PERFORMANCE COMPARISON OF WORM GEAR AND BEVEL GEAR MECHANISMS WITH ELBOW MECHANISMS

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ABSTRACT

This study is about a semi – automatic dish washing machine which is cost efficient and also about various mechanisms which help in transmitting power from the source which is motor to the brush through various mechanical objects like shafts bearings etc. The modelling of every object is made using design software and converted the file into STEP file to carry analysis on the 3-D model in Ansys software. The maximum speed of the motor is 1200 RPM but for safety reasons it is considered as 1400 RPM. First the parts are designed using standard calculations and found theoretical dimensional values for each part individually, based on the theoretical values the 3-D models are created in CREO software which is a designing software, the analysis is carried on the model. Three mechanisms are considered to transmit power those are elbow mechanism, worm gear mechanism and bevel gear mechanism. The results obtained in the Ansys software are compared to evaluate which mechanism is correct to make the machine work smoothly.

The present work mainly focused on finding the problem with gear-less transmission. Power transmission for shafts with the help of gears in a machine is complex while designing and manufacturing, power losses may occur due to sliding motion and the shaft orientations is very limited. In this study, the gearless power transmission is designed to transmit power at an angle of 90^0. The system is designed in Creo 8.0 and analysed in Ansys 2022 to check the feasibility of the system. The speed analysis revealed that the speed ratio of the output shaft and input shaft remained 1:1 during the operation. During analysis the deformation has occurred at the corners of the elbow links. During fabrication different problems occurred like accuracy, number of links selected etc., so to make the machine work alternate mechanisms like worm gear and bevel gear mechanism are selected to transmit power at a right angle.

Keywords: - Design of Dishwasher, Elbow Transmission, Bevel Gears, Worm Gears, Power Transmission, Analysis.

INTRODUCTION

1.1 GENERAL

Dishwashing is that the most typically performed task within the world; nevertheless, most families wash dishes by hand, which is physically demanding and chemically damaging. As far as manual process is anxious in houses of India, washing is finished by hand scrubbing which is straining to the muscles through its energy and postural requirements. it's visiting also cause clinical, anatomical disorders and back pain which may affect the operator ‘s health. Many of their household chores are performed by the women and some could also be very physically challenging and time-consuming [1]. So, in several ways within which we are able to improve their lifestyle, and one aspect that we are going to improve on is that the way they wash their dishes. Currently the chore of washing dishes is performed by the women and can be very labour intensive because it's finished for up to several hours hebdomadally. the identical are often experienced in marriage ceremony with caterers [2]. We reside in twenty first century. this can be often the time of automation and is involved in every field like research, production, entertainment, transportation, communication etc. From past 20 years automation in every field is increasing rapidly. Human always tries to cut back his mechanical efforts with the help of mechanical linkages of robots [3]. during this automation home appliances and household working machines have gotten special demand. Washing dishes is most done activity within the globe, in most of family’s people wash dishes by hand which is straining to muscles and detergent is chemically harmful [4].

Washing is completed by hand scrubbing in Indian homes, which puts a strain on the muscles because of the energy and posture demands. In earlier years the many home appliances has invented and were globally accepted [5]. In earlier years the many home appliances has invented and where globally accepted dishwasher is a mechanical device for cleaning eating-utensils and dishes [6]. Dishwashers can be found in private homes and hotels. Unlike manual dish washing machines, which depend largely on physical scrubbing to remove soiling, the mechanical dishwasher cleans by the brush and by spraying water, at the dishes. A mix of water and detergent is circulated. Once the wash is finished, the water is drained. After the rinse cycle finishes and the water is drained, and the dishes are left in the atmosphere for drying [7].

The dishwasher's job is to distribute and direct detergent solution and rinse fluids over, under, and around the dishes to loosen and eliminate grime [8]. When each phase of the cycle, the dishwasher must remove soil-laden fluids from the machine and provide for dish drying after the cleaning process is completed.

GEARLESS TRANSMISSION

Gears are used to accurately convey power in a variety of industries, including aerospace, automobiles, marine, defiance, and industrial applications including as cutting, milling, lifting, and transportation [9].

The fundamental disadvantage of gears is that their power decreases as a result of slippage and other backlashes, resulting in vibrations and increased gear wear. Input and output hubs, as well as elbow links that might be flexible or immovable, make up a gearless transmission [10]. The gearless mechanism is simple to operate; it is designed to replace worm gears, and the hubs are positioned at the proper angle for power transmission. The elbow links are inserted into the holes drilled into the elbow, and when the driving shaft rotates, the elbow links begin to slip into the holes. the elbow links will travel back and forth in the holes provided, and the power will be transmitted without any losses such as backlashes [11].

