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Comparative Analysis of Resilient Grid Coupling by Analytical Design

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Abstract: Resilient Coupling comprises mainly two hubs, grid spring and cover to protect the spring to fly off to centrifugal force and to prevent grease to come out. Grid Spring element is so designed that it provides resiliency for variable flexibility of a coupling and damping properties making the coupling very for drives involving high shock loads to the extent of 80%. Unlike gear and disc coupling, resilient coupling have unique ability to reduce vibration by as much as 30%. Misalignment – Angular, Parallel or Axial, that inevitably occurs between rotating shafts, which are independently supported, is also taken care of by the spring element within allowable limits. The grid is torsionally flexible. The circumferential flexibility is progressive due to the curved profile of the grooves – state of the art in resilient coupling design. The grid spring element absorbs impact energy by spreading it over time and thus reduces the magnitude of the peak loads.
Keywords: Torsional shear stress, stiffness, deflection, resultant stress

I. INTRODUCTION

Resilient Grid Coupling is composed of two shaft hubs, a metallic grid spring, and a split cover kit. Torque is transmitted between the two coupling shaft hubs through the metallic grid spring element. Grid coupling are a popular coupling option where both high torque levels and damping requirements exist. Grid couplings have a unique ability to reduce vibration by as much as 30%, and cushions shock loads to safeguard driving and driven power transmission equipment. They are easy to install and simple to maintain [8]. The grid spring element absorbs impact energy by spreading it out over time, and thus reduces the magnitude of the peak loads. This is possible because of the progressive contact that occurs between the curved profile of the hub teeth and the flexible grid. As the load increases, more of the tooth comes into contact with the flexible grid spring element.

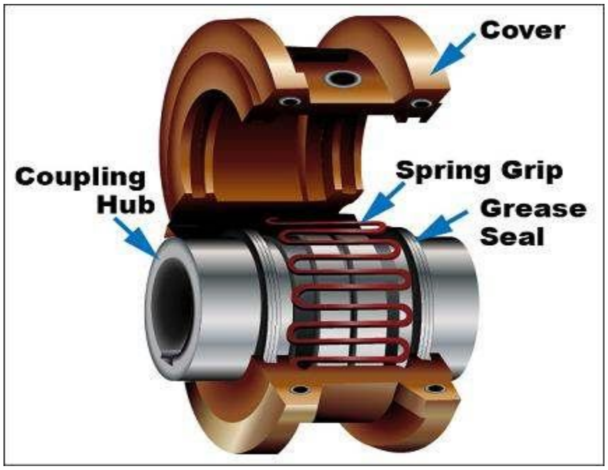

Fig.1 Resilient coupling

A. Problem Arises In Coupling

While it has great dampening vibration, the size of coupling becomes bigger in size. When couplings get dry, they require lubrication and check for leakages so the environment near area will be cleaned. Grid fails due to several reasons; the grid fails on misalignment, overload and higher torques. When shock load occurs, it will experience torque and cannot withstand the higher torque and fails. The location of the grid fracture on grid rung along with permanent operating data such as number of load cycles before failure can often be a guide to the probable failure load cycles could be the frequency of a vibratory load. The number of start-ups or speed changes or when misalignment in a load favours it could be in the number of shaft revolutions.

B. Remedies To Eliminate The Problem

We must do maintenance at regular intervals. Try not to use parallel shaft misalignment and only designed to handle about a half a degree of angular misalignment. Do daily lubrication so wear and tear gets low.

II. AN ACQUAINTANCE WITH THE RESILIENT COUPLING

A coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power.[1,2] The primary purpose of couplings is to join two pieces of rotating equipment while permitting some degree of misalignment or end movement or both. In a more general context, a coupling can also be a mechanical device that serves to connect the ends of adjacent parts or objects. Couplings do not normally allow disconnection of shafts during operation, however there are torque limiting couplings which can slip or disconnect when some torque limit is exceeded. Selection, installation and maintenance of couplings can lead to reduced maintenance time and maintenance cost.

