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A Novel Design and Finite Element Analysis of Ball Drive Mechanism for Effective Power Transmission under Complex Orientation of the Shaft

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Abstract
Generally, it is predicted that upgrading and optimizing the mechanical power transmitting elements are necessary in terms of meeting the requirements of transmitting the power between complex mechanical means as a demand. In this contest, the requirement of transmitting the power exactly between two inclined and non intersecting shaft are predicted as a demand. Since, sprocket is one of the key components for chain drive; chain may be replaced with balls placed in the tooth of sprocket wheels. So that the particular mechanism is termed as ball drive mechanism. It is different types of approach that has been developed to transmit the power mechanically in different orientations of the two shafts promptly. Therefore an accurate prediction for the dynamic characteristics of the system using ansys software necessary. The existing ways of transmitting the power mechanically includes gears, chain drives, belts, ropes & couplings etc. In this paper, a modest attempt is made to analyze the forces exerted by the balls on the tooth of the sprocket wheels. The results of the dynamic analysis shows that approach tries to establish a new method of using balls to drive the shaft effectively and more efficiently.

Keywords: Ball Drive Mechanism, Sprocket, Solid Works, Ansys, Power Transmission.

Introduction
Shafts have different means to transmit power and torque. For example, it can use gears, pulleys, sprockets, etc and also have some grooves to keep these elements rigid and avoid their vibration, such as key seats, retaining ring grooves. The power transmission between two aligned shafts can be done by flexible shafts, spacer shafts, universal shafts, belt drives. Flexible shafts transmit rotary motion between two components that are not aligned. They are flexible enough to bend around obstacles, yet stiff enough to transmit motion and light load and another common machine control. I n a typical application, a high speed printing press has 12 large rollers that need on the fly adjustment. Spacer shafts are usually installed when significant alignment changes are anticipated during operation of the machine. Through the length of the spacer shaft, the angular changes at the spacer shaft end remains same even when larger machine positional occur. The alignment position for the machine fitted with the spacer shaft that have flexible elements at each end as not critical as for machines that have short flexible couplings installed. Universal joints, more commonly known as U-joints, allow positive transmission of rotating power at a much larger angle than is permissible with a flexible coupling. Belt drive should satisfy law of belting otherwise it will slip to the side and drive cannot be performed. When belt drive transmits power, one side will become tight side and other side will become loose side. The ratio of tension depends on the angle of lap and coefficient of friction. If coefficient of friction is same on both the pulleys smaller angle of lap will be used in the formula. If coefficient of friction is different, the minimum value of product of coefficient of friction and angle of lap will decide the ratio of tension, i.e. power transmitted. In this problem definition is the power transmission between non aligned shafts can be done both by hydraulic and pneumatic means but while using those devices external power sources is required and leakage due to working fluid is more and there is complexity in the arrangement where availability of space is limited. So accurate velocity ratio cannot be attained between driving and driven members. So, transmitting the power between two non aligned shafts at an accurate angle actuation is essential factor for various industrial applications.

Working Principle
Mechanically, the power is transmitted between two parallel shafts by using spur gears, whereas two intersect shafts by using bevel gears and two non-intersecting gears by using worm gears, when the two shafts are at small distances. Here, we are using chain drive with balls resting on the teeth of sprocket wheels for transmitting the power between two non-parallel & non-intersecting shafts. The balls are arranged in the teeth of the sprocket wheels and they are not connected, but they are in contact with each other. When we give the input to the driver shaft, the minute actuation can be reflected in the driven shaft or vice versa. The transmission of power is obtained with greater flexibility in all complex orientations of shafts and the path of balls that travels are shown in fig.1and simulation in fig.1-fig.11.

