factor / Service Factor (Ks) | 1.5 |
- Bearing ID | 25 | mm |
- Bearing OD | 47 | mm |
- Thickness | 12 | mm |
- Static Load Rating | C01 | 6.55 | KN |
- Dynamic Load Rating | C1 | 11.9 | KN |
Radial load at Bearing A  
Axial Load at Bearing A
RADIAL LOAD RATING FOR BEARING
AXIAL LOAD RATING FOR BEARING
EQUIVALENT DYNAMIC BEARING LOAD
Bearing life in Revolutions

Fr\(a\) 796.264  N  
Fa\(a\) 0  N  
\(X\) 1  
\(Y\) 1  
\((Xf_a + Yf_a) \times Ks\) 
L\(\text{Rev}\) 989.00  Millions of revolutions

Figure 5. Drafted View of Gearbox

5. Conclusion

The objective was to customize CATIA V5 for design two stage spur gearbox with minimum user requirements (inputs). With the help of this customization gearbox is generated. Also the time required for generating part model (three dimensional model) of gearbox is reduced to few minutes. This part model can be used to draft different views of the gearbox which can directly be used for manufacturing processes. Thus, customization will increase productivity of the designer with increase in quality of design which in turn reduces lead time for design of gearbox.

References

[1] Ruchik D. Trivedi (2013). 3D Parametric Modeling for Product Variants Using Case Study on Inner Ring of Spherical Roller Bearing. Mechanical Engineering Tracks of the 3rd Nirma University International Conference on Engineering. Procardia Engineering 51(2013)709 –714.

[2] Umesh Bedse (2016). Developing a GUI based Design Software in VB Environment to Integrate with CREO for Design and Modeling of CI Engine. International Journal of Latest Trends in Engineering and Technology (IJLTEL), Vol. 6 Issue 4 March 2016, ISSN: 2278-621X.

[3] Indrajitsinh J. Jadeja (2014). Developing a GUI based Design Software in VB Environment to Integrate with CREO for Design and Modeling using Case Study of Coupling. International Journal of Engineering Sciences & Research Technology April, 2014 [088-4095] ISSN: 2277 9655.

[4] Dhaval B. Shah (2013). Parametric Modeling and Drawing Automation for Flange Coupling Using Excel Spreadsheet. International Journal of Research in Engineering & Technology (IJRET) Vol. 1, Issue 2, July 2013, 187-192 © Impact Journals.

[5] L.Karikalan (2018). Design and Analysis of Two Stage Reduction Gearbox for All Terrain Vehicles. International Journal of Advance Engineering and Research Development Volume 5, Issue 03, March -2018 e-ISSN (O): 2348-4470 p-ISSN (P): 2348-6406.
[6] Saša ĆUKOVIC (2010). Automatic Determination of Grinding Tool Profile for Helical Surfaces Machining Using CATIA/VB Interface. UPB Scientific Bulletin, Series D: Mechanical Engineering, January, 2010 Vol. 72, Issue. 2, 2010 ISSN 1454-2358.

[7] Thakkar A. and Patel Y., 2012. Integration of PRO/E with Excel and C language for design automation, India: IIERT, pp. 1-4.

[8] V.B.Bhandari “A text book of design of machine elements”, McGraw-Hill education India Pvt. Ltd.

[9] R.S.Khurmi and J.K.Gupta “A text book of Machine Design”, Euraisa Publication House, 2005 pp1021-1065.