Design and Manufacturing of Cycloidal Speed Reducer
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Abstract—Cycloidal speed reducer (rotational speed regulation device) covers a wider range of transmission ratios, have a higher load-carrying capacity, exhibit a smoother running, the higher accuracy, the easier adjustment of the transmission ratio, the smaller workspace than any other kinds of the reducer and a good efficiency and such characteristics make them attractive for industrial applications, especially for robotics applications, machine tools and linear axis positioning in assembly machinery in the field of engineering. Friction exists at all points of contact between the moving elements of Cycloidal speed reducers, as one of the main causes of power losses in power transmission. This paper proposes simple, exact, theoretical and experimental investigation on an innovative Cycloidal speed reducer i.e the main part of cycloid reducer. Key words: Cycloidal Speed Reducer, Manufacturing of Cycloidal Speed Reducer

I. INTRODUCTION
Todays design engineers are demanding machinery and equipment with higher speeds, greater accuracy, and more flexibility. At the same time, they are looking for miniaturization, allowing them to maximize production in less floor space. These standards for better machinery apply to servo motors and servo speed reducers as well. We are meeting or exceeding these standards without state-of-the-art Cycloidal speed reducers. Cycloidal technology has long been considered the most durable, compact design for speed reducer mechanisms. Cycloidal technology by us offers the best cycloidal performance available today. Our compact pancake design has the shortest axial package in the industry. True zero backlashes, the widest range of ratios, plus unmatched positional accuracy, give ultimate flexibility to the design engineer. The word Cycloid, with its adjective Cycloidal, is derived from Hypocycloid which describes the curve traced by a point on the circumference of a smaller circle rotating inside the circumference of a larger fixed circle. Just like words such as helical, worm, spur, and bevel, cycloidal is a generic adjective; it merely describes the gearing mechanism inside the speed reducer. No manufacturers shall claim the exclusive use of this word.

II. PRINCIPLE
First know how to determine the reduction ratio of a Cycloidal reducer.

\[ \text{Ratio} = \frac{P - L}{L} \]

Where, \( P \) = Number of ring gear pins/rollers.
\( L \) = Number of lobes on a Cycloidal disc.
The number of ring gear pins/rollers (P) equals 12, and the number of lobes (L) on the Cycloidal disc equals 11.

\[ \text{Ratio} = \frac{(12 - 11)}{11} = \frac{1}{11} = 11:1 \]

As the input shaft turns, the eccentric bearing goes into a rocking motion. This rocking motion exerts an outward radial force on the Cycloidal disc.

![Fig. 1: Cut away view of ring gear sub assembly.](image)

Confined inside the ring gear housing with pins/rollers, the Cycloidal disc goes into a planetary motion as the eccentric bearing turns. As a smaller circle rotates inside the circumference of a larger circle, the smaller circle goes into a planetary motion. Relative to its own center, the smaller circle is rotating in the CCW direction. However, relative to the center of larger circle, the smaller circle is advancing in the CW direction. Cycloidal mechanism works the same way. The smaller circle as described earlier is now almost as large as the larger circle and has the shape of a Cycloidal disc. The larger circle now has the shape of a ring gear with pins/rollers. As the eccentric bearing drives the Cycloidal disc, the Cycloidal disc rotates in one direction relative to its own center. However the Cycloidal disc advances in the opposite direction relative to the center of the speed reducer. This planetary motion looks almost like the wobbling movement of hula hoops.

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As the eccentric bearing turns one revolution, the Cycloidal disc advances in the opposite direction by (360/L) degrees or (P/L) pitches of pins/rollers.

The output direction of Cycloidal reducer with single stage reduction equals to the opposite of input direction.

In order to convert the wobbling motion of a Cycloidal disc into the smooth concentric movement of output shaft, several output shaft rollers are placed inside the small circles of a Cycloidal disc. These rollers are also attached to the output shaft pins. The difference (2C) between the diameter of output shaft roller and the small circle is exactly twice the eccentricity (C) of eccentric bearing. This distance (2C) is also the radial difference between the valley and crest of a Cycloidal disc lobe.