Shafts are used to convey power in all machines, and there are numerous varieties of transmission systems., such as belts end pulleys, gears, couplings, key tapered bushings. It used to be quite difficult to transfer power between two shafts of different diameters [12]. If belt concerns such as slip, strain, heat accumulation, limited speed, belt power failure factor, and so on are taken into account [13]. A gear is a mechanical component having cuts and teeth that mesh with each other to transmit power. Gear teeth are generally same in shape, and gears can alter speed, torque, and direction. The advantage of gears over belts and pulleys is that there is far less slipping in gears compared to belts and pulleys; slipping occurs only when gears become worn out due to extensive use [14]. A coupling is a sort of power transmission device that joins the ends of two shafts while allowing for some misalignment. A key tapered bushing is a type of transmission component that is typically seen on motors, gearboxes, and shafts. Bores are connected to bushes via shafts [15]. At both ends, the outer and inner diameters can be varied. To prevent sliding and shaft misalignment, two bushes are linked with screws. Flexible or rigid elbow links are bent at needed angles up to 180^o in gearless transmissions [16].

Fig. 1.1 Assembly of Gear Less Transmission

The elbow mechanism is small and lightweight. Our college provides the majority of the materials. The pieces are simple to make at our college shop, and the cost is likewise lower. This project provides us with manufacturing expertise, experience, skill, and fresh ideas. In terms of gear efficiencies, the key aspect of the mechanism is the relatively high efficiency between the input and output power shafts [17]. The main issue with gear transmission is that gear production is a complex process that takes a long time and requires a high level of precision, as well as a high manufacturing cost. Another significant issue is that transmissions with gears create jamming due to backless errors and emit more noise than other drives owing to pitch mismatch. Gearless transmission system is another name for this elbow mechanism [18]. This mechanism is primarily used to replace bevel gears in applications where motion must be transferred at 900 RPM. As a result, the angle between the rods in the elbow mechanism is usually set to 900 degrees. By adjusting the angle of the L-pins or providing a universal joint at the corner, this device can also be utilised to transmit power at varied angles [19]. Any diameter of the driving and driven shafts can be employed with this mechanism.

WORM GEAR

Worm gears are made up of a worm and a gear (also known as a worm wheel) with non-parallel, non-intersecting shafts that are 90 degrees apart. The worm looks like a V-type screw, while the gear looks like a spur gear. The worm is usually the driving component, with the worm's thread moving the gear teeth forward [20]. A worm gear's worm, like a ball screw, can have a single start or many starts, implying that the worm has several threads, or helices. A single-start worm advances the gear by one tooth for every full rotation (360 degrees). As a result, a 24-tooth gear will have a 24:1 gear reduction [21]. As illustrated in

Fig., the gear reduction on a multi-start worm equals the number of teeth on the gear divided by the number of starts on the worm [22].

The worm and worm wheel are utilised in the Winch machine's gear box to lift the sand bucket. The stress on the teeth causes the worm wheel to fail during operation. Stress focus is to blame for the failure. The crack appears in the middle of the tooth's thickness. As a result, the tooth breaks at the thickest point in the middle [23]. The failure of the wheel occurs after around 20 days. As a result, the corporation will have to replace the worm wheel, which would be costly. Worm wheel stress calculations at various tooth thicknesses are a three-dimensional challenge. This work gives a review of stress pattern analysis utilising 3D Photoelasticity techniques and FEA [24].

Fig. 1.2 Assembly of Worm Gear

BEVEL GEAR

Metals and alloys will never be able to meet the demand that is always being developed and expanding as a result of today's market and technological advancements [25]. Combining current materials to replicate and augment metals and alloys will enable us to satisfy the ever-demanding performance needs for a range of applications. Composite materials have risen newly developed material processing technologies have propelled us to the forefront of material technological progress. Due to their most notable benefits, such as high specific strength, high specific modulus, and unique electrical properties, composite materials have received a lot of attention from the technical community and are touted as potential metal substitutes in the nuclear, oil installations, automotive, aircraft and aerospace structural, sports equipment, and transportation industries [26]. Gear pumps, watches, electronics, and washing machines are only a few examples of the many applications for composite transmission gears [27]. Excellent corrosion resistance, a high strength-to-weight ratio, high impact resistance, and design flexibility are only a few of the beneficial characteristics of composites [28]. These qualities make items made of composite materials high-quality, durable, and economical (Mallick, 2007, Deborah, 2010, Autor, 2006, Valery et al., 2007, Denial et al., 2003). Although composite materials may often withstand high impact resistance quite well, their utility in some industrial applications may be constrained by their frequent poor tolerance to low velocity impacts [29]. Although the types of damage that might happen are occasionally hard to see physically, they can significantly affect the materials' structural integrity [30].

