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Development and Performance Test of Gearless Power Transmission System

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Abstract
In modern machineries, the motion and power need to be transferred from one shaft to other for various and complex activities. Also, it is essential to achieve such objectives with maximum efficiency and minimum cost. For transmitting power between different orientations of shaft, various medium like belt, chain and especially gears are used. But due to cost of manufacture of gear, interchangeability in parts and very limited shaft orientations, need arises for an alternative system. In this project a Gearless power transmission system has been studied, a possible gearless power transmission layout is designed and developed where it can transmit power from one shaft to other without any gear being used. This project deals with transmission of power from one shaft to other at right angle by means of sliding links that form revolute pair with the hub. Links bent at right angle slide inside the holes in the hub and three links were used. Thus, as the holes in input hub rotate; it pushes the links and in turn output hub is rotated. Depending upon the power, the system was tested and it ran safely up to 985 rpm when the motor power was 1 hp and up to 246 rpm when the motor power was 0.25 hp. If the system was run higher than this permissible limit, the transmission system produces unwanted noise. Also, when the system was run lower than the mentioned rpm, it could not transfer motion from the input shaft to the output.

Key Words: Gearless drive, Power transmission, Sliding links, Elbow power transmission

1. Introduction

In modern world the living standard of human being were developed by adopting more and more equipment and technology. Today's world requires power or motion on each and every field. An essential requirement of the present world is to achieve the objectives with maximum efficiency at minimum cost. To achieve higher efficiency, proper power transmission is the prime concern of modern era. If someone wants to transfer power efficiently from its source of generation to the required place to obtain required task, then power transmission is vital concern. Different types of medium like chain-sprocket, belt-pulley, friction drive, hydraulic coupling and gears are used to transmit power between two shafts. Some of them are used to transmit power within a short distance like gears or couplings [1]. Belt-pulley or chain-sprocket is another type of transmitting mechanism where the power can be transmitted to a long distance. A belt is a looped strip of flexible material used to mechanically link two or more rotating shafts. Belt drives are used as the source of motion transfer efficiently or to track relative movement. Another type of transmitting drive exits which is known as friction drive. A friction drive or friction engine is a type of transmission that, instead of a chain and sprockets, uses two wheels in the transmission to transfer power to the driving wheels. But in friction drive system, the problem with this type of system is that they are not very efficient [2]. Normally gear is used to transmit power between two shafts in short distances. For transmitting power to adjacent shafts, various types of gear are normally adapted. These gears can be used for transmitting power in various orientation of the shaft. For example, in parallel shaft helical gear, spur gear and herringbone gear are used. Again in non-parallel or intersecting shaft, bevel gear and worm gear are used and spiral gear and skew bevel gear are used in non-parallel shaft as well as non-intersecting shaft [1]. But there are some inherent disadvantages associated with bevel and worm gearing stated as complexity in manufacturing. Again gears are costly to manufacture, lubrication and cooling are more difficult, limited to transfer power for short distances, special machining process is required to produce, no freedom of interchangeability, replacement of the entire set of the gears, complex calculation in design are the limitation of the gear drive system [3].

An influential mechanism ought to be introduced which might be eliminated this sort of drawbacks. Therefore, gearless power transmission concept is introduced. As it replaces gears and transmits motion without the aid of gears it is also called as Gearless Power Transmission mechanism. Gearless transmission mechanism is capable of transmitting power at any angle without any gears being manufactured. Instead of using any gears, this technology elegantly convert's rotational motion using a set of cylindrical hubs, bent to 90°, in a clever, simple, smooth process that translates strong rotational force even in restricted spaces. A gearless power transmission is provided for transmitting rotational velocity from an input connected to three bent links. Both the input shaft and a hub have rotational axes. The rotational axis of the input shaft is disposed at an angle of 90° respect to the

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rotational axis of the hub. As a result, rotation of the input shaft results in a processional motion of the axis of the bent link. The rotary and reciprocating motion of bent link transmit rotation of prime mover to the 90° without any gear system to an output shaft without gears. The transmission includes input shaft, hub, links etc. [3].

