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Design, Analysis and Simulation of Compact Cycloidal Drive

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ABSTRACT

Gear's are used for power transmission. There are various types of gears used for various purposes. Some various gears are as follows spur gears, helical gears, bevel gears, worm gear, etc. In this paper we are going to discuss briefly about the cycloidal gears and their future scope in the field of science. A cycloidal gear is mainly used to increase or decrease the speed. We are going to use it to decrease the speed while increasing the accuracy of the projectile. In this paper we are going to consider the cycloidal gears for the projectile of the missile. There can be of Single stage or multi-stage depending on the gear ratio that is required. After comparison with the other types of gearbox and speed reducers maximum reduction of gear ratio is achieved by cycloidal speed reducer

Keywords: Solid works, 17-4 Ph steel, Gear, Output Shaft, Input Shaft

I. INTRODUCTION

Gears are initially invented by Alexandria who belong to Greek in the third century B.C., they were further improved by Archimedes. Planetary gears were first introduced by Scotland engineer William Murdoch but was patented by James Watt in October 1781. A Gear is a toothed wheel which comes in contact with the other gear in order to transmit the power from one component to other[i].

The project mainly deals with the design, analysis and Simulation of the Cycloidal Speed Reducer.Speed Reducers are used to convert from mechanical energy to rotational energy. In the Cycloidal speed reducer, a planet gear which is of Cycloidal shaped teeth will be rotating about a fixed Sun gear which is in the shape of Circular pins. The Cycloidal Speed Reducer has a mechanism of Constant Speed Internal Gearing mechanism[ii].

It reduces the speed of an input shaft by a certain ratio. The speed can be reduced in a Single stage or a multi stage. Here we are trying to reduce in Single stage. The speed is reduced by connecting the input shaft which drives the eccentric bearing. That eccentric bearing further drives the cycloidal disc which is connected to an output shaft.The Cycloidal gear is generated with the help of Epicyclic curve generation method curve. This gear is generated by epicyclic curve generation. In this, we are going to analyze and simulate the components of the Cycloidal Speed Reducer that we are going to use. The sample calculations have been discussed further in the paper[iii].

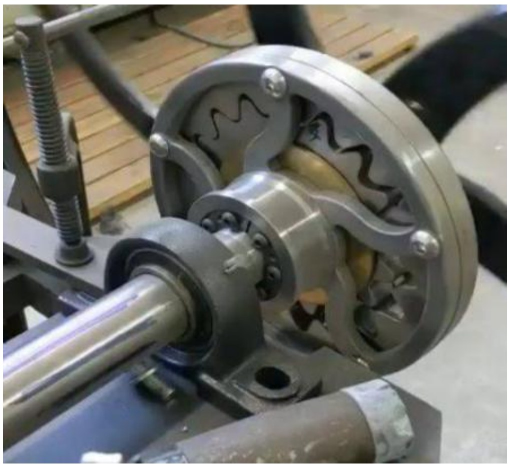


Figure 1: Speed Reducer

II. Material Properties

Properties	value	units
Yield Strength(min 2% offset)	145000	*psi*
Tensile Strength	160000	*psi*
Elastic Modulus	$28.5*10^6$	*psi*
Thermal Conductivity	18.4	$W/(m-K)$
Specific Heat	460	$J/(kg-K)$
Thermal Expansion Coefficient	7.1e - 05 ($7.1*10^6$)	$/K$
Poisson's Ratio	0.3	N/A
Mass Density	7806	kg/m^3
Shear Modulus	$77.4*10^6$	N/mm^2

Table 1: Determines the physical and mechanical properties of 17-4 PH Steel and their respective values

Element	% Present
Carbon (C)	0.07
Sulphur (S)	0.03
Manganese (Mn)	1
Iron (Fe)	73
Nickel (Ni)	5
Silicon (Si)	1
Phosphorous (P)	0.04
Chromium (Cr)	15.91
Copper	3.5
Cb + Ta	0.45

Table 2: Determines the chemical properties of 17-4 PH Steel and their respective values

III. FINITE ELEMENT METHOD

Meshing is performed in order to find the forces and load distributed at a specified point.