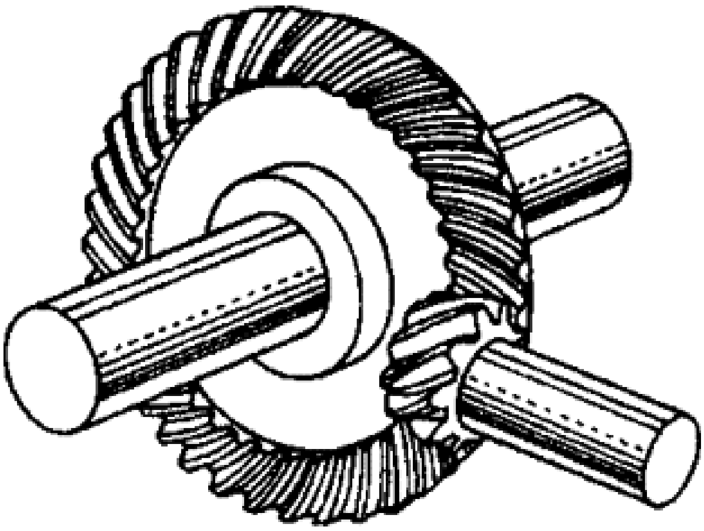

Fig. 1.3 Assembly of Bevel Gear

LITERATURE SURVEY

DISH WASH MACHINE

Evolution of the semi-automatic dishwashing machine is examined in this study. This study outlines the construction and design of semi-automatic dishwashing machines. Between 55 and 75 °C (130 to 170 °F), the plates are routinely cleaned by spraying hot water rather than cold water to loosen the sticky and greasy particles. Clean using a solution of water and detergent, then rinse with clean water to eliminate the detergent residue. The machine was capable of producing 20 plates each minute. The dishwashing machine is well-built and easy to use. The detergent was used in a very diluted quantity and was biodegradable, as a result, less detergent is needed. Semi-automatic dishwashers can save time and effort for both humans and machines. Semi-automatic dishwashing machines with belt drive are preferred because they have a longer life and are more efficient. To clean the item from all sides, a multi-jet system will be used. The machine has the potential to wash 24 dinner sets at once utilising two rotary jets driven by a single pump connected in parallel. The purpose of this project is to design a dishwasher that is both efficient and easy to use. A dishwasher was designed to be used for dishwashing in household kitchens and small restaurants. The tub (washing chamber) is where the washing takes place, and the rack is where the dirty dishes are stored. CREO was used to create detailed design drawings for all of the machine parts. According to the machine's performance analysis, the number of plates washed and the time taken were 20 plates per minute (1 minute), 5 plates per minute, and 5 plates per minute for the machine and manual operation, respectively. The machine can produce 20 plates each minute (1880 per hour). Plates are washed without breaking in the machine.

GEAR LESS TRANSMISSION

The proposed arrangement can be used for any set of diameters with any profile of shafts for skew shafts of any angle, but the shafts must have rotational motion about their own axis, transmission of motion is very smooth and desirable, and it is only used for the equal R.P.M. During the experimental phase, proper joints for revolute pair were created by using pins or specific types of links for the driving and driven shafts. The mechanism may transmit at any angle between 0 and 180 degrees. performed design and analysis of gearless elbow mechanism in Ansys software by varying number of pins. Based on the information from the stimulation, the friction loss will be increased by increasing the number of pins but also makes the product heavy and increases the power transmission efficiency ant various angles. When the right method is followed during fabricating, the friction created is very low, and the cost and design remain simple. The mechanism needs less working area and the operating of the mechanism is simple. power transmission is possible when the driver and driven shafts rotate at the same speed and about the same axil.

Worm Gear

The gears with various pressure angles were modelled using CREO software, and an analysis was performed. ANSYS was used to verify the conclusions provided by the theoretical technique. wear on the wheel tooth components at each position. The procedure of calculating the wear of each location on the wheel tooth surface is repeated in a succession of wear steps. The impact of lubrication is examined in this study. They used photoelasticity to examine the bending strength of helical gear in their work. The experimental results are backed up by finite element simulations. every type of gear, including geometry, gear related parameters, deflections, effect of heat generation, stress concentration, and efficiency.

Bevel Gear

The maximum primary stress responsible for tooth bending failure is lower in face breadths of 12mm compared to 7, 8, 9, 10, and 11mm. The authors discovered that there is a security component that is also agreeable and compatible with the outcomes. discovered that a 12 mm change in face width is sufficient for a safe driving and a long gear life when compared to present gears. examined gears on the basis of consecutively engaging projections known as teeth, gears being direct contact entities that work together to transmit movement and power from one rotary shaft to another, that is almost significant mechanical transmission types in the field of mechanical engineering, it has a variety of types and is widely used, but the effects of gear failure are frequently serious. used loaded contact concert, tooth root bending stress, and tooth contact stress of a couple of gears, all of which are important indexes in the sequential engagement process.