In this project a gearless power transmission system has been developed for transmitting motion at right angle without using any gears. This method may be a rattling mechanism that carries force through 90° bends [4]. For that el-bow mechanism is used which is an ingenious link mechanism of kinematic chain principle and slide. Based on these ideas, the following objectives can be summarized for this project.

- To design and construct a model gearless power transmission mechanism.
- Performance test of the constructed model of gearless power transmission mechanism.

2.1 Gearless Power Transmission

This system is used to drive the machine without using any gear. The gearless transmission or El-bow mechanism is a device for transmitting motion at any fixed angle between the driving and driven shaft. This system consists of number of links that would be within three to nine. The more the number of links, the smoother is the operation. These links slide inside hollow cylindrical hub thus formatting a sliding pair. This mechanism has three such sliding pair. These links are placed in a hole in the cylindrical hub and are fastened at 120° to each other [3].

The input shaft power is supplied by an electric motor. The working mechanism of the gearless power transmission system will be understood from the schematic diagram and photographic view as shown in Fig. 1 and Fig. 2. An unconventional form of transmission of power on shaft located at an angle. Motion is transmitted from driving to the driven shaft through the links which are bent to conform to the angles between the shafts. These links are located at the holes equally spaced around a cylindrical hub and they are free to slide in and out as the shaft rotates. This type of drive is especially suitable where quite operation at high speed is essential but only recommended for low torque operation. The operation of this transmission will be apparent by the action of one link during a revolution. It is assumed that as the driving shaft is rotating clockwise, the driven shaft will rotate counter clockwise. As shaft turns through half revolution, the link slides out from both driving shaft and driven shaft and at that time the link will be at the top position between two shafts. Then during the remaining half this link slide inwards until it again reaches to inner most position as shown in Fig. 1. In the meanwhile the other links have of course passed through the same cycle of movements all links are successively sliding inwards and outwards [3]. Although this illustration shows a right angle transmission, this drive can be applied also to shafts located at intermediate angle between 0° and 90 °.

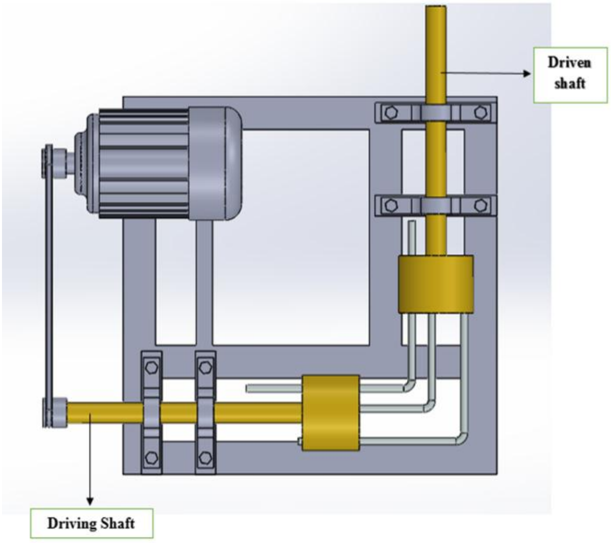

Fig. 1: Schematic arrangement of Gearless Power Transmission System

Fig. 2: Photographic view of Gearless Power Transmission

2.2. Comparison between Gear and Gearless drive

It is seen that gearless drive differs to a great extent not only in their manufacturing method or working principle but also in other aspect. These aspects are briefly discussed below:

***Manufacturing method*: ** Gears are made on special purpose machines. Hence, they are costly to manufacture and there is no interchangeability. The gearless drive has this advantage that it is machined and made on conventional machines and it gives freedom of interchangeability [3].