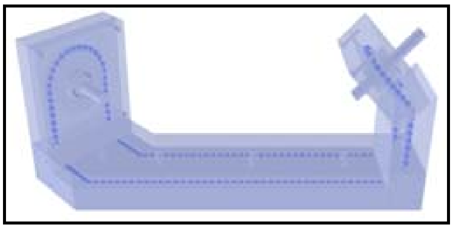


Figure1: Design of Ball drive Mechanism

Formula Used

$\sigma = M*Y/I$

$M=WL/2$

$I=bd^3/12$

Factor of Safety (FOS) = Ultimate Stress / Working Stress

Tabulation

Table 1: Chemical composition of EN 8 Steel

Chemical composition (%)	
Carbon	0.36-0.44
Manganese	0.60 – 1.00
Phosphorus	0.050 max
Silicon	0.10 - 0.40
Sulphur	0.05 max
Iron	Balance
Chromium	-
Molybdenum	-
Nickel	-

Table 2: Properties for EN 8 Steel

S. No	Parameters	Design Values
1	Yield Stress(N/mm^2)	465
2	Factor of safety	2
3	Working Stress(N/mm^2)	232.5

Table 3: Calculated Design Parameters

S. No	Parameters	Sprocket	
		Driver	Driven
1	Shear Force (N)	1223.4	1781.16
2	Shear Area (mm^2)	30.61	29.30
3	Shear Stress (N/mm^2)	39.96	60.81
4	Working Stress(N/mm^2)	232.5	232.5
5	Bending Moment (N)	6117.4	8905.8
6	Moment of Inertia(mm^4)	23.90	20.94
7	Deflection (mm)	1.5305	1.4645
8	Bending Stress(N/mm^2)	391.74	622.85

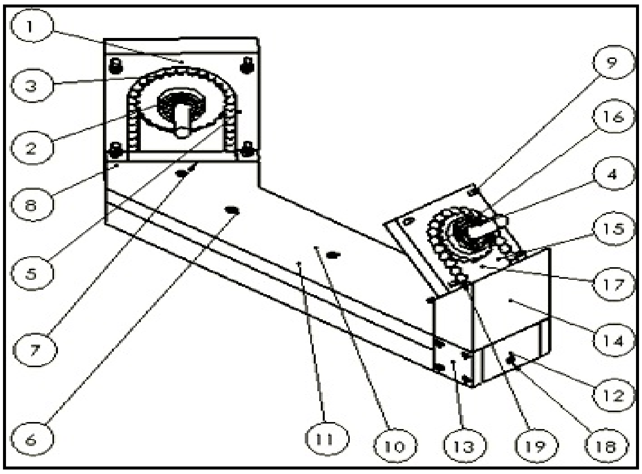


Figure 2: Billing of Materials

Table 4: Bill of Materials of EN 8 Steel

S. No	Part Name	Quantity
1	Driver Housing	1
2	Support Bearing	4
3	Driver Sprocket	1
4	Driven Sprocket	1
5	Driven Housing	1
6	Cover Plate 1	1
7	Side Guide Block 1	1
8	Cover Plate for SGB 1	2
9	Base Guide Block	1
10	Cover Plate for BGB	1
11	Side Guide Block 2	1
12	Cover Plate for SGB 3	2
13	Vertical Guide Block	1
14	Cover Plate 2	1
15	M 6 Bolt	8
16	M 5 Bolt Long	7
17	M 5 Bolt	20
18	Shaft	2
19	Ball	164

Finite Element Analysis

A. Modeling and Meshing (ANSYS)

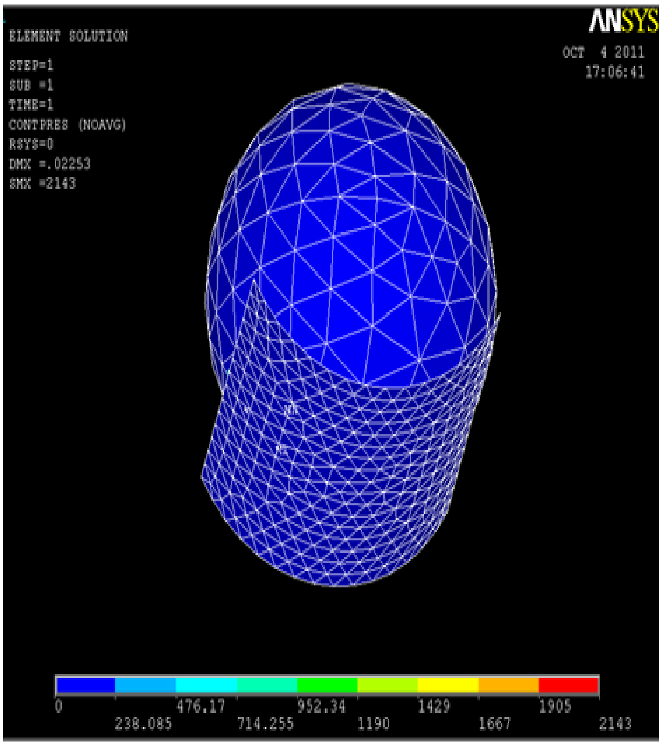
Consider contact analysis between spoke of sprocket and ball as following steps are