METHODOLOGY

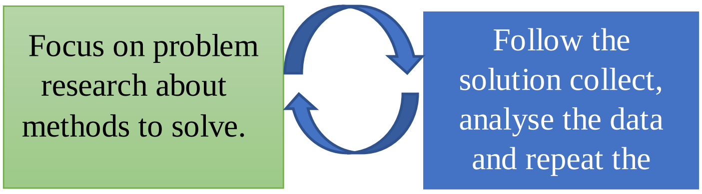

Fig Methodology of the project

This study is elaborated below.

- The first and main step is to find the problem and try to find the solution.
- To make any machine a standard process need to be followed so a geometry needs to be designed and the process parameters need to be found.
- The boundary conditions and initial condition of the parameters should be defined.
- The input and the environment around the geometry need to be defined to get the results accurately.
- The input parameters like friction between the moving parts, clearance etc are to be mentioned.
- During the test the type of materials are to be mentioned to get the accurate results, the temperature of the stimulation environment also plays an important role in the stimulation.
- The stimulation needs to be carried out.
- Monitor the stimulation and check if the stimulation is carrying out in the right way.
- Check the obtained results and note the results to make comparison with next stimulation results.
- Make changes in the design according to the previous obtained results and repeat the process and collect all the results.
- The grid or mesh have to be generated to proceed with the test, which is the process of which are elements and the connecting points of the elements are called nodes.

- Compare the results with the previous results and make changes in the design, this process of changing the design according to the results is called updating or improvement
- Make a documentation on the results comparisons, the process selected, the steps involved to make the design work improve etc

Gearless Transmission

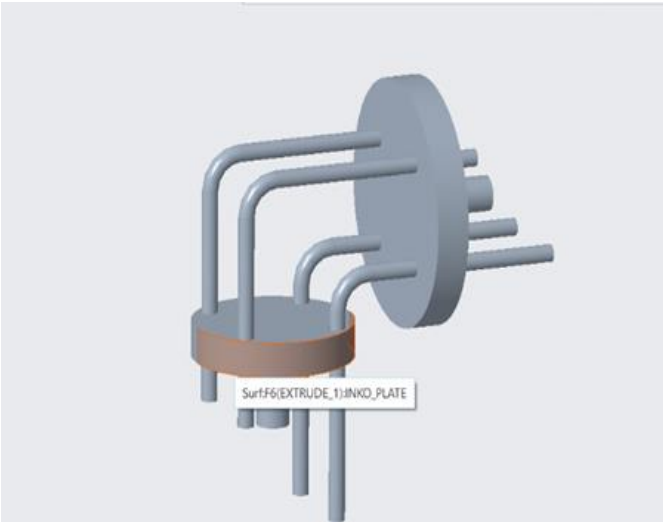

Fig. 3.4 Gear Less Elbow Mechanism

Gear less transmission consists of 3 major components:

Cylinder with holes (cast iron)

- Rods with bend at required angle. 3.4
- Shafts (iron)
- Bearings.

Bearing

This is the machine's most important component. The roller brushes are made to order and to the specifications of the customer. The diameter and length of the overall structure may be changed. Brushes with or without a shaft are available. The number of applications that might be used is enormous.

A hollow hole in the wooden layer connects these stiff brushes to the wooden roller, as seen in Fig. 3.3.

Motor

An electrical machine that transforms direct current electricity into mechanical energy is known as a direct current (DC) motor. The most prevalent forms of forces are generated by magnetic fields. Almost all DC motors contain an electromechanical or electronic mechanism that, on a regular basis, alters the direction of current flow in a component of the motor. A linear motor provides force and motion in a straight line, while the bulk of them generate rotational motion. DC motors were the first to be widely used because they could be powered by existing direct-current lighting power distribution networks. The speed of a DC motor may be varied by changing the supply voltage or the current intensity in the field windings. Small DC motors are used in a variety of applications.