***Causes of failure*: ** The varied forms of failures like indentation, corrosion, erosion, fatigue etc. occurs in gear drive system. Cause of the wearing of the gear tooth resulting in the tooth leads to the replacement of the entire gear set, which is very expensive. The failure will be present in the gearless drive also but the result of those will be not be as severe as in the case of geared one [3]. Again only defected link/links replacement needs to be done.

Lubrication and Cooling: In gearless drive the lubrication and cooling system is simple and easy where as the lubrication system in gear drive system is complex. Again cooling is a big issue in gear drive system [3].

Others: Different speed at any angle is possible in gearless drive which is not possible in gear drive system [3].

2.3 Basic Components

The basic component required to establish the gearless power transmission system is: an AC motor, V-belt, Shaft and cylindrical hub, Elbow links and Bearings. A systematic arrangement of Gearless power transmission system having of all its component is shown in Fig. 3.

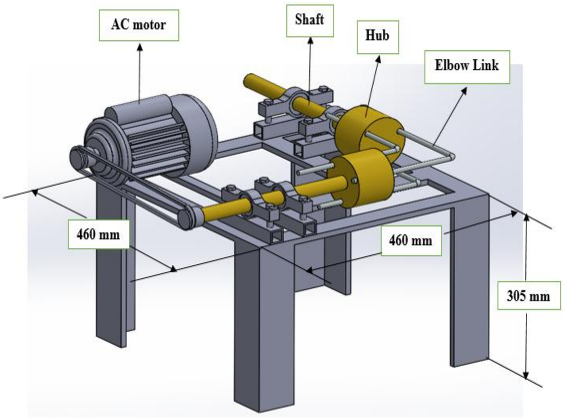

Fig. 3: Schematic arrangement of the final assembly.

3. Literature Review

The Gearless mechanism is a link mechanism of slider and pair, also known as El-bow mechanism**.** The component is exceptionally valuable for cornering or transmitting movements at right angle. However in certain mechanical application gearless transmission at right angle can likewise work at insensitive or exact edge plane and can be contrasted with worm and worm rigging or slant and pinion gear which are constantly utilized as a part of the business for various application. Similarly high proficiency between the info and the yield power shafts as to the rigging efficiencies [4].

The motion study and simulation of various mechanisms has been frequently studied for several years. Prof. MahanteshTanodi performed experiments on the gearless power transmission offset parallel shaft coupling [4]. Amit Kumar and Mukhesh Kumar developed the gearless power transmission between the skew shafts (SRRS mechanism) [5]. Hassanzadeh et. al. performed kinematic and kinetic study of Rescue Robot [6]. Gadhia Utsav D. has given the Quarter model of Wagon-R car's rear suspension by making analysis on ADAMS software [7]. However, there hasn't been performed any study to sort out problems on gearless transmission mechanism. Gearless transmission for speed reduction through rolling motion induced by wobbing motion, Us [8]. Assad Anis carried out analysis of Slider Crank Mechanism on ADAMS Software package [9]. A. A. Yazdani performed Multi-body Dynamics Simulation of an Integrated Landing Gear System using ADAMS-MSC software [10]. Ranjbarkohan et. al. [11] made use of ADAMS software package and Newton's laws for analyzing the behavior of slider crank mechanism and investigated the effect of engine rpm on connecting link and crankshaft.

4. Design Details

Design consideration

According to [12], some parameters were assumed which are as follows:

Input motor power = 0.75 hp at 1440 rpm; hub diameter inner = 32 mm, Outer = 92 mm, Length of hub = 82 mm; Length of the elbow link = 204 mm and No. of Elbow links = 3. Shaft diameter = 25 mm.

For functioning of the machine and also for testing of the mechanism some calculation are necessary.

Torque Calculation

Assuming motor of 0.75 hp which was available in the laboratory and the torque available was 559.5 N.m.

With rated motor rpm of 1440 rpm, the required transmitted torque was calculated using the Eq. (1).

$$P = \frac{2\pi T n}{60} \quad \text{------------ (1)}$$

The torque transmitted is 3.71 N.m.