Fig.2 Shaft Coupling

Shaft couplings are used in machinery for several purposes. A primary function is to transfer the power from one end to another end. For example a motor transfers power to pump through coupling. Like other common uses are:

1) To alter the vibration characteristics of rotating units.
2) To connect driving and the driven parts.
3) To introduce protection against the overloads.
4) To provide for the connection of shafts of units that are manufactured separately (such as a motor and generator) and to provide for disconnection for repairs or alterations.
5) To provide for misalignment of the shafts.
6) To introduce mechanical flexibility.
7) To reduce the transmission of shock loads from one shaft to another shaft.

The couplings are two types – Rigid and flexible. Rigid coupling does not allowed any linear or angular misalignment. It requires rigid connection on coaxial shaft. The said demerits are overcome by flexible couplings. Generally, flexible couplings are allowed linear and angular misalignment.

Quick installation and easy maintenance reduces labour and downtime costs fully interchangeable with industry standards Versatile stock; metric and imperial size cover fasteners available. Flexible and resilient grid coupling reduces vibration by as much as 30%, and cushions shock loads to safeguard your driving and driven equipment [5]. The flexible nature of the spring-like grid absorbs impact energy by spreading it out over time, thus reducing the magnitude of the peak loads. This is possible because of the progressive contact that occurs between the curved problem of the hub teeth and the Flexible grid. Therefore, as the load increases, more of the tooth comes into contact with the grid, thus supplying superior protection and supreme performance. Top Quality Manufacturing – Made from high tensile alloy steel, the grid spring is carefully formed to shape, then hardened and tempered under controlled conditions [3]. Next, the grids are shortened, compressing the surface molecules and leaving a residually stressed surface. This process creates a stronger surface in compression. Any load applied on the coupling in operation must first surmount the compressive forces created by preening before the tensile stress reaches the grid. This provides a dramatic increase in rating over other coupling types, increases reserve strength for longer life and may permit selection of a smaller coupling, thus reducing cost.

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III.DESIGN METHODOLOGY

A. Design of Shaft

Shafts are designed on the basis of torsional shear stress induced because of the torque to be transmitted. Shear stress induced in shaft for transmitting torque [4] is given by,

$T = (\pi / 16) * \tau * d^3$

$$\tau = \frac{Tr}{J} = \frac{16T}{\left(\frac{\pi}{4}\right)d4}$$

where, T = torque, N mm
d = shaft diameter, mm
τ = shear stress, MPa

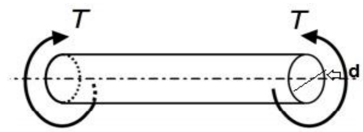

Fig.3 Shaft

B. Design of Hub

A hub is designed considering it as a hollow shaft; with inner diameter equal to diameter of shafts and outer diameter double of that. It is checked for torsional shear stress.

D = 2d

D = Diameter of Hub

Checking under torsional shear stress

$$\tau = \frac{16T}{\pi D3}$$

$\tau \leq \tau_{all}$

$t_f = 0.5\,d$

$L = 1.5\,d$

$D_1 = 3.5\,d$

where, t_f = thickness of flange, mm
D_1 = Outside diameter of flange, mm
L = length of hub, mm

C. Design of spring

A Spring is subjected to pulling load so tensile stress is induced on cross-section of spring [6].

$$\sigma_t = \frac{F}{A} = \frac{F}{b*t} = \frac{T}{b*t*R1}$$ (by taking rectangular cross section area A = b * t)

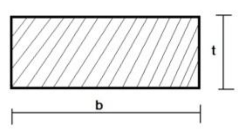

Fig.4 Grid Spring

where, R_1 = Radius of flange outer, mm
b = width of cross-section of spring, mm
t = thickness, mm