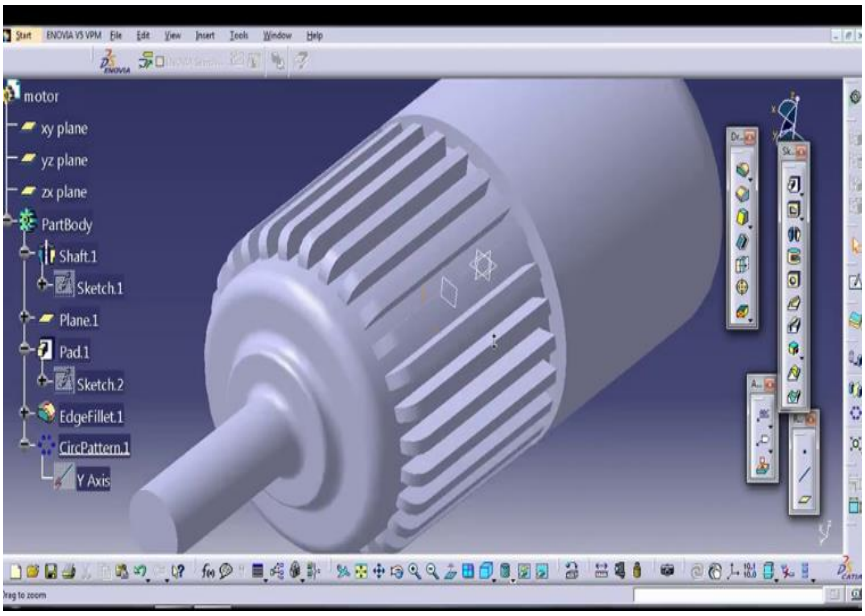

Fig. 3.5 Design of Motor

Shaft

A number of tiny shafts are employed. Abrasive cloths are used to polish mild steel with a diameter of around 20mm. Two 30mm shafts are employed, which are turned and stepped while being held in a center lathe. One end of the steel shaft is connected to the Roller, while the other end is equipped with a brush. It aids in the easy and smooth

Design of Hub

Considering external diameter (D1) is 50mm and internal diameter where holes are placed is 46mm while the thickness of the thickness of the hub is considers as 10mm. The mass of the system in 15kg. Four holes are drilled to the hub to insert the elbow links in the hub the holes are drilled 30mm away from the centre and distance between all holes are 30mm each. The material used to fabricate the hub is stainless.

The total load on the system is P = mg = 147.25 N.

rotation of the roller brush.

Shear stress $\tau = \frac{TP}{J}$

$$J = \frac{\pi}{32}(D^4 - d^4) = 174019.1003$$

$$\tau = \frac{1472.25\ x\ 147.25}{174019.1003} = 1.25 \text{ N-mm}$$

Design of Shaft

The shaft diameter and length are to be assumed as 20mm and 45mm respectively.

The material used while fabricating the mechanism is cast iron

Shear stress $\tau = \frac{TP}{J}$

$$J = \frac{\pi}{32}(D^4 - d^4) = 15707.9632 \text{ mm}^4$$

τ = 13.80 N mm

Design of elbow links

The elbows' diameter and length are supposed to be 12 mm. The mechanism is constructed out of cast iron. This device makes use of four elbow links. Each of the elbow links is bent at a 90° angle. The length of the elbow from the bend to each angle is 75mm.

The sectional modulus (Z) = 0.78 x R^3 = 168.48 kg/mm^3

Bending Stress σ = PL/4Z = 41.17 N/mm^2

CALCULATIONS OF WORM GEAR

The worm wheel is made of Phosphor Bronze PB2.Some important parameters of existing worm gear are

$$\frac{z_1}{z_2} \times \frac{q}{m} = \frac{1}{60} \times \frac{12.18}{2.82}$$

Pitch Circle Diameter (Wheel) 168.84 mm

Pitch Circle Diameter (Worm) 34.36 mm

Pressure Angle 20°

Max. Torque Transmitted 33157.27 N.mm

Considering

N = rpm = 1440 rpm

Power = 12 kw

N = speed range = 60

Efficiency = 82%

1. selection of material

Material is bronze for better strength sliding velocity of bronze when sliding velocity is considering is considered as 3m/s is

Bending stress of bronze considering sand chill

$$\sigma_b = 900\, kg/mm^2 \text{ (Rotation in both directions)}$$

$$\sigma_{ultimate} > 39 kg/mm^2$$

2. minimum centre distance

From data book

A = centre distance

$$a = \left(\frac{z}{q} + 1\right) \sqrt{\left(\frac{540}{\frac{z}{q}(\sigma_c)}\right)^2 (M_t)}$$

$\sigma_c = \ design\ surface\ stress$

$$(diameterfactorinfiallychoose)\ q = \frac{d}{m_x}$$

$$m_x \Rightarrow axid\ module\ moment\ (mm)$$

$$i = \frac{z}{Z}(or)\frac{n}{N}$$

$$i = \frac{1440}{60} = 24 \qquad \left(i = \frac{z}{Z}\right)$$

Assuming number of starts in the worm wheel as '3'

$$\therefore\ z = i \times Z$$

$$z = 24 \times 3 = 72$$

$$\{M_t\} = M_t . K . kd$$

$$k_d = dynamic\ load\ factor$$

$$M_t = 71628 \times \frac{hp}{n} i\,\Omega \Rightarrow 97420 \frac{kw}{n}\ i\,\Omega$$

$$M_t = 97420 \times \frac{12\ i\Omega}{1440} \Rightarrow 97420 \times \frac{12 \times 24 \times 0.82}{1440}$$

$$M_t = 15{,}976.88\ kgf/cm$$

3. calculation of and module

$$M_a = 1.24 \sqrt[3]{\frac{\{M_t\}}{Z_q[\sigma_b]}} \Rightarrow 1.24 \sqrt[3]{\frac{15976.88}{3 \times 11 \times 5 \times \sqrt{900}}} = 1.832$$

$$for\ Z_v = \frac{Z}{\cos^3 \delta} \Rightarrow \frac{72}{\cos^3 15.25} = 80.174$$

$$\tan \delta = \frac{Z}{q} = \tan^{-1}\left(\frac{3}{11}\right) \Rightarrow 15.25 = \delta$$

