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DESIGN AND ANALYSIS OF ADJUSTABLE TORQUE SPRING BALL CLUTCH

D. T. Gawade*, R. V. Mahamuni , S. H. More
*Mechanical Department , Skn-Sinhgad Institute of Technology & Science,Lonavala, Pune

ABSTRACT
The main purpose of safety spring ball clutch is to protect the system from overloads, but in this paper we are using it as torque limiting device. Also it is designed so that it can be used, according to application, over a particular range of torque instead of constant value of torque. Along with this there is another arrangement for disengagement, for maintenance purpose, at will by using solenoid. Design of this spring ball clutch involve; for particular range of torque value , the requirement of spring stiffness, desingn of input flenge and cylindrical body for easy engagement and disengagement of clutch. The analysis is done by using Unigraphix as modeling software and ANSYS 14.0 as analysis software for critical parts.

KEYWORDS: Safety clutch with spring and ball, over load protection, torque limiting device, adjustable torque value, performance investigation.

INTRODUCTION
Most of industrial applications where it uses shaft-drive mechanism as shown in fig. 1 and there should be some overload device protection to avoid coupling or shaft from failure as well as to avoid electric burn of the motor. For this purpose the torque limiters are used.
The invention of torque limiter is concerned more particularly with a self-releasing clutch which will transmit only a limited amount of torque from one rotary element to another [1].Safety clutches with balls are a viable solution to protect the transmission against overloads that could occur as a result of some abnormalities in functioning or as a result of incorrect man oeuvres performed by the machine operator [2]. These torque limiters are tamper-proof. Once installed, the torque value cannot be changed. The torque value can be changed in the field, however; the Safety ball clutch must be disassembled and the springs replaced to achieve the new torque value.

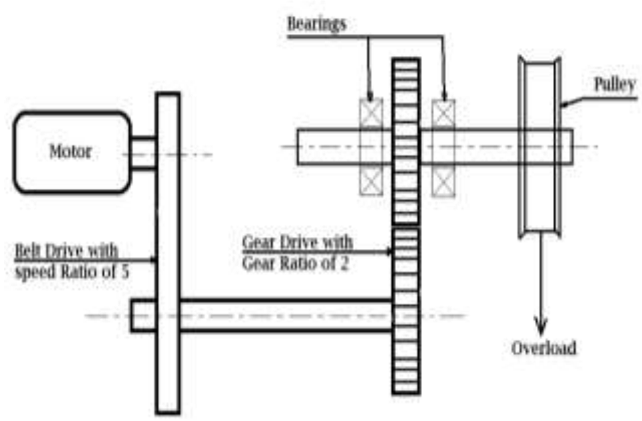

Fig. 1 Shaft drive mechanism (without Spring Ball Clutch)

Conventional spring ball clutch is of a Flying ball type which transmits torque from input to output using balls held by a spring in assembly when overload occurs the balls will come out of assembly and thus disconnecting input and output thereby saving part failures. Hence in this paper the spring ball clutch is so designed that the balls will not come out of assembly when there is overload. There will only be slipping of the balls, this comes as an advantage as the clutch can be preset without removing it from assembly and this will save considerable amount of downtime of process as compared to the conventional clutch. The location of Spring ball clutch is shown in the Fig. 2.

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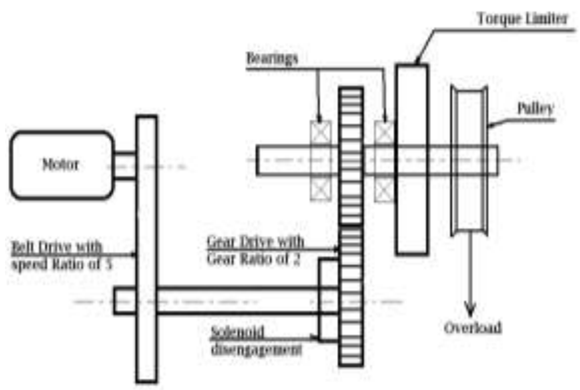

Fig. 2 Shaft drive mechanism (with Spring Ball Clutch)

In Fig. 2 there is another arrangement done for the purpose of disengagement at will, by using electromagnetic solenoids. So that we can disengage the motor from gear train without stopping the motor i.e., for the purpose of maintainance.

METHODOLOGY

System design

In this section there is design of the system which is shown in the fig 1. It contains the motor of 50 watt, 230 volt (50 Hz), 0.5 amp and speed range 0-5000 rpm. It is connected to the belt drive of speed ratio of 5 and then it is connected to gear train of gear ratio 2. So at 5000 rpm torque produced by motor will be 0.1 Nm, multiplying it by Speed ratio of belt drive and gear ratio, we get the torque at the input flange of the Torque limiter equal to 1.0 Nm.