-Direct stress on cross-section of spring due to twisting of spring is:

$$\sigma_d = \frac{F}{A} = \frac{T}{b*t*R1}$$

Also, bending stress due to induced bending moment is:

$$\sigma_b = \frac{My}{I} = \frac{Fey}{I}$$

$$\sigma_b = \frac{Tey}{IR1}$$

where, I = Moment of inertia, mm^4

y = Radial distance from centre or neutral axis of cross section, mm

The spring is subjected to load in such a way that more than one stresses are induced so by taking combined stresses [7],
Combined stress $\sigma_r = \sigma_d + \sigma_b$

$$\sigma_r = \frac{T}{b*t*R1} \pm \frac{T*e*y}{R1*I}$$

Other parameters are:
-Length of spring: $L_s = \pi D_1$

-Spring index: $C = \frac{L}{t}$

-Stiffness (K) $= \frac{EA}{L}$

-Deflection (δ) $= \frac{F}{K}$

Similarly, by selecting different cross section area for spring component the said design parameters are determined.
The standard cross sections are (1) Rectangle (2) Square (3) Elliptical (4) Circle

D. Flowchart for Design of Grid Spring

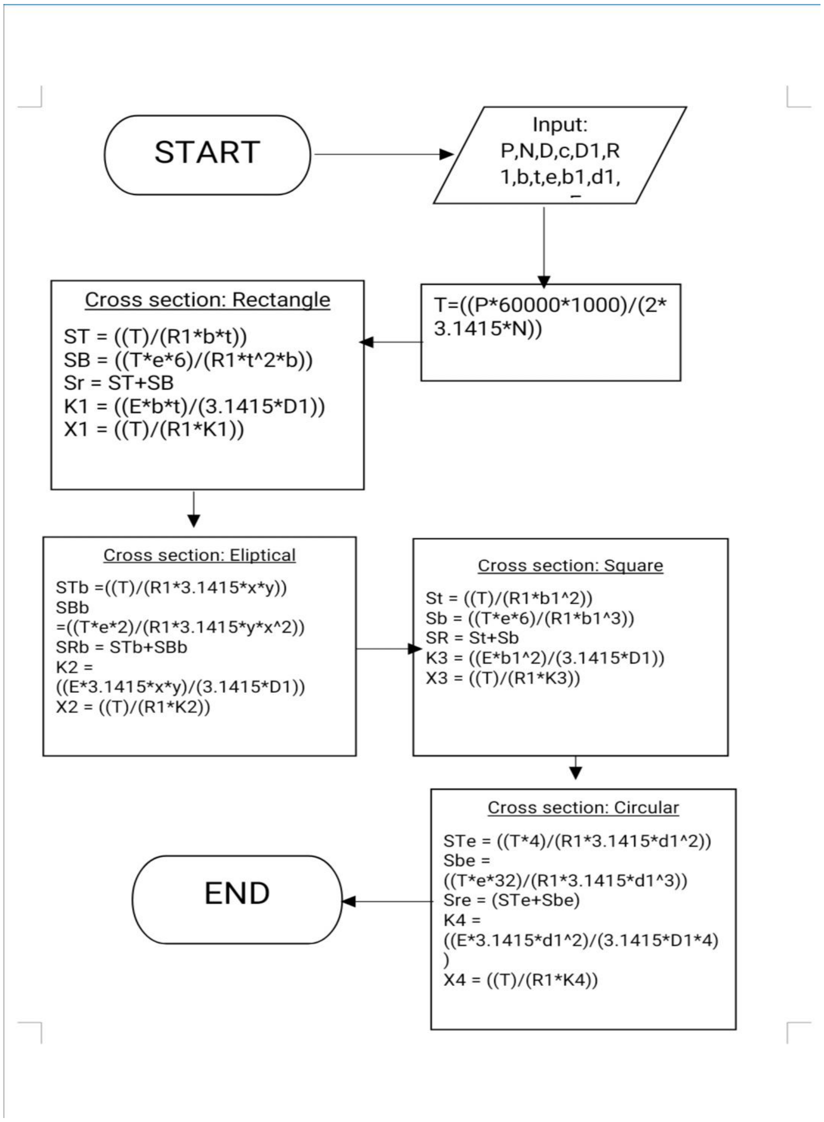

Fig.5 Flowchart for algorithm

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E. Programming in MATLAB

```
% Design Of Resilient Grid coupling
P = 50;  N = 1600; D = 184;  c = 0.8; d = D/2;
D1 = 1.5*D; R1 = D1/2; b = 15; t = 5; e = 0.8;
b1 = 5; d1 = 5; x = 2.5; y = 7.5; E = 200000;
disp ('Torque in N*mm')
T = ((P*60000*1000)/(2*3.1415*N))
disp(sprintf('%10.2f',T))
disp ('Design Of shaft subjected to torsoinal stress in N/mm^2')
S = ((16*T)/(3.14*d^3))
disp ('Design Of Hub subjected to torsoinal stress in N/mm^2')
S1 = ((16*T)/(3.14*D^3))
disp ('Cross section: Rectangle')
disp ('Design Of Spring subjected To tensile stress in N/mm^2')
ST = ((T)/(R1*b*t))
disp ('Design Of Spring subjected To bending stress in N/mm^2')
SB = ((T*e*6)/(R1*t^2*b))
disp ('Resultant stress in N/mm^2')
Sr = ST+SB