For the present study, Solid Works is used.
The Cycloidal Speed Reducer is designed using Solid Works 2020.

The mesh analysis is done using solid works to achieve optimum meshing conditions and exact numerical results[iv].

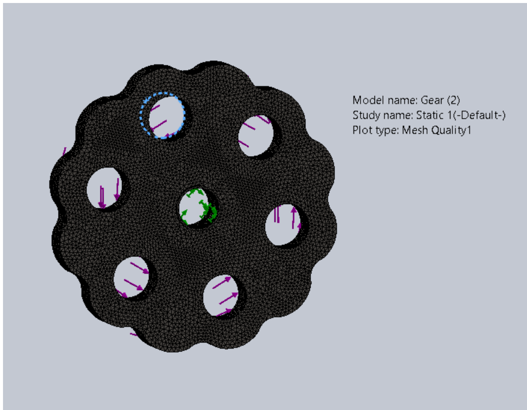


Figure 2 : Indicates the Meshed model of gear.

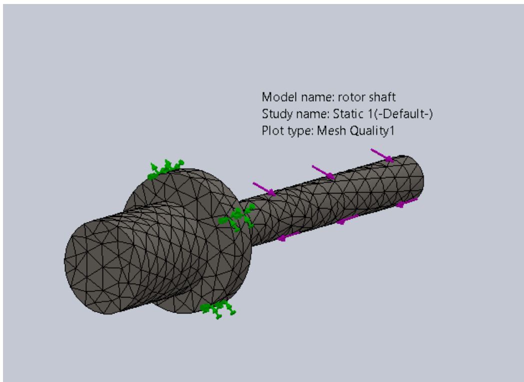


Figure 3 : Indicates the Meshed model of Input shaft

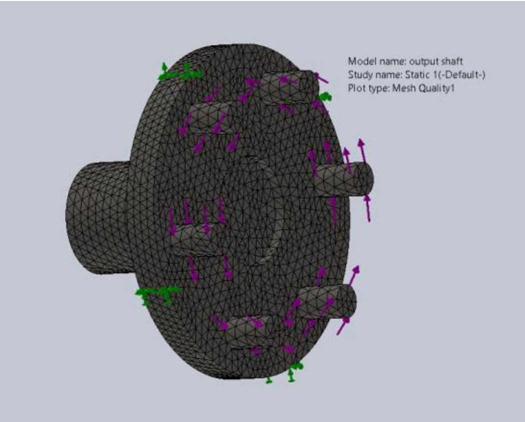


Figure 4 : Indicates the Meshed model of Output Shaft.

IV. Calculation

Gear ratio:

$$i = \frac{Z_2 - Z_1}{Z_1}$$

$$i = \frac{13-12}{12}$$

$$i = \frac{1}{12}$$

$$i = 1:12$$

1) **Coefficient displacement of the profile cutting instrument :**

$$1-\frac{\sin\gamma_t}{\cos(\frac{\pi\varepsilon_{n,\min}}{z_1+1})} \geq 1-\sqrt{1-\frac{4(z_1+2)^3 r_c^*}{27z_1(z_1+1)^2}}$$

Where $\gamma_t = 30$

$$\varepsilon_{n,\min} = \frac{z_2}{\pi}\arccos(\frac{\sin\gamma_t}{1-x_{\max}})$$

$$\varepsilon_{n,\min} = \frac{13}{\pi}\arccos(\frac{\sin 30}{1-0.49})$$

$$\varepsilon_{n,\min} = 47.0282$$

$$1-\frac{\sin 30}{\cos(\frac{\pi(47.0282)}{12+1})} \geq 1-\sqrt{1-\frac{4(12+2)^3 1}{27*12(12+1)^2}}$$

$$0.49 \geq 0.1058$$

$$x_{\max} = 0.49$$

ie. Max coefficient of profile cutting instrument for the gear.