4. calculation of corrected centre disc

From data book

$$a = 0.5 m_x (q + z + 2x)$$

$$x = 0 (addendum\ modification\ if\ not\ considered)$$

$$a = 0.5 \times 1.832(11 + 72 + 0 = 0.5 \times 1(11 + 72 \times 2 \times 0) \Rightarrow a = 41.5$$

To keep the design a = 41.5 should be considered because M_r mass value for worm gear should not exceed

5. sliding velocity

$$v_{s=} \frac{v_1}{\cos \delta}; v_1 = \frac{\pi\ d_1 n}{60}$$

$$d_1 = q m_x \Rightarrow 11 \times 1 = 11cm$$

$$v_1 = \frac{\pi \times 11 \times 1440}{60} = 8.29 m/s$$

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$$v_s = \frac{8.29}{\cos 1525} = 8.59 m/s$$

6. calculation of face width(b)

$Z = 3, from\ data\ book$

$$b = 0.75d, = 0.75 \times 11 = 8.25cm$$

7. length of worm

For Z = 3 and X = 0

$$L \geq (12.5 + 0.09Z)m_x$$

$$L = (12.5 + 0.09 \times 3) \times 1 = 12.77\text{cm}$$

$$\text{Allowance } M_x = 10\ to\ 16\ by\ 35\ to\ 40\ cm$$

$$\text{L} = 12.77 + 0.4 = 13.77cm$$

8. checking of induced stress

$$\sigma_c = \frac{540}{\left(\frac{Z}{q}\right)} \sqrt{\left(\frac{\frac{Z}{q} + 1}{a}\right)^3 \{M_t\}}$$

$$\sigma_c = \frac{540}{\left(\frac{72}{11}\right)} \sqrt{\left(\frac{\frac{72}{11} + 1}{41.5}\right)^3} \times (15976.18) = 808.43$$

$$\sigma_b = \frac{1.9\{M_t\}}{M_x q Z\ {}^1/_2} = \frac{1.9 \times 15976.18}{1 \times 11 \times 72 \times 0.499} = 76.80 kgf/cm^2$$

$$\therefore\ design\ is\ safe$$

9. heat generated and dissipated

$$H_g = (1 - \Omega) \times power = (1 - 0.82) \times 12 \times 10^3 = 2160\ watts$$

$$h_d = h_{cr} \Delta t A$$

$$2160 = 10 \times 40^0 \propto A$$

$$A = 5.4m^2$$

10. efficiency

$$\Omega = \frac{\tan\delta}{\tan(\delta + \rho)} = \frac{\tan(15.25)}{\tan(15.25 + 1.14)} = 0.92 \Rightarrow 92\%$$

CALUCATIONS OF BEVEL GEAR

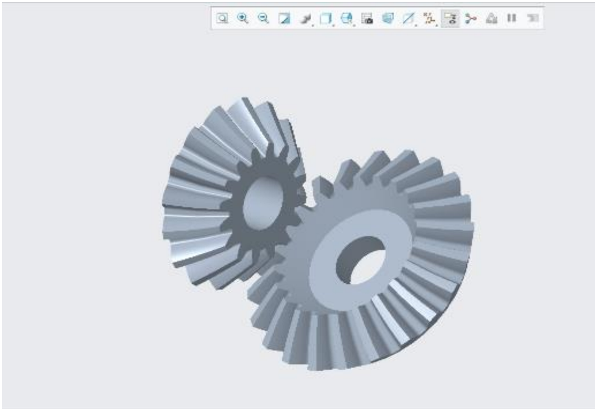

Fig. 3.8 Design of Bevel Gear

1) selection of material says C_{45} steel

Power = 12 Kw

Speed (N) = 1440 rpm

Gear ratio = 3(assumption)

2) life of gear will be between

10,000 − 25000 hrs

Selecting 20,000 hrs

3) young's modulus

E = 2.1 x $10^5\ N/mm^2$

calculation of centre distance (or) cone distance

For bevel gear

$$\text{Cone distance R} \geq \psi y\sqrt{i^2+1 \times \sqrt[3]{\left(\frac{0.72}{(\Psi y-0.5)}\right)^2 \times \frac{E(Mt)}{i}}}$$

young modulus for $C_{45}\ steel\ E = 2.16 \times 10^6\ kgf/cm^2$

$$\frac{core\ distance}{force\ width} = \frac{R}{b} = 3\ (from\ both)$$

When i= $1 to\ 4$

$\sigma_c = 7400.28\ kgf/cm^2$

$$\text{R}= 3.\sqrt{3^2+1}\sqrt[3]{\left(\frac{0.72}{(3-0.5)\times 7400.25}\right)^2 \times \frac{2.16\times 10^6 \times 659.61}{3}}$$