disp ('Stiffness of spring in N/mm')
K1 = ((E*b*t)/(3.1415*D1))
disp ('Deflection of spring in mm')
X1 = ((T)/(R1*K1))
disp ('Cross section: Elliptical')
disp ('Design Of Spring subjected To tensile stress in N/mm^2')
STb =((T)/(R1*3.1415*x*y))
disp ('Design Of Spring subjected To bending stress in N/mm^2')
SBb =((T*e*2)/(R1*3.1415*y*x^2))
disp ('Resultant stress in N/mm^2')
SRb = STb+SBb
disp  ('Stiffness of spring in N/mm')
K2 = ((E*3.1415*x*y)/(3.1415*D1))
disp ('Deflection of spring in mm')
X2 = ((T)/(R1*K2))
disp ('Cross section: Square')
disp ('Square Spring Subjected to Tensile Stress in N/mm^2')
St = ((T)/(R1*b1^2))
disp ('Square Spring Subjected to Bending Stress in N/mm^2')
Sb = ((T*e*6)/(R1*b1^3))
disp ('Resultant stress of Square cross section in N/mm^2')
SR = St+Sb
disp  ('Stiffness of spring in N/mm')
K3 = ((E*b1^2)/(3.1415*D1))
disp ('Deflection of spring in mm')
X3 = ((T)/(R1*K3))
disp ('Cross section: Circular')
disp (' Circular Spring Subjected To Tensile Stress in N/mm^2')
STe = ((T*4)/(R1*3.1415*d1^2))
disp ('Circular Spring Subjected To bending Stress in N/mm^2')
Sbe = ((T*e*32)/(R1*3.1415*d1^3))
```



```
disp ('Resultant Stress for circular spring in N/mm^2')
Sre = (STe+Sbe)
disp  ('Stiffness of spring in N/mm')
K4 = ((E*3.1415*d1^2)/(3.1415*D1*4))
disp ('Deflection of spring in mm')
X4 = ((T)/(R1*K4))
```

IV. RESULTS AND DISCUSSION

In the recent design, the range of power is taken from 0.5 to 400 KW with step of values within this range. At a definite value of torque, the possible cross sections are selected to do stress analysis. Induced stresses in a spring are tensile and bending due applied torsional load on coupling. However, combined stresses are calculated to get resultant value. The spring stiffness and deflection are also calculated to design other parameters.