Here we are designing the spring ball clutch to limit the value of torque to 1.25 Nm i.e., by considering 25% of overload.

Calculation of Tangential Force on Balls (F_t)

$$F_t = \frac{2 * M_t}{D}$$

$$F_t = \frac{2 * 1.25 * 10^3}{D}$$

Assuming pitch circle diameter of the grooves (D) = 90 mm

$$F_t = \frac{2 * 1.250 * 10^3}{90}$$

$$F_t = 27.777 \text{ N}$$

Calculation of Total Spring Force on Balls (F_s):

$$F_s = F_t \left[\frac{\cos\alpha - \mu \sin\alpha}{\sin\alpha + \mu\cos\alpha} - \mu \right]$$

Where,

α = Angle of inclination of groove = 45^0

μ = Coefficient of friction between the balls and body of the clutch = 0.08

$$F_s = 27.777 \left[\frac{\cos 45 - 0.08 \sin 45}{\sin 45 + 0.08 \cos 45} - 0.08 \right]$$

$$F_s = 23.522 \text{ N}$$

Calculation of Force on Each Spring (F):

$$F = \frac{F_s}{Z_b}$$

Where;

Z_b = Number of balls in clutch = 3 No's

$$F = \frac{23.522}{3}$$

$$F = 7.8408 \text{ N}$$

Stiffness of Spring (K_s):

Table2. Stiffness and permissible static and dynamic loads for helical compression springs[3]

Wire Diameter (mm)	Outer Diameter (mm)	Stiffness Of spring per turn K1 (N/mm)	Permissible load	
			Static Load (N)	Dynamic Load (N)
1.0	12.0	7.98	32.4	14.5

$$K_s = \frac{K_1}{n}$$

$$K_s = \frac{7.98}{6}$$

$$K_s = 1.33 \text{ N/mm}$$

Compression of Spring to Exert a Force 'F' (δ_1):

$$\delta_1 = \frac{F}{K_s}$$

$$\delta_1 = \frac{7.8408}{1.33}$$

$$\delta_1 = 5.8953 \text{ mm}$$

Movement of Ball While the Clutch is Slipping (δ_2):

$$\delta_2 = \frac{d}{2}(1 - \cos\alpha)$$

Where,

d = Diameter of ball =14 mm

$$\delta_2 = \frac{14}{2}(1 - \cos 45)$$

$$\delta_2 = 2.050 \text{ mm}$$

Maximum Deflection of Spring (δ_{Max}):

$$\delta_{max} = \delta_1 + \delta_2$$

$$\delta_{max} = 5.8953 + 2.050$$

$$\delta_{max} = 7.9453 \text{ mm}$$

Free Length of Spring (L_f):

$$L_f = \text{Solid length} + \text{Maximum deflection} + \text{Clearance between adjacent coils}$$

$$L_f = n'd + \delta_{max} + (n' - 1)$$

Where,

$$n' = n + 2$$
$$n' = 6 + 2$$
$$n' = 8$$
$$L_f = 8 * 1.0 + 7.9453 + (8-1)$$
$$L_f = 22.9453 \text{ mm}$$

Pitch of Spring Coil (P):

$$p = \frac{L_f}{n-1} = \frac{22.9453}{6-1}$$

$$p = 4.589 \text{ mm}$$

Table2. Estimated Parameters of Spring Ball Clutch

Sr.No.	Parameters	Notation	Value
1.	Diameter of ball	(d)	14 mm
2.	PCD of grooves	(D)	90 mm
3.	Angle of inclination of grooves	(α)	45^0
4.	Rod diameter of springs	(d')	1.0 mm
5.	Outside diameter of spring	(D')	12 mm
6.	Pitch of coil	(p)	5 mm
7.	Free length of spring	(L_f)	24 mm

Design of Input Flange

Table3. Material selection[3]

Designation	Ultimate Tensile strength N/mm^2	Yield strength N/mm^2
EN 24	800	680

As Per ASME Code;

$$f_{S_{max}} = 108\ N/mm^2$$

The weakest section on the Input flange is where the shaft is attached to the flange. Hence we check for the shear failure.

D=diameter of shaft=16mm

$$T = \frac{\pi * f_s * d^3}{16}$$

$$1.25 * 10^3 = \frac{\pi * f_{s_{act}} * 16^3}{16}$$

$$f_{s_{act}} = 1.55\ N/mm^2$$

As $f_{S_{act}} < f_{S_{max}}$,Input Flange is safe under torsional load.

Design of Cylindical Body

Cylindrical body can be considered to be a hollow shaft subjected to torsional load.