Finally for x we have $0.49 \geq x \geq 0.1058$

2) **Diameter of pitch circle:**

$$d_1 = m*z_1 = 5.5*12 = 66mm$$

3) **Teeth height:**

$$h_1 = m(1-x) = 5.5(1-0.51) = 2.695mm$$

4) **Minimal teeth curvature radius:**

$$\rho_{\min} = \frac{m}{2}(\frac{3(z_1+1)\sqrt{3z_1x(2-x)}}{(z_1+2)^{\frac{3}{2}}} - 2.r_c^*)$$

$$\rho_{\min} = \frac{5.5}{2}(\frac{3(12+1)\sqrt{3(12)(0.51)(2-0.51)}}{(12+2)^{\frac{3}{2}}} - 2(1))$$

$$\rho_{\min} = 5.2086mm$$

5) **No.of teeth of the pin wheel:**

$$z_2 = z_2 + 1 = 12 + 1 = 13$$

6) **Diameter of the pitch circle:**

$$d_2 = mz_2 = 5.5(13) = 71.5mm$$

7) **Diameter of the pins:**

$$d_2 = 2(r_c * m) = 2(1*5.5) = 11mm$$

8) **Contact angle between lobe and planitary gear:**

$$\beta = \arcsin(1-x) = \arcsin(1-0.51)$$

$$\beta = 29.3406^\circ$$

9) **Centre Distance:**

$$a_w = \frac{m}{2}(1-x)$$

$$a_w = \frac{5.5}{2}(1-0.51)$$

$$a_w = 1.3475mm$$

10) **Maximum angle of transmitting movement:**

$$\gamma_{\max} = \arcsin(1-x)$$

$$\gamma_{\max} = \arcsin(1-0.51)$$

$$\gamma_{\max} = 29.3406^\circ$$

All the calculation are performed considering the torque at no load condition, For overall calculations (Bandwidth, Speed required for motor, Torque required for motor, power, Speed and torque of motor) refer to the second paper.

V. RESULTS

a. Simulations of the cycloidal speed reducer components.

i. Cycloidal Gear

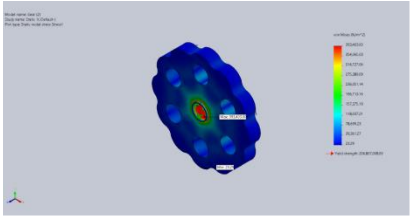


Figure 5 : The calculated max von Mises strength is 393,403 N/mm^2 which is very safe since the yield strength is 206,807,008 N/mm^2.

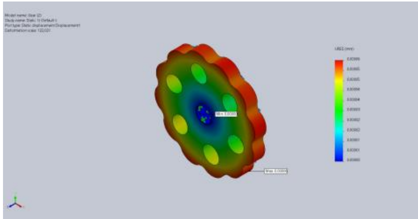


Figure 6: The max deformation achieved is 0.00006 mm

ii. Input Shaft

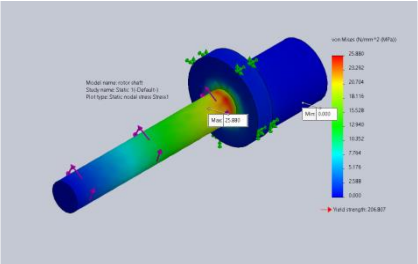


Figure 7: The calculated max von Mises strength is 25.88 N/mm^2 which is very safe since the yield strength is 206,807 N/mm^2.