Step1: Pre Processor- Element type- Add/Edit/Delete
Select Solid 185 8 Node
Step2: Element type
Step3: Material Properties- Material models- Linear-Elastic- Isotropic
$E= 2x\ 10^5\ N/mm^2$
Poisson Ratio= 0.3
Density= 7830 kg/m^3
Step4: Modeling- Create- Spoke by importing opinion
Step5: Modeling- Create- Volume by Radius R= 44.657
Step6: Modeling- Operate- Area- Divide by Arc
Divide Ball into two Parts
Step7: Meshing- Mesh Tool- Mesh type- TET
Step9: Contact Manager- Contact Wizard
Step10: Load-Definite Load- Structural- Displacement
Step11: Load-Definite Load- Structural-Pressure
F= 1223.48 N
Step12: Solution- Solve- Current LS
Step13: Results

B. Boundary Conditions

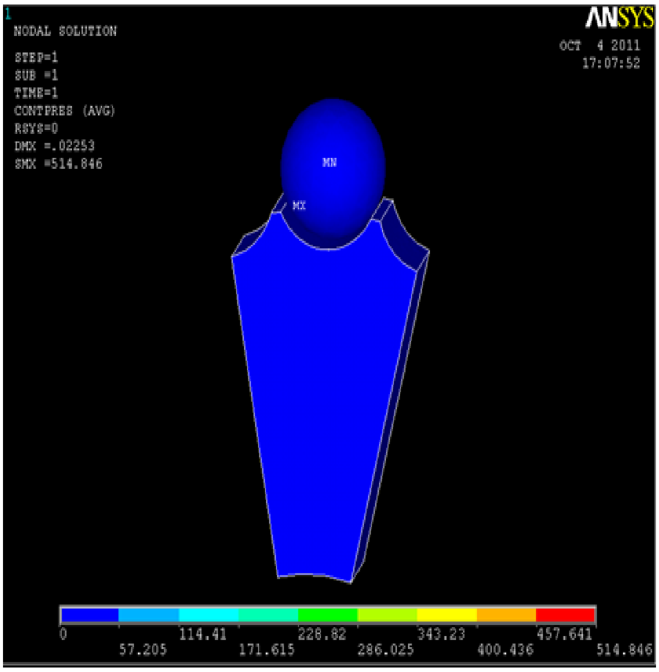
Step1: Pre Processor- Element type- Add/Edit/Delete
Select Solid 185 8 Node
Step2: Element type
Step3: Material Properties- Material models- Linear-Elastic- Isotropic
$E= 2x\ 10^5\ N/mm^2$
Poisson Ratio= 0.3
Density= 7830 kg/m^3