Design of Shaft

The stresses normally adopted in shaft design [11] are: max. tensile stress = 60×10^6 N/m^2 and max. shear stress = 40×10^6 N/m^2. The shaft shear stress was evaluated using Eq. (2).

$$S_S = \frac{16\,T}{\pi D^3} \quad \text{---------- (2)}$$

Considering 25 % overload, T_{max} was 4.6375 N.m.

As the shaft is subject to torsional stress, the shaft diameter was calculated using Eq. (3).

$$T = \frac{\pi \times S_S \times D^3}{16} \quad \text{---------- (3)}$$

Taking factor of safety of 2.5, the shaft diameter was 21 mm. In actual construction 25 mm was taken.

Design of the Hub

Considering hub internal diameter is 32 mm and outer diameter is 92 mm and length is 82mm, the mass of the system is 28 kg.

It is known that force, F = mg = 275 N. The bending stress of the hub was evaluated using Eq. (4).

$$\sigma_b = \frac{FDi^2}{Do^2 - Di^2} \text{ ---------- (4)}$$

So, the calculated value of bending stress is 37.84 × 10^3 N/m.

Design of the Elbow Link

It is known that the same torque will be transmitted to elbow link. So, torque on each elbow link will be total torque divided by 3 and it will be 1.5458 N.m. Thus, the elbow link diameter would be obtained by using Eq. (5).

$$T = \frac{\pi \times Ss \times D2^3}{16} \text{ ---------- (5)}$$

Considering factor of safety of 1.5, the diameter of the link will be 8.626 mm. In actual 8.5 mm was chosen. The bending stress on the link was evaluated using Eq. (6).

$$\sigma = \frac{PL}{4Z} \text{ ---------------------------- (6)}$$

It is known that, the section modulus for circular rod [13],

$$Z = \frac{\pi D^3}{32} \text{ --------------------------- (7)}$$

The calculated value of section modulus can be obtained by using eq. (7) was Z = 60.29× 10^6 kg/m^2. So the calculated value of bending stress on the link [using Eq. (3)] was 473 × 10^6 N/m^2.

5. Construction of the Model

Finally all the components and parts of the project were constructed using locally available materials and are mounted on a frame. The motor available in the lab was used in this project. The hubs and links were fabricated in the lab. The bearings and pulleys were purchased from local market. Fig. 4, shows the final constructed model or assembly of the gearless power transmission system in right angles.

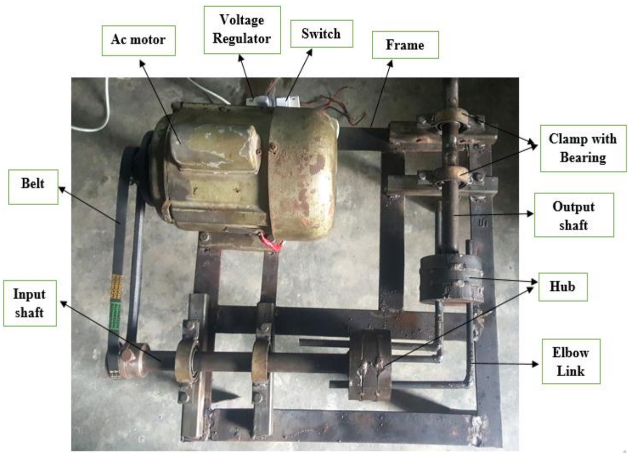

Fig. 4: Photographic view of Final setup of the project

6. Performance Test

Performance test of the gearless power transmission system consists of-

- Estimation of input motor speed, input shaft speed and output shaft speed at various power.
- Calculate speed loss between input and output shaft.
- Estimation of transmitted torque from motor at different motor speeds.
- Estimation of maximum speed for various powers at maximum torque.

The outcome of the performance tests are presented in Table 1.

Table 1 Experimental and calculated data

Power hp	Motor Speed rpm	Input shaft speed rpm	Out. shaft speed rpm	Speed loss %	Transmi-tted torque N.m
720.2	1367	1432	1425	0.48	5.03
712.4	1255	1325	1316	0.67	5.42
712.4	1214	1284	1273	0.85	5.60
707.2	1153	1225	1213	0.97	5.85
704.6	1113	1187	1174	1.09	6.04
702.0	1055	1130	1117	1.15	6.35
694.2	1017	1093	1055	3.47	6.51
691.6	963	1040	1010	2.88	6.85
689.0	928	1005	968	3.68	7.09
686.4	877	956	925	3.24	7.47
683.8	845	875	858	1.94	7.72
678.6	766	797	778	2.38	8.46
678.6	766	798	753	5.64	8.46
676.0	624	656	636	3.05	10.35
676.0	597	630	611	3.02	10.81
673.4	560	592	574	3.04	11.48
673.4	502	533	515	3.38	12.81
670.8	447	478	461	3.56	14.33
660.4	324	342	328	4.09	19.46
652.6	272	283	274	3.18	22.91

Maximum torque was evaluated using Eq. (8) and using the maximum stress, maximum torque is estimated and finally the maximum permissible speed is estimated. It is known that,

$$T_{max} = \frac{\pi \times \tau \times D_2{}^3}{16} \text{ ----------------------- (8)}$$

Now the maximum stress τ = 60 x 10^6 N/m^2

and with diameter D_2 = 8.50 mm, the maximum torque will be, T_{max}= 7.23 N-m

For this torque maximum permissible speed was achieved for various powers. The maximum permissible speeds are presented in Table 2.

Table 2: Maximum permissible speed estimation

Power hp	Torque (T_{max}) N.m	Maximum permissible speed rpm
1.00	7.23	985.30
0.75	7.23	738.97
0.50	7.23	492.65
0.25	7.23	246.32

7. Result and Discussion

Results: The constructed model works well as per the design but because of friction in the hub and vibration of the system some speed losses are found. The speed loss varies with changing of power because of vibration of the system varies with speed. The vibration is the result of unskilled workmanship and also the clearance between the hub and links was more. The maximum speed loss occurred when the power was 678.6 watt and the loss is 5.64%. With the help of this system, one could efficiently reduce the cost in power transmission. A certain initial torque is required to start the input shaft rotation and the minimum torque is 22.92 N.m. It is observed from the table that for various input power of motor the maximum permissible speed of the system varies. The maximum permissible limit for the 1.0 hp motor is 986 rpm and for 0.25 hp motor is 246 rpm. This value is the safest running speed of this gearless power transmission system. The input shaft speed, output shaft speed, motor speed, transmitted torque, speed loss all are estimated and shown in respective table.

Discussion: From the tabulation of all data, it can be said that the gearless power transmission system works smoothly when the system run with permissible speed limit. As speed loss is occurred in the system owing to frictional effect and vibration, it could be reduced by proper manufacturing and using lubrication. For that simple technique could be applied for lubrication to drill oil hole in the cylinder body and fill up with oil. As the surface finish cannot be done properly, so vibration often occurs when the power is transmitted in a right angle. So it can be reduced by providing surface finish.

In gearless power transmission system, the power can be transmitted at varied angle. But these are depending upon the angular limitation of the elbow joints. With more analysis and advanced analysis within the style wide-ranging applications of the drive may be discovered.

8. Conclusion

1. This projects looks very simple and easy to construct but actually was difficult to conceive and imagine without seeing an actual one. Hence, it has been mould to present this project at 90^o (El-bow mechanism) only.
2. This system runs well and transmits power in angular direction when appropriate links are used with little loss.
3. The system has the freedom of interchangeability and most important thing is its low manufacturing cost.
4. This system does not work at very low transmitting torque. Improper drilled hole may cause problem, and sudden load may break down the mechanism. The speed ratio of the mechanism is almost 1:1.

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