Table – 1 Calculated design parameters

Power (KW)	Torque (N.m)	Shape of Cross section	σ_t (MPa)	σ_b (MPa)	σ_R (MPa)	K (KN/mm)	δ (mm)
0.5	0.823	Rectangle	0.32	0.155	0.475	70.73	$3.4x10^{-4}$
		Ellipse	0.41	0.131	0.54	55.55	$4.3x10^{-4}$
		Square	0.96	0.46	1.42	23.57	$1\ x10^{-3}$
		Circle	1.23	0.789	2.02	18.51	$1.3x10^{-3}$
10`	39.78	Rectangle	4.95	2.38	7.33	22.26	0.016
		Ellipse	14.87	7.14	22	7.42	0.05
		Square	6.25	2	8.25	17.48	0.021
		Circle	18.938	12.12	31.05	5.82	0.011
50	298.415	Rectangle	28.83	27.68	56.51	17.3	0.125
		Ellipse	36.71	23.5	60.2	13.58	0.16
		Square	86.5	83.03	169.53	5.76	0.37
		Circle	110.15	140.96	251.09	4.53	0.47
100	795.774	Rectangle	55.8	53.61	109.41	12.53	0.33
		Ellipse	71.1	45.5	116.6	9.84	0.42
		Square	167.53	160.83	328.36	4.17	1
		Circle	213.3	273.03	486.33	3.28	1.27
200	1736.23	Rectangle	120.57	231.5	352.068	12.43	0.72
		Ellipse	153.51	196.5	350.01	9.76	0.926
		Square	361.71	694.5	1056.2	4.14	2.18
		Circle	460.55	1179.01	1639.56	3.25	2.78
400	3472.47	Rectangle	198.32	380.78	570.1	11.16	1.45
		Ellipse	252.51	323.22	575.72	8.77	1.85
		Square	594.97	1142.34	1737.31	3.72	4.35
		Circle	757.54	1939.3	2696.84	2.92	5.5

The above table shows the relation between different parameters of spring and power transmitted through it. It is clearly seen that the resultant stress value of the rectangle cross section is the least among the other cross sections which is making it the best cross section for the spring.

Following graphs show the characteristics of behaviour of spring at different power transmission for different cross section area.