$$= 8.5cm\ (minimum\ cone\ distance)$$

Calculation of minimum module

$$\text{Transverse module } m_t \Rightarrow R = 0.5 m_t Z_1 \sqrt{i^2+1}$$

$$8500 = 0.5 \times mt \times 20 \times \sqrt{3^2+1}$$

$$\text{Assumed } (z = 18\ to\ 28\ number\ of\ teeth\ on\ pinior)$$

$$m_t = \frac{8500}{0.5 \times 20 \times \sqrt{3^2+1}} = 0.268 = 2.6mm$$

From data book standard module for safety is $m_t = 4\ mm$

$$\sigma_B = \frac{1.4}{n} \times \frac{kbl}{k_\sigma} \times \sigma$$

$$\sigma = 0.25(\sigma_u + \sigma_y) + 500\, kgf/cm^2$$

$$\sigma_u = 63.71\, kgf/cm^2$$

$$\sigma_y = 36\, kgf/cm^2$$

$$\therefore \sigma = o.25(7000 + 3600) + 500 = 3150\, kgf/cm^2$$

$$\text{For } C45\ steel\ factor\ of\ safety = 2.5(n)$$

Addendum modification

$$\text{Steel } k_\sigma = 1.5$$

$$k_{bl} = 1(for\ N > 10^7)$$

$$\sigma_B = \frac{1.4\ hbl}{2.5 \times 1.5} \times \sigma$$

$$= \frac{1.4 \times 1}{2.5 \times 1.5} \times 3150 = 1176\ kgf/cm^2$$

Calculation of average module (m_{av})

$$m_{av} = m_m - \left[m_t - \frac{b\ \sin\delta_1}{z_1}\right]$$

$$Mean \Big/ average\ module\ , m_m = m_t - \frac{b}{z_1}\sin\delta$$

$$\text{From } \frac{R}{b} = \psi y$$

$$b = 4.216$$

$$\tan\delta_2 = 30$$

$$\delta_1 + \delta_2 = 90$$

$$\tan\delta_2 = i = 3 \Rightarrow \delta_2 = \tan^{-1}(3) = 71.56^0$$

$$\delta_1 = 90 - \delta_2 - 90.71.56 = 18.43^0$$

$$m_m = \left[m_t - \frac{b}{z_1}\sin\delta\right]$$

$$= \left(0.4 - \frac{4.216}{20} \times \sin 18.43^0\right)$$

M= 0.333cm ⇒3.33mm

4) corrupted cone distance

$$R = 0.5\, m_t z\sqrt{i^2 + 1}$$

$$= 0.5 \times 0.4 \times 20\sqrt{10}$$

$$= 12.649 > (R_{min})$$

While introducing any product some minimum calculations are must and they have some parameters likewise in this project we are going to uses the bevel gears, worm and elbow transmission. For bevel gear there are two methods one is Hertz and Belayev equations, another Lewies and Buckingham equations to design a bevel gear. Bevel gear calculations are done using Hertz and Belayev equations. Some of the values are straightly taken from the data book. Worm gear project design calculations is also done using Hertz and Belayev equations.

RESULTS AND DISCUSSION

5.1 GEARLESS TRANSMISSION

To verify the working performance of the mechanism, it is analysed in Ansys Workbench 2022 software. The input is given as 30 units and the rotation speed is at 1^o rotation per 1 sec. The input and output speed ratio are 1:1. The graph shows the output from the virtual motor makes the shaft to rotate and the time and angle of rotation. Results obtained on the system in Ansys software is plotted on graphs i.e., time vs displacement and time vs stress. The image of place where maximum deformation is occurring and the stress at the elbow bend.

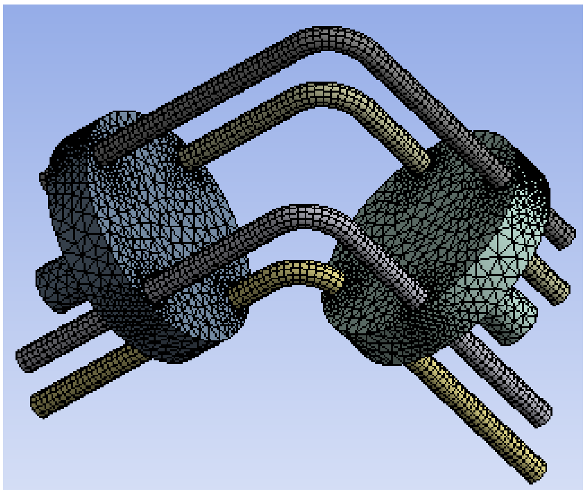

Fig. 5.1 Meshing of Gear Less Transmission

The meshing is the process of dividing the hole geometry into small pieces which are in triangle shape is shown in the Fig. 5.1. The meshing process is carried on using default settings which has a growth rate of 1.5 and maximum element size of 96.435mm. it is allowed to have very fine mesh at the joints and at the corners, the elbows have uniform mesh throughout the surface and the area at the holes and around the holes the mesh is generated very finely. The number of elements in this mesh is 43346 and nodes are 99693, nodes are the connecting points between the mesh elements.