Simulation



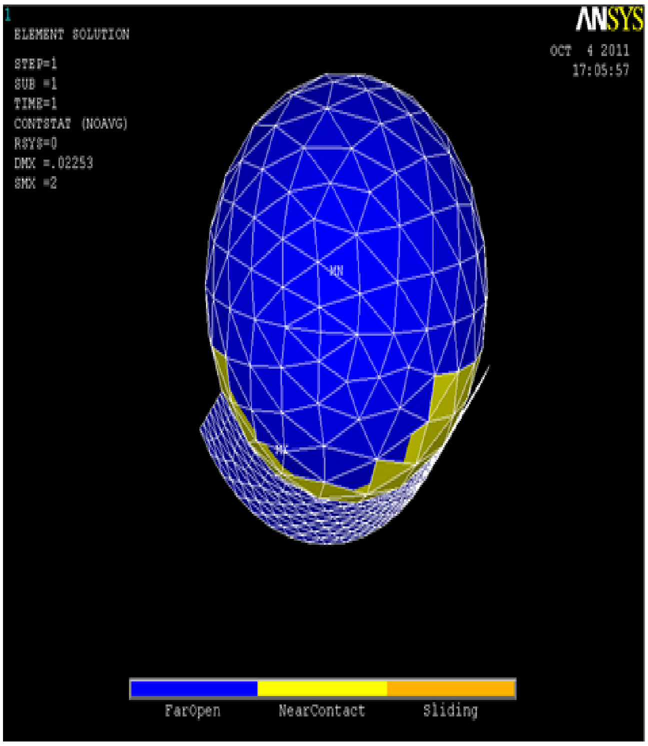
Maximum Deformation= 0.02253 mm
Maximum Stress= 2143 N/mm^2

Figure 3: Contact Pressure Development



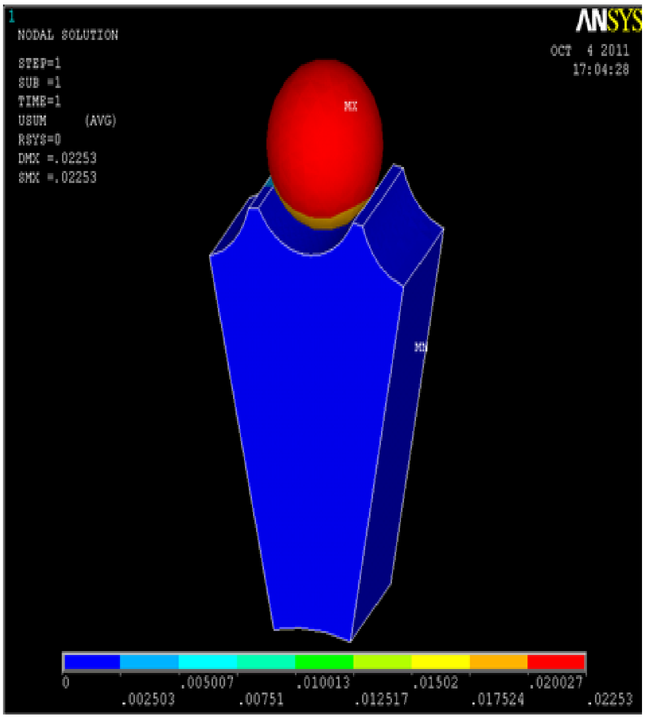
Maximum Deformation= 0.02253 mm
Maximum Stress= 514.846 N/mm^2

Figure 4: Contact Pressure in Ball



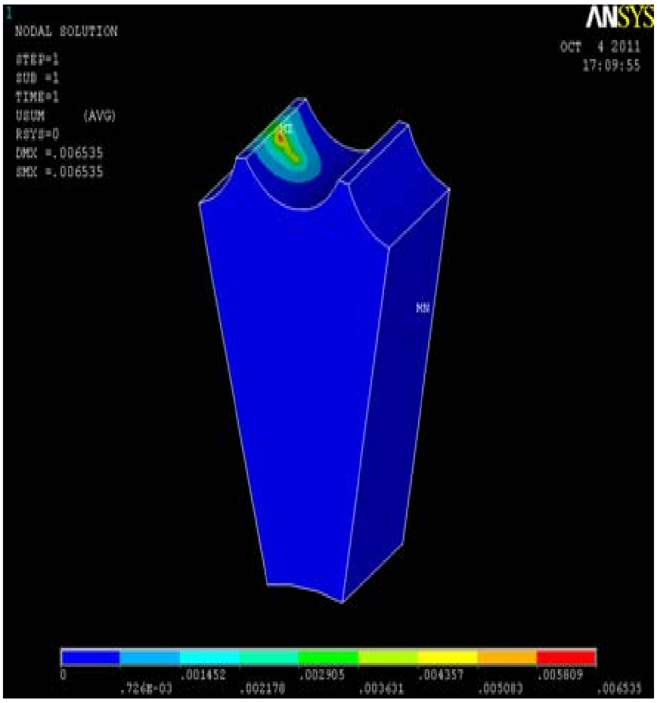
Maximum Deformation= 0.02253 mm
Maximum Stress= 2.0 N/mm^2