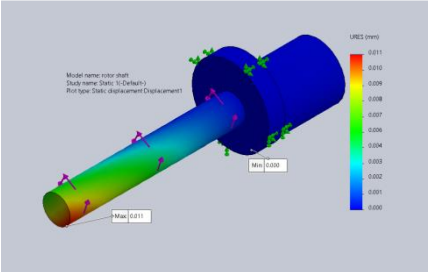


Figure 8: The max deformation achieved is 0.011 mm

iii. Output Shaft

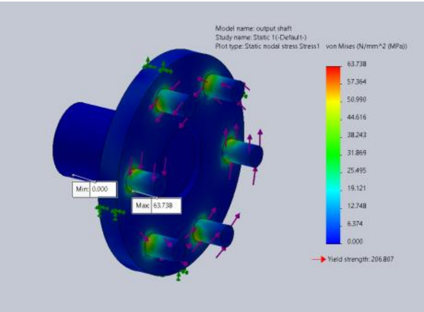


Figure 9: The calculated max von Mises strength is 63.738 N/mm^2 which is very safe since the yield strength is 206,807 N/mm^2.

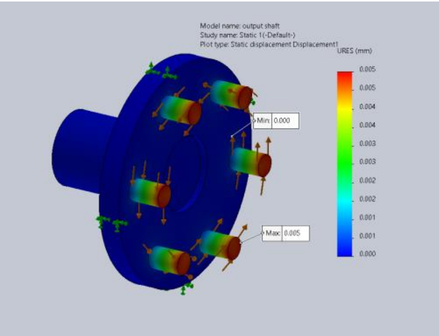
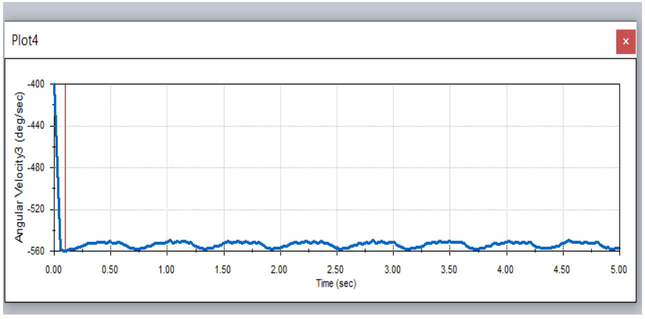


Figure 10: The max deformation achieved is 0.005 mm

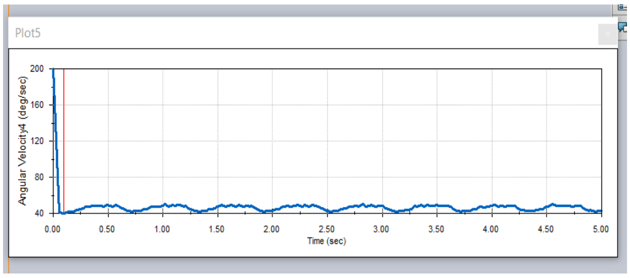
b. Graphs Obtained

i.



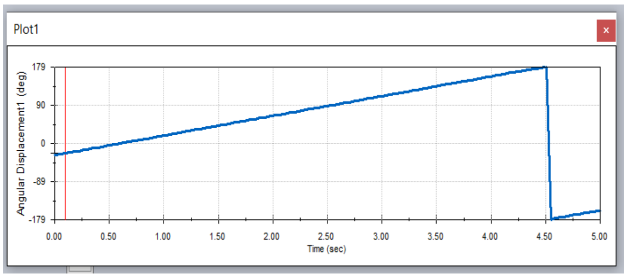
Graph 1 : The graph plotted between input angular velocity v/s time

ii.



Graph 2:The graph plotted between output angular velocity v/s time

iii.



Graph 3: The graph plotted between angular displacement v/s time

VI. Future Scope

- In future the cycloidal Speed reducer can be used in jets, etc.
- It can be used in the gear box where there is huge amount of power generations.
- If possible they can also be used in the automobiles (Race cars).
- And in future, Analysis can be made for higher gear speeds approximately of 8000-12000 rpm.

VII. Conclusion

- Since there are not too many vibrations in the resultant graphs obtained, we can say that the noise/sound caused is very less.
- All the calculated stress are below the yield strength, we can declare that the design is safe and the deformation is also negligible.
- The factory of safety is 3.

The speed is reduced from 570-580 rpm to 40-50 rpm in Single stage and in the second stage, it would be reduced to 10-12 rpm.

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