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ORIGINAL RESEARCH ARTICLE

IMPROVED GEARLESS TRANSMISSION SYSTEM

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ABSTRACT

Gearless transmission is an elbow mechanism that transmits power with little losses. The system is mainly used to reduce the usage of complex gears likewise the wearing conditions of the gears that requires high cost of repairs and or maintenance. Therefore, exploration into this study lead to rejuvenate ideas through which power was transmitted using different mechanism by replacing a bevel gear with an elbow mechanism for transmitting the power between the two shafts at 90°. The mechanism hubs were fixed at both ends of the shafts through which power was transferred. The sizes of the pins and links were measured, likewise the holes were drilled precisely. In this study, three elbows were connected radially at an angle of 120° to the center of the axis. The transmission was made cost-effective and efficient with the average efficiency of 94.8% and a complete freedom of interchangeability whereby the total cost of production was #76,000. Of this arrangement, the mechanism has effective and minimum amount of power (10.18Nm) at the handle needed for a complete revolution. It's a simple working principle, smooth with an effective and lesser power needed to propel it.

1.0 Introduction

Power transmission in this gearless system simply means the process of transmitting signal from one shaft of the system via another through some connections like belt, rope, chain and gears. For transmitting the power- train from one shaft to another that are non-parallel (intersection) and coplanar in which bevel gearing is generally employed. An influential mechanism (the concept gearless power transmission) according to Pinghua et al. (2020) should be introduced to eliminate this sort of drawbacks. It consists of links that lies inside the arrangement with symmetrically-spaced holes arranged on the solid cylindrical disc. The number of the links is between three and or nine. As the number of the links was increased, the smoother the operation became.

Today, due to unavailability of resources, it is imperative using the resources available at hand for the purpose intended. Generally, the problem with gear transmission is that, the production of gears is complex processes that requires more time and a great deal of precision is also required for mass production. Another major problem of gear drive transmission is that, it causes backless error leading to jamming and becomes more noisy compared to other drives because of pitch mismatch. Ranjbarkohan (2011) and Kumar (2015) system loaded with L-pins at 012° of the tubular disc. The pins are made up of the Stainless Steel (X6cr17). The gearless mechanism produced has an improved efficiency of 94.8% as compared to that of Kumar (2015) with 92.1%

performed through a study on a multi angular gearless drive and also that of Htway et al. (2019), Somraj and Sallesh (2017) with 3, 5 7 and 9 odd pins respectively. Barot and Patel (2020) designed a gearless mechanism to transmit power at different angles between 0-180° of the shafts and analyzed in Comparative Expression analysis level (CREO5) for checking the feasibility of the transmission system. It showed the speed ratio of the shaft 1:1 during operation and indicated a maximum displacement at the elbow links same with that of Chakradhar et al. (2019) loaded with 3 numbers of L-pins.

1.1 Application of the Gearless Transmission System

The gearless transmission has the wider application as an extension for a socket wrench. Here, the design made it easy and faster in automotive and other mechanical industries where direct access to bolt and screws are often limited. However, there are conceivable applications for this technology that extend into various arenas to mention but a few;

i. It could invariably be used for gang drilling.
ii. The elbow system could be used for periscope in submarine.
iii. Lubrication pump for Computerized Numerical Control (CNC) lathe.
iv. Used in vehicles (go-carts).