With the arrangement above, the mechanism is capable of converting the rocking motion of an eccentric bearing into the wobbling planetary motion of a Cycloidal disc. This motion is then transformed to the smooth concentric movement of output shaft through the output shaft rollers. The speed reduction is achieved, and torque transmission is accomplished.
III. METHOD OF OPERATION

In the picture shaft is shown yellow in the picture below. It is made with an eccentric cam at the end of the shaft. The cam sits inside the center of the cycloid disc. As it rotates the cam moves the cycloid disc in a circular orbit. The outer fixed pins and rollers restrain the disc and force it to roll around inside the ring of fixed pins. As the disc rolls it moves the inner set of pins and roller attached to the output shaft.

One rotation of the cam moves the cycloid disc over one outer pin. As the disc rotates the inner pins are forced around with it at the speed of the disc. This means that there is a reduction in gearing and the output turns at slower revolutions than the input shaft.

Fig. 2: 2D view of Cycloidal assembly.

The nature of the design makes their size much smaller than a conventional toothed gear drive for the same gearing ratio. This means you need less space to mount them. They weigh less and are more easily maneuvered by installation and repair personnel. The smaller internals and sliding action of the rotating components makes the gearbox quieter than conventional gearboxes.

They are ideal where shock loads are expected because all the parts are in compression and not in tension, as is the case with conventional gearbox teeth. Their quietness makes them ideal to use where operators need to work close to equipment or for equipment located near offices, hospitals and like. Their reliability and longevity is outstanding flexibility.

IV. DESIGN OF MOTOR

The motor is prime drive in our machine, it convert electrical power in to mechanical power. It gives rotary motion to mechanism. The motor design is very important design aspect in machine design practice.

\[ P = \frac{2nT}{60} \]  \hspace{1cm} (1.1)

Where, \( N \) = Rpm of motor = 1200 rpm
\( T \) = Torque transmitted by motor
\( P \) = Power of motor
\( T_n \) = 4450 N-mm

So for increasing the torque we use Cycloidal type reduction gear box.

V. DESIGN OF TRANSMISSION

As project the basic transmission is done through pulley and v-belt arrangement.

It required low speed for operation. As the project is compact so the transmission is done through v-belt. The v-belt is mostly used in m/c where a great amount of power is to be transmitted from one pulley to another when two pulleys are very near to each other.

The v-belts are made of fabric and cords, moulded in rubber and covered with fabric and rubber. These belts are mounted to at trapezoidal shape and are made endless.

As we know, \[ \frac{\text{Speed of motor}}{\text{Speed of arbor}} = \frac{\text{Diameter of arbor pulley}}{\text{Diameter of motor pulley}} \] … (2.1)

\[ \frac{1200}{250} = \frac{50}{250} \]
\[ x = \frac{50 \times 1200}{250} \]
\[ x = 240 \]

\( N_{\text{Motor pulley}} = 240 \text{ rpm.} \)

We know transmission ratio = \( \frac{50}{50} = 5 \)

So torque increased = \( 4450 \times 5 = 22250 \text{ N-mm} \)

We are going to select and manufacture gear box of ratio =1:12

Thus the total torque output of gear box will be,
\( T = 22250 \times 12 = 267000 \text{ N-mm} \)

Force applied on pin = \( \frac{x}{3} = \frac{240}{30} = 8900 \text{ N} \)

NUMBER OF V-BELTS

Selecting v-belt of A-class which transmits between 0.1KW-3KW

Thus selecting 1.4KW

\[ N = \frac{\text{Total Power transmitted}}{\text{Power transmitted per rope}} \]
\[ N = \frac{559.5}{1400} = 0.399 \]

Say 1 belt. So 1 belt is sufficient for transmission of power

VI. SELECTION OF MATERIAL

Selecting material C-45

Yield strength =320 N/mm²

Selecting factor of safety = 2

Thus maximum bending and tensile strength =160N /mm²

And maximum shear strength =80N /mm²

VII. DESIGN OF PIN SHAFT

A. Torsion

When the shaft is twisted by the couple such that the axis of the shaft and the axis of the couple coincides, the shaft is subjected to pure torsion and the stresses at any point of cross section is torsion or shear stresses. Shaft design on basic of study.