A. Rectangular cross-section

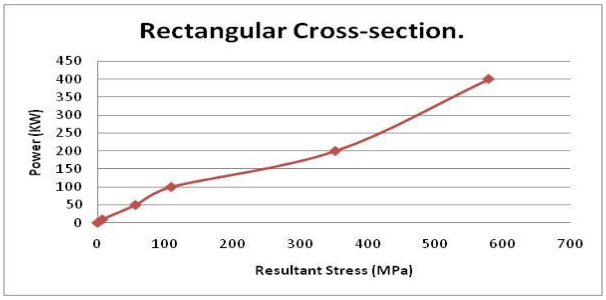

Fig.6 Power vs Resultant stress

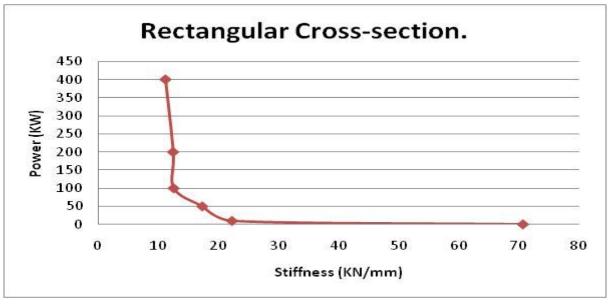

Fig.7 Power vs Stiffness

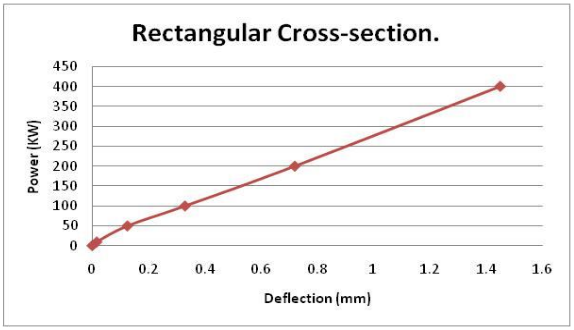

Fig. 8 Power vs Deflection

B. Elliptical cross-section

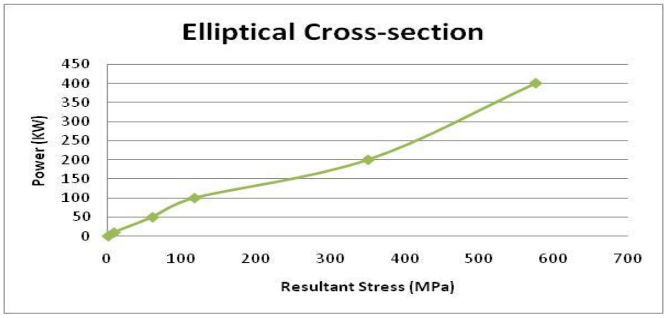

Fig.9 Power vs Resultant stress

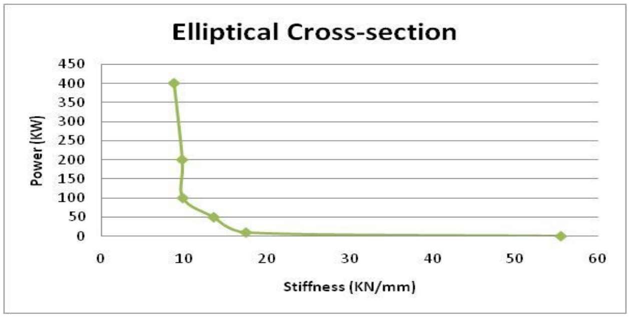

Fig. 10 Power vs Stiffness

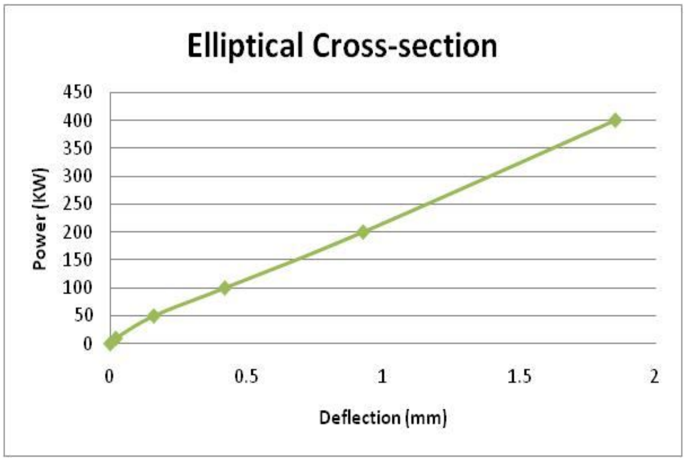

Fig.11 Power vs Deflection

C. Square cross-section

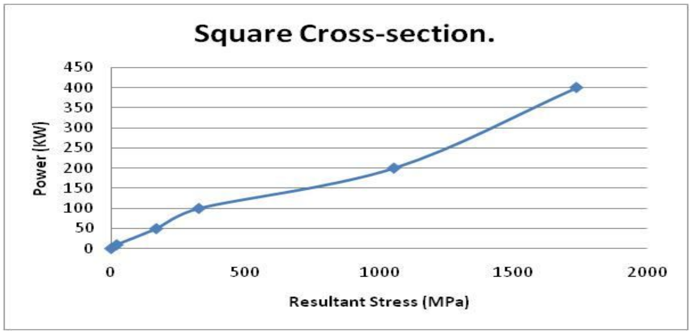

Fig.12 Power vs Resultant stress

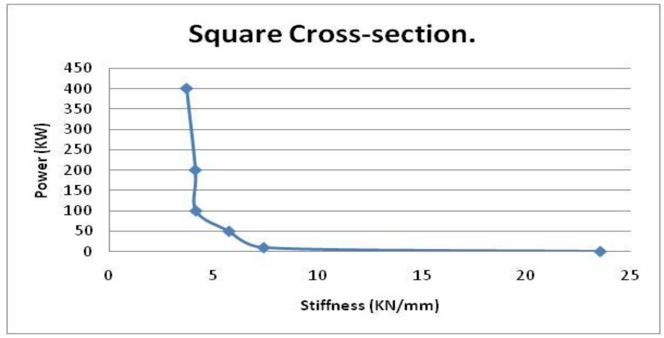

Fig.13 Power vs Stiffness

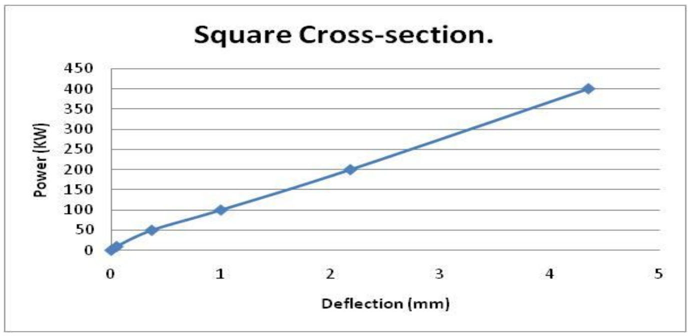

Fig.14 Power vs Deflection

D. Circular cross-section

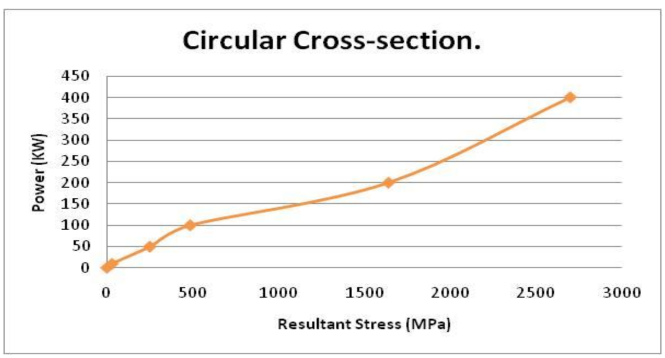

Fig.15 Power vs Resultant stress

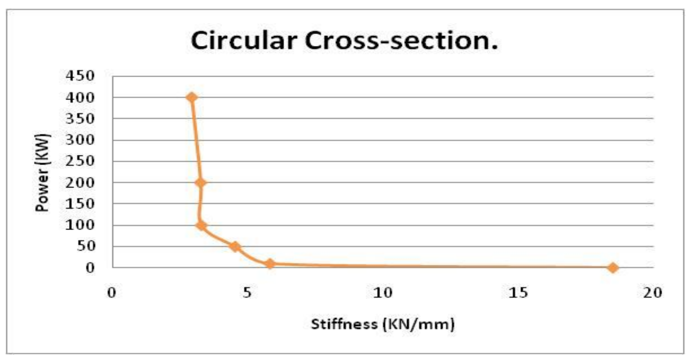

Fig.16 Power vs Stiffness

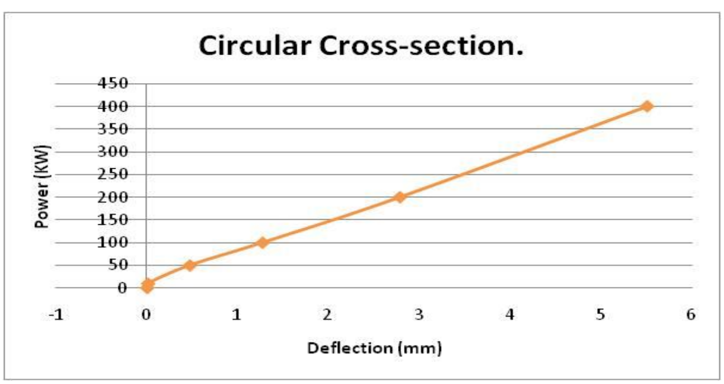

Fig. 17 Power vs Deflection

With increase power, the resultant stress and deflection are increased but stiffness is decreased in each cross-section of spring

V. CONCLUSION

From above data we can conclude that in rectangular cross-section spring we have minimum stress value. Taking the value for 400 KW power, rectangle has stress value of 570.1 MPa. As comparing it with the different cross sections circular cross section is the one with the highest stress value of 2696.84 MPa. We have also compared the stiffness value and the deflection of the spring for different cross sections. The Stiffness value is reducing as the power transmission increases. The Stiffness in rectangle holds good value as compared to other cross section. Rectangular has 11.16 KN/mm and circular has 2.92 KN/mm for 400 KW. Same way for deflection the as the power increases the deflection increases. The cross section of rectangle has the least deflection as compared to other cross sections. The value of rectangle cross section is 1.45 mm and the circular cross section has the value of 5.5 mm for the 400 KW. Also square and elliptical has intermediate values of the stiffness and deflection. So making rectangular cross section is the most compatible design for the spring.

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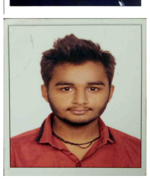

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