1.2 Principle of Operation of Gearless Transmission System

A common form of gearless transmission system is normally an angle located shaft that is transmitted from the driving shaft via the rods to the driven shaft bent to fit the angles between the shafts. The shafts need to be spaced equally around the circle at openings and are free to slip in and out during shafts rotation. The drive (Figure 1a) is predominantly suitable and quiet for high-speed operation though its recommendation but only for light duty operations (Katharine et al., 2013). For an improved gearless transmission system as shown in Figure 1b, it has the power to replace both bevel and crown gears with greater efficiency unlike that of Micah et al. (2021) for power transmission with a little change. The system could serve as an innovative idea which could be of great benefit to the society at a larger scale. The mechanism shows a deceptive turn by the action of one rod during revolutions. Figure 1b shows the replica of Figure 1a where the driving shaft 'A' is revolved and the driven shaft 'B' also rotates but in counter clockwise. As the shaft 'A' turns through half revolution, rod 'C' slides out of both shafts 'A' and 'B' respectively at the first half revolution. At the remaining half of the revolution, rod 'C' slides inwards until it reaches the inner most position. Therefore, all rods are successively sliding inwards and outwards. As this illustration shows a right angle transmission, the drive could be applied also to shafts located at midway the angles between 0° and 90 °. During construction of the transmission system, holes of the given rods are located accurately at the same position in each shaft, and the holes are equally spaced in radial and circumferential directions.

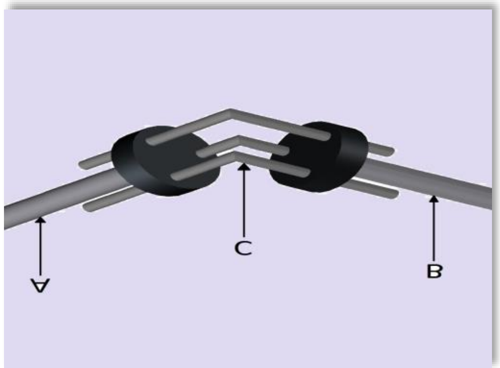

Figure 1a: Gearless Transmission Shaft

Figure 1b: Improved Gearless Transmission System

2. Materials and Methods

2.1 Design Considerations

- ✓ Holes in each cylinder must be equally spaced for equal rotation.
- ✓ Angle between holes = 120° to avoid overlap
- ✓ No. of rods = 3 based on the requirement of the system
- ✓ The greater the number of rods, the smoother the operation and higher the efficiency according to Somraj and Sallesh (2017)
- ✓ 3-8 rods feasible for greater efficiency
- ✓ End of the cylinders have the input and output shaft fitted with screws to prevent abnormal shift of the pins
- ✓ Each shaft is supported on bearings for easy rotation.
- ✓ Main assembly is mounted on a frame for support.

2.2 Materials Selection

The choice of materials for engineering purposes depends on the following factors:

1. Availability of the materials for specific purpose.
2. Suitability of the materials for the specific purpose.
3. The cost of materials for the intended purpose.
4. Physical and chemical properties of the material
5. Mechanical properties of the material.
6. Corrosion resistivity of the material

2.3 Mechanism Component Operations

2.3.1 Supporting Frame

The supporting Frame is often a structural system that supports other components of the physical construction that limits the construction extent and gives it strength and shape. The shaft is the bar or rod used in the construction of the mechanism for transmitting the power. Ball bearing are fixed at the terminals of the shaft to allow easy rotation of the shaft in order to prevent the wearing of the shaft terminals. While the bolts are fasteners that consist of the threaded linings holes and pitches and nuts are used for fastening or tightening parts.

2.4 Design Calculations. This is to determine the parameters of the components parts of the improved gearless transmission system

2. 4.1 Design of the handle

In determining the parameter of the handle of the improved gearless
Transmission system, power of the handle =1/7 horse power (hp) (1)
But, 1 horse power (hp) = 746 watt

$$= 746 \times {}^{1}/_{7} = 106.57\ Nm/s$$

Revolution per minute of the handle (speed) $N = 100\ rpm$
From Equation 1,
Power of the handle (P) = 106.57 watt.