Table3. Material selection[3]

Designation	Ultimate Tensile strength N/mm^2	Yield strength N/mm^2
EN 24	800	680

As Per ASME Code;

$$f_{S_{max}} = 108\ N/mm^2$$

The weakest section on the Driven hub is front section where the thread dimensions are 40 x 2 pitch

Do = 40mm

Di = 20 mm

Check for torsional shear failure:-

$$T = \frac{\pi * f_{S_{act}}}{16} * \left(\frac{{D_o}^4 - {D_i}^4}{D_o}\right)$$

$$1.25 * 10^3 = \frac{\pi * f_{S_{act}}}{16} * \left(\frac{40^4 - 20^4}{20}\right)$$

$$f_{S_{act}} = 0.1666 N/mm^2$$

As $f_{S_{act}} < f_{S_{max}}$,Cylindrical body is safe under torsional load.

Analysis of critical parts

Input Flange and Cylindrical Body are the most critical parts of the spring ball clutch hence their analysis in ANSYS is necessary.

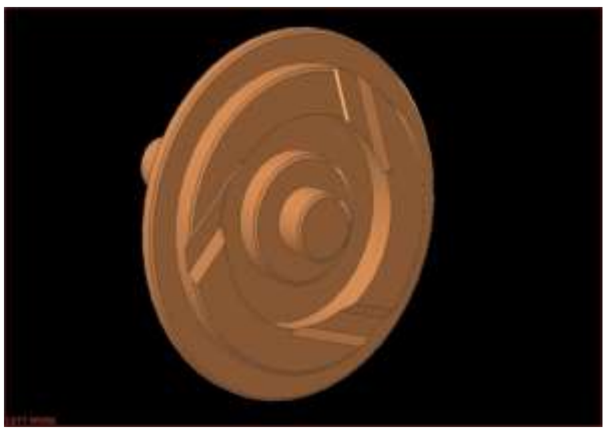

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Fig.3 Input Flange of Spring Ball Clutch

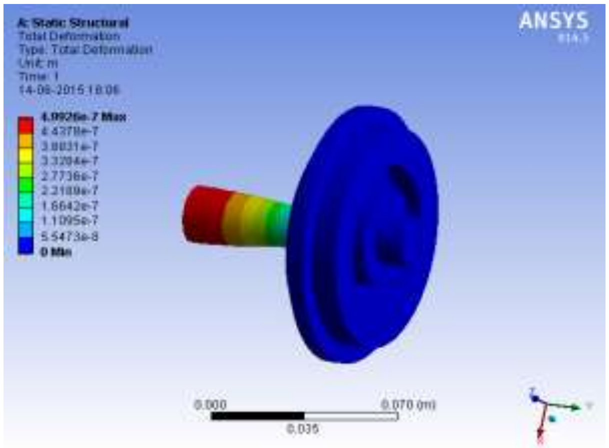

Fig. 4 Total deformation results on ANSYS for input flange of Spring Ball Clutch

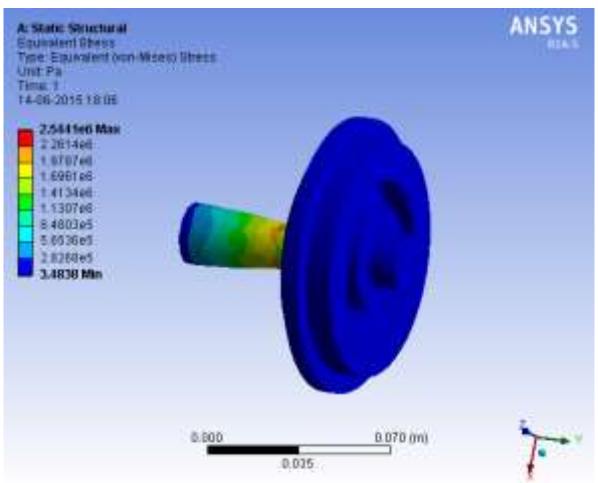

Fig. 5 Von mises stresses results on ANSYS for input flange of Spring Ball Clutch