Figure 5: Contact Status in Ball



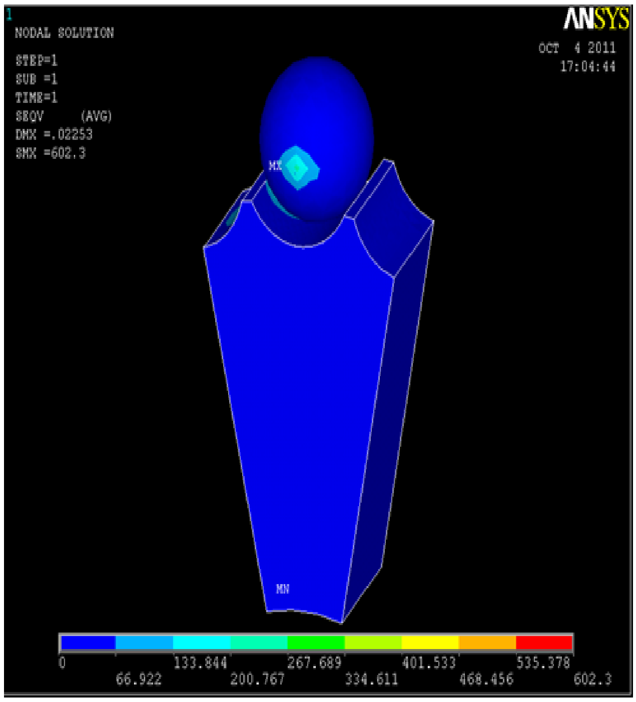
Maximum Deformation= 0.02253 mm
Maximum Stress= 0.02253 N/mm^2

Figure 6: Deformation in Ball



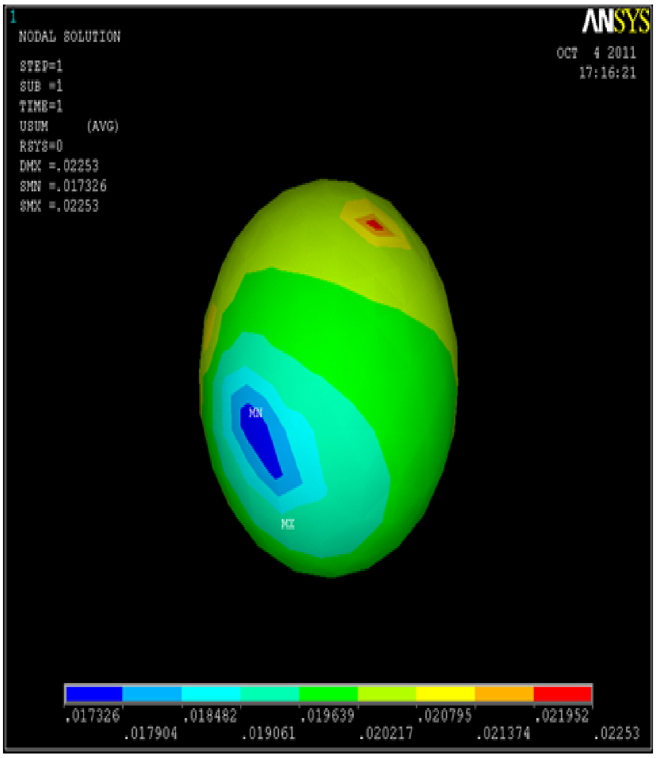
Maximum Deformation= 0.02253 mm
Maximum Stress= 0.006535 N/mm^2