$$P = \frac{2\ \pi N\ T}{60} \quad (2)$$

Where, N = speed of the shaft in rpm

T = Torque transmitted

From Equation 2, $106.57 = \frac{2\pi \times 100 \times T}{60}$

T = $10.18\ Nm$
T = $1018\ Nmm.$

2.4.2 Shaft Design Parameter

From Equation 2, transmitted torque T = 1018 Nmm

$$Tmax\ =\ 1018\ \times 1.25\ = 1272\ Nmm$$

As the shaft in Figure 2 is imperiled to pure torsional stress,

$$Tmax = \frac{\pi \times fs \times d^3}{16} \quad (3)$$

$$1272\ = \frac{\pi \times 40 \times d^3}{16}$$

$$\mathrm{d} = 5.5mm$$

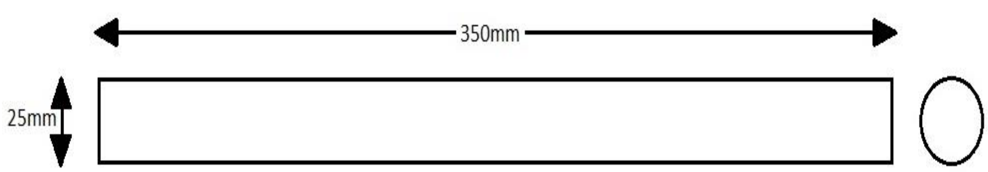

Figure 2: Shaft of the Improved Gearless Transmission

The maximum bending moment (M_t) of the transmission shaft is give as,

$$M_t = \frac{W \times L^2}{4} \quad (4)$$

Where W is the shaft weight which is equal to 13.23N and L is the length of the shaft 350mm

Therefore, Mt= $405184.4\ Nmm$,

Bending stress of the shaft (σ),

$$\sigma \ = \ 32M_t \times d\ ^3 \quad (5)$$

σ = 202.6N/mm^2

Tensional shear stress (τ) of the shaft,

$$\tau \ = \frac{16M_t}{\pi d^3} \quad (6)$$

$$\tau = \frac{16\times405184.4}{\pi\times20\ ^3} = \ 257.94N/mm^2$$

2.4.3 Hub Design Parameter

From Figure 2 with an internal radius ($\mathrm{r_o}$)10mm, outer radius ($\mathrm{r_o}$) 40mm with a length of 30mm; Density of the mild steel = $7860\ \mathrm{kg/m^3}$

$$\text{Volume of the Hub} = \pi(\mathrm{r_o}^2 \ - \ \mathrm{r_i}^2) \ \times \ \text{length} \quad (7)$$

$$\text{Vol. of hub} = \ \pi(40^2 - 10^2) \ \times \ 30$$

$$= \ 141371.7mm^3$$

$$= \ 1.41 \times 10^{-4}m^3$$

Mass of hub = $\text{Density of mild steel} \times \text{Volume of Hub} = 7860 \times 1.41 \times 10^{-4} = \ 1.11\ \text{kg}$

$$\text{Weight of hub} = m \times g \quad (8)$$

$$\text{Weight of hub} = 1.11 \times 9.81$$

= 10.9N

Evaluating the bending stress of the hub, it becomes;

$$\Sigma_b \ = \frac{W\times {D_i}^2}{{D_o}^2 - {D_i}^2} \quad (9)$$

Where D_i and D_o are the inner and outer diameter of the hub, while W is the weight of the hub

$$\Sigma_b \ = \frac{10.9\times20^2}{80^2-20^2} \ = 72.66N/mm$$

The improved gearless transmission system is presented in Figure 3.

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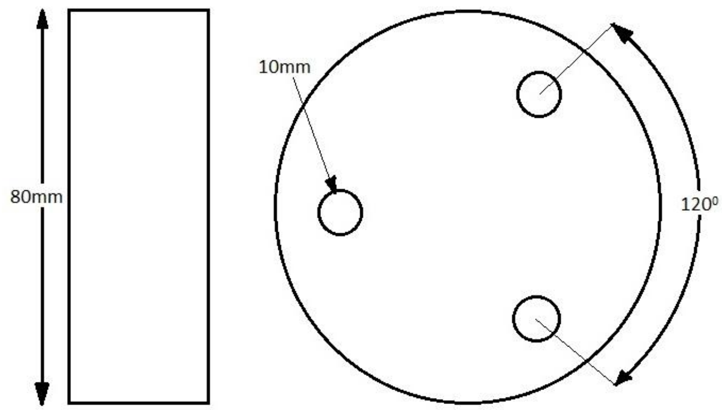