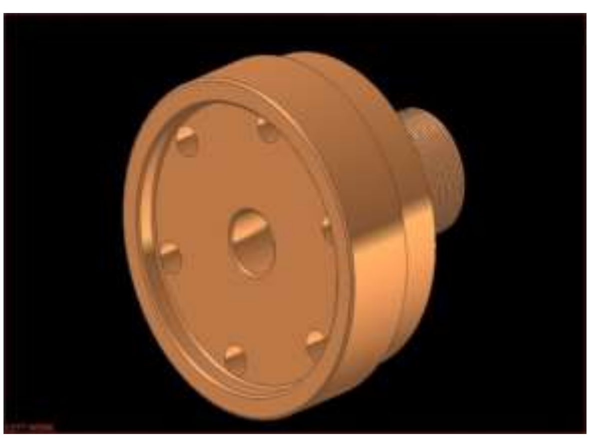

Fig.6 Cylindrical body of Spring Ball Clutch

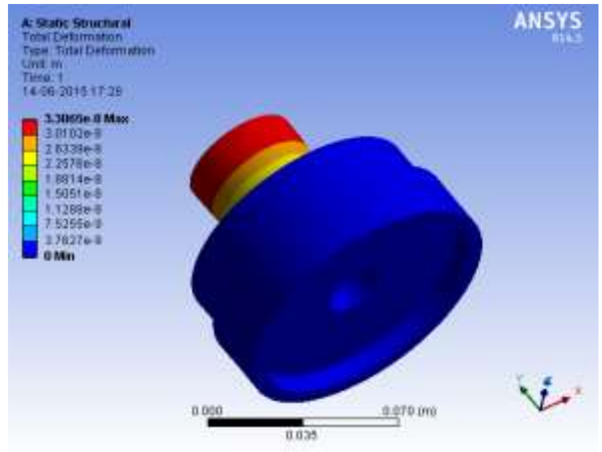

Fig.7 Total deformation results on ANSYS for Cylindrical Body of Spring Ball Clutch

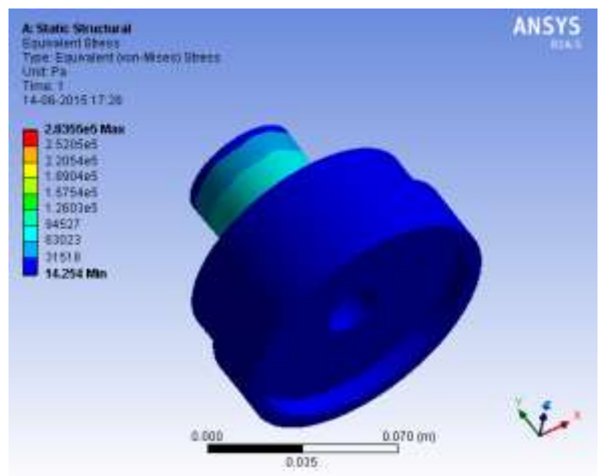

Fig.7 Von mises stresses results on ANSYS for Cylindrical Body of Spring Ball Clutch

RESULTS AND DISCUSSION

***Table2.* Comparison of Ansys results with teoretical results**

Part Name	Maximum Theoretical Stress N/mm^2	Von-Mises Stress N/mm^2	Maximum Deformation mm	Result
Cylindrial Body	0.166	0.283	$3.38x10^{-8}$	Safe
Base Flange	1.55	2.544	$4.99x10^{-7}$	Safe

Maximum stress by theoretical method and Von-mises stress are well below the allowable limit, for the Input flange and cylindrical body, hence the designs of these parts are safe.

CONCLUSION

By designing this type of clutch it is possible to disengage the motor from the transmission automatically. Here all the designs are verified with the results of ANSYS, so every design stated are safe. These type of clutches can be used to protect motor from overload as well as we can disengage the motor from transmission at will i.e., for maintainance purpose, without stopping motor.

REFERENCES

[1] Patent 3,893,553,"United States", July 8, 1975, "OVERLOAD RELEASE CLUTCH", 1975.
[2] Silviu Popa, Gheorghe Moldovean, Elena Eftimie, Torque Transmitted By Safety Clutches With Balls And Spherical Rabbets Radial Disposed, ANNALS OF THE ORADEA UNIVERSITY, Fascicle of Management and Technological Engineering, ISSUE #1, MAY 2014
[3] PSG College of Technology, Coimbatore. "Design Data" Revised Edition 1978.
[4] Elena Eftimie, Simple Clutches With Multiple Functions, Machine Design, Vol.5(2013) No.1, ISSN 1821-1259, pp. 61-64.
[5] Stroe Ioan, Elastic And Safety Clutches With Intermediate Rubber Elements, ANNALS of the ORADEA UNIVERSITY. Fascicle of Management and Technological Engineering, Volume IX (XIX), 2010.
[6] V. B. Bhandari "Machine Design Data Book" by McGraw Hill Education Pvt. Ltd. 2014
[7] Petere Payne Dean, Westbrook and Conn, "Overload Protection For Power Drives", U. S. Patent 2,901,076, Aug. 25,1959.

AUTHOR BIBLIOGRAPHY

	**Mr. Dattaprasad T. Gawade** PG Student of Design Engineering at Skn-Sinhgad Institute of Technology & Science Lonavala, Pune, Maharashtra, India.
	**Mr. R. V. Mahamuni** Lecturer at Mechanical Engineering Department Y.B.Patil Polytechnic, Akurdi, Pune,Maharashtra,India
	**Prof. Sunil H. More** Assistant Professer Mechanical Engineering Department at Skn-Sinhgad Institute of Technology and Science, Lonavala, Pune, Maharashtra India Email: