Automation of Design & Modeling Aspects of Bush-Pin Coupling

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Abstract. As we know that the coupling is a device used for transmitting high torque from one shaft to another in industrial applications. In this paper designing and modeling of bush-pin coupling has been performed. The software MS-Excel, CATIA V5R20, and MATLAB are utilized for designing, modeling, and simulating the bush-pin coupling. The design and modeling process has been automated by the synchronization with MS-Excel and CATIA V520. This automated process will be helpful in the understanding concept of designing and modeling by the researcher and industrial experts. This process will also save time and energy which will be helpful in optimization of different input parameters to achieve high torque at low investment.

1. Introduction

Coupling is a mechanical component used for transmitting torque between two rotating shafts as shown in Fig 1. It provides the permanent joining of two rotating shafts. It is connected between two shafts with different-different methods such as collinear, parallel, intersecting axes.

There are different-different types of coupling used with different purposes. e.g Rigid Coupling – This coupling is required when the precise alignment b/w two shafts are necessary. There are three types of rigid coupling[1] i.e. Muff type Coupling, Flange Coupling, and Split-muff type Coupling. Flexible Coupling – This coupling can tolerate misalignment between the shafts. There are three types of flexible coupling i.e. Bush pin-type coupling, Oldham type coupling, and Universal type coupling. Bush-pin coupling is a type of flexible coupling, which is used for high power transmitting b/w two shafts. It is similar to rigid coupling in which rubber bush and pins are used instead of bolts. It can tolerate lateral, axial, or angular misalignment.[2] Flexible coupling transmitted load from one flange to another flange by the tension in the rings from the bolts in one flange, to the bolts in different flange.

The advantages of bush-pin coupling are to prevent transmission of shock and absorb vibration from one shaft to another. Construction is simple and it is easy to assemble and dis-assemble. It is also easy to design and manufacture the coupling. The disadvantages are its cost is more compared to rigid coupling and it requires more radial space.

Figure 1: Flexible Coupling
2. Literature Review
This activity inspired authors to the simulation model of a flexible coupling.[3] 3D modeling is mostly used as a substitution and complementation of the conventional 2D drawing. However, in general, many draftsmen do not have the skills of performing such 3D modeling as well as it takes more time for completion of the model.[4] For the 1st procedure, the coupling is designed as a solution of the given case which determines the dimensions for the main coupling parts. The simulation is applied to the designed coupling by using CATIA model designer & Simulation add-on for good results on the main stress and deformation section that provided from main acting forces, as a result from the solution of a problem.[5] The optimization selected the algorithm, implemented in MATLAB MathWorks software and coupled with numerical based code. The code of MATLAB program has been shown in the last in Appendix-A. The output result of the MATLAB program command window has been shown also in last Appendix-B. The data for the text case example has been utilized from the textbook[6]. The selection material has been utilized from the databook[7]. Uncertainty in inventory and back orders was handled by [11–16].

3. Text Case Example
The list of input parameters for the test case example is provided in table no. 1

| INPUT DATA                      | VALUES     |
|--------------------------------|------------|
| Power                          | 20         |
| Speed                          | 720 rpm    |
| Permissible stress of shaft (40C8) | 95 Mpa  |
| Permissible stress of key (40C8) | 100 Mpa  |
| Crushing stress of key (40C8)   | 300 Mpa    |
| Permissible stress of pin       | 35         |
| Crushing stress of pin          | 200 Mpa    |
| Permissible stress of flange (FG200) | 16.67 Mpa |
| Service factor                  | 1.5        |

Table 1: Text Case Example

After the manual solution, we get the following output parameters.
1) The diameter of the shaft = 30 mm
2) The diameter of the outside hub = 60 mm
3) The diameter of the pitch circle of pins = 120 mm
4) Length of hub = 45 mm
5) The thickness of output flange = 15 mm
6) The thickness of the protective rim = 8 mm
7) The diameter of the pin = 7 mm
8) The diameter of the inside of bushes = 22 mm
9) The diameter of the outside of bushes = 42 mm
10) The effective length of rubber bushes = 35 mm
11) Key length = 45 mm
12) Key width = 8 mm
13) Height of key = 7mm

4. Design Automation using Excel Spreadsheet

MS-excel has a spreadsheet program. Developed relation linked program in this spreadsheet and to find out our real-life problem as per requirement. The list of input and output parameters (see figure 2) from the text case example given data entering in input tables. then, design calculating of procedure of bush pin coupling step-wise-step follow (see figure 3). Further check under safe real-life problem taking it. We are using a functioning tool for applied automated linked formula through empirical relation to solving out all dimensions. Design condition equations and select the safe value from the data book and applied through conditional formatting toolbar.

![Microsoft Excel spreadsheet](image)

**Figure 2: Input and output parameters of Bush-pin coupling**
Figure 3: Steps for the design of Bush-pin Coupling

5. SYNCHRONIZATION OF DESIGN TABLE WITH CATIA
We synchronized the design table of matrix laboratory coding with the designing software of CATIA. It makes a different feature like the pad, shaft, circular pattern, etc as per requirement parts design has created[8]. User parameter defines each parameter desired the attached with each dimension then linked relation function obtained automated calculate values as a single parameter based like a shaft diameter (in figure 4). Select Design Table function, it works synchronization with pre-existing excel spreadsheet file (as shown in figure 5). Creation of a model of flange part automatically. Overall become an automated system generate for another user can operate easily just to modify input values as a requirement in an excel spreadsheet. The final product of all parts of Bush-pin coupling (as shown in figure 6).
Figure 4: Modeling of the flange of Bush-pin coupling

Figure 5: Synchronization of Excel and CATIA
CONCLUSION

The design procedure is automated through Excel software can be applied to solve other real-life problems related to bush-pin coupling. The design model is also automated in CATIA using the function, relation with a synchronized design table. Any person can update the model just by modifying the sheet. This takes comparatively very less time to generate complex part models concerning generating them individually.

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APPENDIX-A
Programming Calculation in MATLAB
MATLAB stands for matrix laboratory. It is a programming platform, which is based on matrix languages (built-in math functions)[9]. Develop algorithms and create models.
Design problem of Bush pin coupling calculating all the specific parts dimension using by programming in MATLAB[10]. Coding of bush pin coupling is given below:-
clc
clear all
format ShortG
%Initialise the variables
syms d d1 dh d2 dbu
%Given parameter
P=20000; n=720; sigmab=200;
%Step 1: Diameter of shaft
taus=0.5*380/2;
Mt=60*P*1000/(2*pi*n);
Mtmax=1.5*Mt;
eq=eval(solve(taus-(16*Mtmax/(pi*d^3))));
d=eq(eq>0);
d=ceil(d)+2;
%Step 2: Dimension of flanges
tauf=0.5*200/6;
db=2*d; lh=d*1.5; D=d*4; t=d*0.5; tp=0.25*d; t1=ceil(tp);
J=pi*(db^4-d^4)/32;
%Torsional shear stress at hub
tau=Mtmax*db/(2*J)
if (tau<tauf)
disp('Hub design is safe for torsional shear.');
else
disp('Not Safe')
end
%Shear stress in flange at the junction
tau=2*Mtmax/(pi*db^2*t)
if (tau<tauf)
disp('Flange design is safe for shear stress.');
else
disp('not safe')
end
%Step 3: Diameter of pins
taup=35; sigmap=400/2;
N=6;
d1=0.5*d/N^.5;
d1=ceil(d1);
%Shear consideration
tau=8*Mtmax/(pi*d1^2*D*N)
if (tau<taup);
disp('Pin design is safe.');
else
disp('not safe')
a) end
%Bending consideration
\[ p = \frac{2 \cdot M_{t_{\text{max}}}}{D \cdot N}; \]
\[ m_b = p \cdot (5 + \frac{35}{2}); \]
\[ eq = \text{eval} \left( \text{solve} \left( \sigma_{m_b} - \frac{32 \cdot m_b}{\pi \cdot d^2} \right) \right); \]
\[ d_2 = eq (eq > 0); \]
\[ d_2 = \text{ceil} (d_2) + 1; \]

%Step 4: Dimension of bushes

\[ eq = \text{eval} \left( \text{solve} \left( d_{bu}^2 - 2 \cdot M_{t_{\text{max}}}/(D \cdot N) \right) \right); \]
\[ d_{bu} = eq (eq > 0); \]
\[ d_{bu} = \text{ceil} (d_{bu}) + 1; \]
\[ lb = d_{bu}; \]

%Step 5: Dimension of key

\[ \tau_{\text{uk}} = 0.5 \cdot 400/2; \]
\[ l = h; b = 8; h = 7; \]

%Check the design of key

\[ \tau = \frac{2 \cdot M_{t_{\text{max}}}}{d \cdot b \cdot l}; \]

if \( \tau < \tau_{\text{uk}} \)

\[ \text{disp}('\text{Key design is safe for shear consideration.}') \]
\[ \text{else} \]
\[ \text{disp}('\text{not safe}') \]
\[ \text{end} \]

\[ \sigma_{\text{mk}} = 1.5 \cdot 400/2; \]
\[ \sigma_{\text{mk1}} = 4 \cdot M_{t_{\text{max}}}/(d \cdot h \cdot l) \]

if \( \sigma_{\text{mk1}} < \sigma_{\text{mk}} \)

\[ \text{disp}('\text{key design is safe for crushing consideration.}') \]
\[ \text{else} \]
\[ \text{disp}('\text{Not safe}') \]
\[ \text{end} \]

%Design of flexible coupling

fprintf('\text{Diameter of shaft = } %.0f \text{ mm}', d)
fprintf('\text{Outer diameter of hub = } %.0f \text{ mm}', db)
fprintf('\text{Length of hub = } %.0f \text{ mm}', lh)
fprintf('\text{Pitch Circle Diameter = } %.0f \text{ mm}', D)
fprintf('\text{Thickness of flange = } %.0f \text{ mm}', t)
fprintf('\text{thickness of protecting rim = } %.0f \text{ mm}', t1)
fprintf('\text{Diameter of Bushes = } %.0f \text{ mm}', dbu)
fprintf('\text{Diameter of Pins = } %.0f \text{ mm}', d1)
fprintf('\text{Number of Pins = } %.0f \text{ ', N)
fprintf('\text{Dimension of key is } %.0f \times %.0f \times %.0f \text{ mm}', b, h, l)
APPENDIX-B
Output Results of MATLAB Command Window

\( \tau = 10.007 \)

Hub design is safe for torsional shear.

\( \tau = 4.6908 \)

Flange design is safe for shear stress.

\( \tau = 28.719 \)

Pin design is safe.

\( \tau = 73.683 \)

Key design is safe for shear consideration.

\( \sigma_{\text{mak}} = 168.42 \)

Key design is safe for crushing consideration.

- Diameter of shaft = 30 mm
- Outer diameter of hub = 60 mm
- Length of hub = 45 mm
- Pitch Circle Diameter = 120 mm
- Thickness of flange = 15 mm
- Thickness of protecting rim = 8 mm
- Diameter of Bushes = 35 mm
- Diameter of Pins = 7 mm
- Number of Pins = 6
- Dimension of key is 8x7x45 mm
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