Figure 3: Hub of the Improved Gearless Transmission

2.4.4 Elbow Rod Design parameter

From Figure 3, Tmax was transmitted to the elbow links in Figure 4, therefore, it is divided by 3, because of the three rotational axis which gives 1272/3 = 424Nmm. That is the diameter of the elbow link obtained by dividing the torque on equal shaft with dimensions 150mm length and 10mm width. Therefore, $Tmax/3 = 1272\ /3 = 424\ Nmm$

$$\text{If } T = \frac{\pi \times fs \times d^3}{16} \tag{10}$$

where fs is maximum, shear stress = 40N/mm

Now D as the diameter = 7.17 mm.

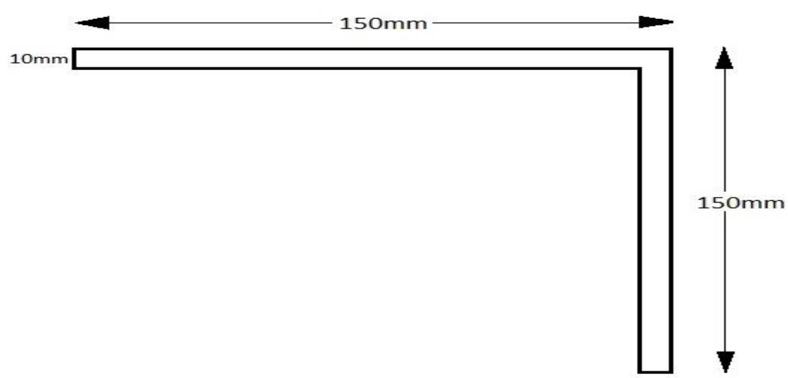

Figure 4: Elbow Link of the improved gearless transmission

2.5 Construction of the Improved Gearless Transmission Mechanism (Principles)

The Gearless transmission mechanism as a system that transmits motion between the driving and the driven shafts at any fixed angle. The mechanism contains a variety of pins and rods that are bent at the right angle. The number of pins were between 3 and 8 because the greater the number of the pins, the smoother and higher the efficiency. The pins sided inside the holes and created a pair of sliders. In this mechanism, the 3 holes were drilled on the circumference of the circle called a pitch at 120° to each other from the middle of the cylinder. The end of the cylinders was fitted with an input and output shaft with the aid of keys and each shaft was supported on a bearing house consisted of a ball bearing. The main assembly was mounted on a mild-steel frame as shown in Figure 1.

2.6 Construction of the Improved Gearless Transmission Hub

Construction of the hub was done by the use of lathe and drilling machine. During the construction, the following operations were used.

1. Marking
2. Cutting
3. Hole drilling
4. Turning
5. Facing

2.7 Procedure for Machining of the improved gearless transmission Hub

i. A mild steel of length and diameter more than 30mm and 80mm respectively was used.
ii. Facing operation was done at both ends to make the piece of length 30mm.
iii. Turning operation was done on lathe to make the piece to 80mm diameter.
iv. The pitch circle diameter of 20mm was marked.
v. Three points on the circle at angle difference of 120° were mark
vi. Drilling of holes of 9mm diameter was done at the above marked points.
vii. Drilling of a blind hole of 9mm diameter was done at the center of the length of the hub to a depth of 20 mm.
viii. Hand tapping of 8 mm was done in the blind hole.

2.8 Construction of the Improved Gearless Transmission Shaft

Operating done for machining of shaft was "facing"

2.9 Procedure for Machining of the Improved Gearless Transmission Shaft

1. A piece of diameter 20mm and length greater than 350mm was used.
2. Facing was done to reduce the length to 350mm.
3. Turning operation was not done as we got the shaft having diameter exactly 20mm.
4. External thread of pitch 2mm was made at one end of the shaft.

2.10 Construction of the Improved Gearless Transmission Pins

Construction of pins was done on the lathe using open hearth and bench vice (bending machine).

2.11 Procedure of Making the Improved Gearless Transmission Pins

1. A rod of length greater than 300mm and diameter 8mm was used.
2. Facing operation was used to reduce the length of the rod to 300mm.
3. The rods were heated, at their Centre on the open hearth at a high temperature so that the stress exceeded the yield stress of the mild steel.
4. The rods were bent at 90° on the bench vice (bending machine) in order to obtain the pin rods.

2.12 Construction of the Improved Gearless Transmission Frame

Construction of the frame was done by cutting and welding operation.

2.13 Simulation of the Improved Gearless Transmission system

Static structural analysis of the system was observed in order to determine the total deformation of the elbow rod, hub and the shaft at 100rpm.

2.14 Performance Evaluation of the mechanism (Efficiency Test)

The efficiency of any mechanism shows the performance of the mechanism. The efficiency of any system is defined as the ratio of the output to that of the input. For this gearless transmission system, the mechanical efficiency was calculated using Equation 11

$$\eta = \frac{No}{Ni} \quad (11)$$

where: η = mechanical efficiency of the gearless transmission, N_o= speed of the shaft at the output in rpm, N_i= speed of the shaft at the input in rpm .

The performance evaluation of the improved gearless transmission system was conducted using Equation 11 and different input shaft speeds.

3. Results and Discussion

The performance of the improved gearless transmission system is presented in Table 2.

Table 2: Performance Evaluation of the Improved Gearless Transmission System

S/No.	N_o	N_i	η
1	100	95	0.95
2	100	92	0.92
3	100	93	0.93
4	100	97	0.97
5	100	96	0.96
6	100	96	0.96

Table 2 shows the experimental efficiencies of the improved gearless transmission system. Therefore, the average efficiency of the system is as follows:

$$\eta_{av} = (95 + 92 + 93 + 97 + 96 + 96)/6 = 94.8\%$$

Thus, the average efficiency of the improved gearless transmission system is 94.8%.

The efficiency of the system could be increased by following ways:

1) Proper lubrication of the pins and hub
2) Lubrication oil of suitable viscosity should be taken.
3) By reducing the weight of the mechanism through proper designing.
4) Finished surface after grinding to reduce the friction between the hub and pins.

The system was found worthy of implementation. Base on the frictional cases and the system vibration, there was little reduction in the speed due to the power reduction which could be modified as research continues and the average efficiency of the improved gearless transmission system obtained is 94.8% greater than the existing gearless transmission systems found in literature. With the help of solid work analysis, after applying all the boundary conditions given in the existing design parameters, all were included in the SimExpress Module. In Solid Work analysis, it works on the Finite Element Method (FEM). SIMEXPRESS Statistical analysis used to conclude the result to determine the efficiency and design analysis.

4. Conclusion

From the data obtained, it is confirmed that the system worked perfectly well with the minor human error or deficiencies compared to the existing modules. The system as evaluated shows improved simple transmission mechanism associated with numerous benefits. It is fairly light in weight, easy to design, easy to manufacture and economically viable both at the time of manufacturing and at running time with minor drawbacks such as inability to transmit velocity ratios other than 1:1, inability to transmit higher torques which could be improved for various uses in the real world such as;

i. For low power transmission between perpendicular shafts
ii. Static applications where 1:1 velocity ratio is to be transmitted
iii. Low-duty vehicles which are not subjected to shocks and vibrations like the cricket matches for transporting drinks.

The gearless transmission system shown in Figure 5 has the power to replace both bevel and crown gears with greater efficiency unlike that of Micah et al. (2021) for power transmission with a little change. Therefore, the system could serve as an innovative idea which could be of great benefit to the society at a larger scale.

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