Therefore 267000 = \( (\pi/16) \times 80 \times d^3 \)
\( D = 11.23 \approx 12 \text{ mm} \)
 Shaft size = 12mm

Taking factor of safety = 1.6

Shaft size = 12 x 1.6 = 20 mm. Loading with transversal shearing force. Connection is checked for contact surface deformation and pin shearing.
Fig. 4: securing pin

Pin shearing stress where,  
\[ F = A \text{shearing force [N, lb]} \]
\[ s_1 = \text{Thickness of bottom board [mm, in]} \]
\[ s_2 = \text{Thickness of top board [mm, in]} \]
\[ d = \text{Pin diameter [mm, in]} \]
\[ i = \text{Number of pins} \]
\[ K_L = \text{Load distribution factor} = 1.6 \]
\[ K_{S_b}, K_{S_p} = \text{Service factor} = 1.2 \]

Induced shear stress  
\[ \tau = k_{S_b} \times \frac{4F}{K_L \times s_1 \times s_2} \times \frac{d^2}{6.5} \times \pi \]  
\[ \tau = 1.2 \times \frac{4 \times 8900}{1.6 \times 3 \times 3.14 \times 8.5} \times 8.5 \]  
\[ \tau = 39.21 \text{ N/mm}^2 \]  
As induced stress is very less than allowable so design is safe.

VIII. DESIGN OF C-SECTION

The vertical column channel is subjected to bending stress. Stress given by \[ M/I = \frac{f_b}{y} \]  
In above equation first we will find the moment of inertia about x and y axis and take the minimum moment of inertia considering the channel of ISLC 75 x 40 size.

We know the channel is subject to axial compressive load.

In column section the maximum bending moment occurs at channel of section.

\[ M = Ra \times L/2 \]
\[ M = 750 \times 1500/2 \]
\[ M = 562500 \text{ N-mm} \]

**Fig. 5: C-section**

We know

\[ F_b = \frac{M}{Z} \]
\[ Z = t \left( \frac{l}{b} + \frac{b^3}{6} \right) \]  
\[ Z = 5 \left( \frac{40 \times 65 + 65^2}{6} \right) \]
\[ Z = 3304 \text{ mm}^2 \]  
Now check bending stress induced in C section

\[ F_b \text{ induced} = \frac{M}{Z} \]
\[ F_b \text{ induced} = \frac{562500}{3304} = 170.25 \text{ N/mm}^2 \]  
As induced stress value is less than allowable stress value design is safe.

IX. DESIGN OF WELDED JOINT OF CHANNEL

The welded joint is subjected to pure bending moment. So it should be design for bending stress. We know minimum area of weld or throat area,

\[ A = 0.707 \times s \times l \]  
Where \[ s = \text{size of weld} \]
\[ l = \text{length of weld} \]

\[ A = 0.707 \times 5 \times (75 + 40 + 35 + 58 + 35) \]
\[ A = 0.707 \times 5 \times 243 \]
\[ A = 859 \text{ mm}^2 \]  
Bending strength of parallel fillet weld  
\[ P = A \times F_b \]  
\[ F_b = 80 \text{ N/mm}^2 \]  
As load applied at the end of lever is 250 N. So moment generated at the welded joint is  
\[ M = P \times L \]
\[ = 250 \times 450 \]
\[ = 112500 \text{ N-mm} \]

We know

\[ F_b = \frac{M}{Z} \]
\[ Z = \frac{6H^3 - bh^3}{6H} \]  
\[ Z = \frac{6 \times 75^3 - 35 \times 58^3}{209824} \]
Calculating induce stress developed in welded joint  
\[ F_{b\text{induced}} = \frac{112500}{209824} = 0.536 \text{ N/mm}^2 \]  
As induced stress is less than allowable stress.

Hence design is safe.

X. DESIGN OF LOBE

As speed reduction ratio is 12:1

Thus selecting roller bearing with 13 rollers in it whose outside diameter is 100 mm and the diameter of roller is 24 mm. Thus the outer diameter of lobe will be 100mm and the inner diameter will be 88mm

The offset of shaft is around 5mm.

Thus the hole size should greater than 2c of the diameter of pin which is 8.5mm

\[ 2c + d = 18.5 \]  
Thus selecting 20 mm hole diameter.

**Fig. 6: construction of lobe**

XI. RESULT

The output speed of Cycloidal speed reducer is 20 RPM
ACKNOWLEDGEMENT
We are thankful to Prof Dipak Choudhari for their guidance and for giving an opportunity to work on this project.

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