Figure7: Deformation of Sprocket



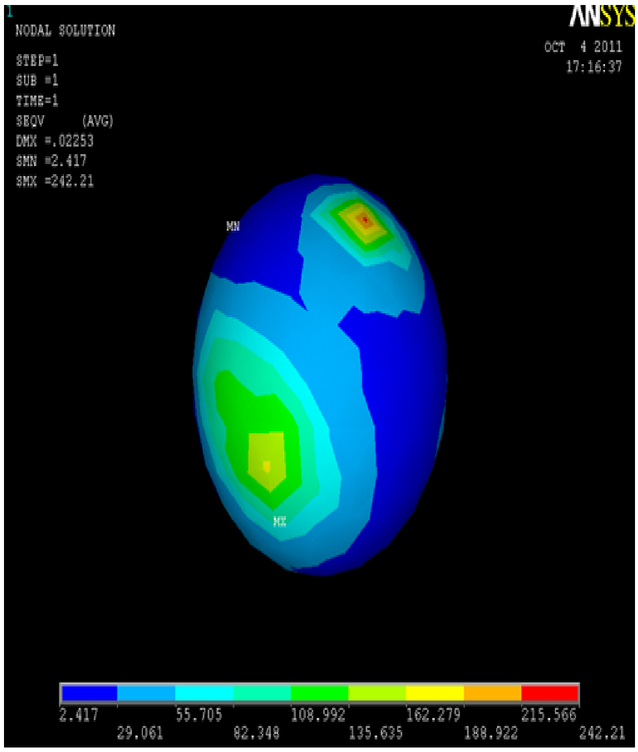
Maximum Deformation= 0.02253 mm
Maximum Stress= 602.3 N/mm^2

Figure 9: Von Mises Stress



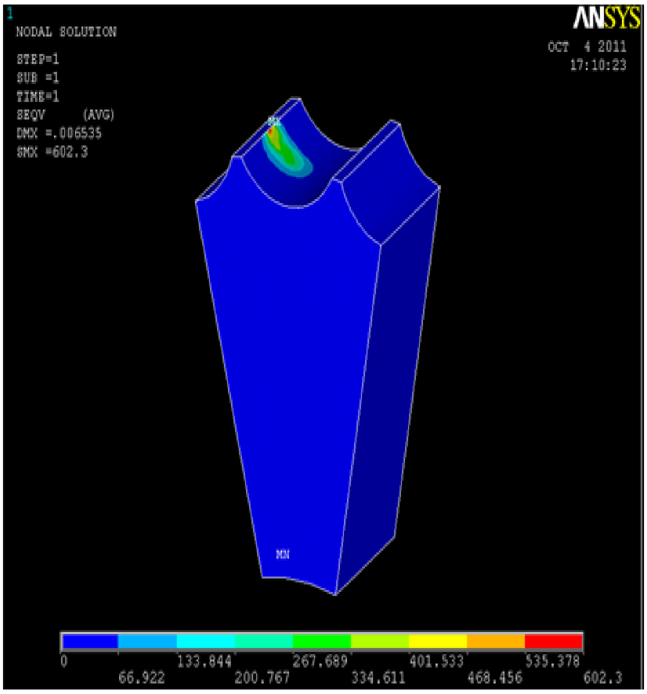
Maximum Deformation= 0.02253 mm
Minimum Stress= 20.017326 N/mm^2
Maximum Stress= 0.02256 N/mm^2

Figure 8: Deformation of Ball



Maximum Deformation= 0.02253 mm
Minimum Stress= 2.417 N/mm^2
Maximum Stress= 242.21 N/mm^2

Figure 10: Von Mises Stress of Ball



Maximum Deformation= 0.006535 mm
Maximum Stress= 602.3 N/mm^2

Figure 11: Von Mises Stress of Sprocket

Conclusion

Finite Element Analysis (FEA) results, reveals that the steel balls exerts the bending stress which is more than the working stress of the material of the sprocket wheel (EN 8 Steel) for the given force. Therefore, there is a greater possibility for the failure of the model. Hence to bear up the extreme values of stresses, the surface of the tooth of sprocket wheels of both driver and driven members are subjected to surface hardening treatment. It is desired to harden the outer surfaces of the sprocket wheels for higher strength with durability. Nitrating is one of the best methods of hardening the component, since EN 8 material is medium carbon steel which contains carbon about 0.45 percent. This process is conducted comparatively low temperatures, minimizes cracking and distortion.

This approach may bring out productive under remote areas for reliable and effective power transmission of new method using balls is established to drive the shaft effectively and efficiently.

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