The red line indicates maximum permissible stress that can be shown in system. which is in straight line and it is max power is applied on the work piece and blue line indicates the point no deformation acquired in that range which is shown in inclined line. Green line indicates allowable permissible stress. It is also shown in inclined line here some load is applied on the work piece.

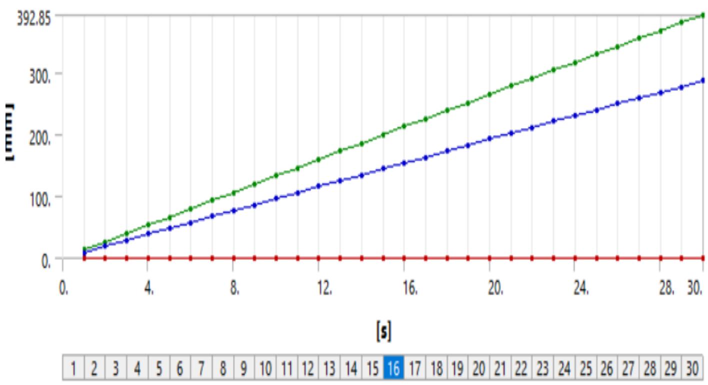

Fig. 5.2 Time and Displacement Graph of Input and Output Shafts.

The time displacement graphs are shown in the Fig. 5.2 it is indicating the moment of the shaft that is rotating at the speed of 1 degree per one second.

The red line indicates maximum permissible stress that can be shown in system. which is in straight line and it is max power is applied on the work piece and blue line indicates the point no deformation acquired in that range which is shown in straight line same like red line no load is applied on work piece. Green line indicates allowable permissible stress. It is also shown in inclined line here some load is applied on the work piece.

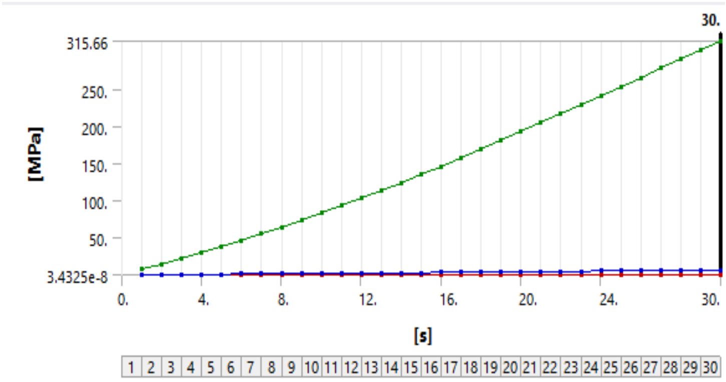

Fig. 5.3 Obtained Stress in Shafts with Respect to The Time and Angle of Rotation.

The above shows the graph of the stress induced while the mechanism is rotating with respective to time as shown in Fig. 5.3.

In equivalent stress blue colour is indicates more which is 7.2938 and more load is applied on the 1 and 3 rod of 90 angles on that angle rod may be applied maximum permissible stress and allowable permissible stress it is 315.66 max. and after 30 angle rods may be breaks.

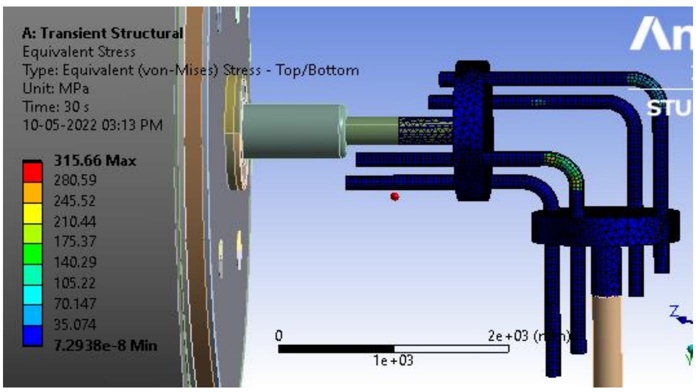

Fig. 5.4 Equivalent Stress of The System

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The equivalent stress is the maximum stress at the yield point, in Ansys the test is carried out by calculating stress values on every element and dividing them into 9 counter plots which indicate maximum and minimum stress elements on the element the blue plot indicates least or minimum stress on the element and the red indicates maximum stress on the body as shown in the Fig. 5.4.

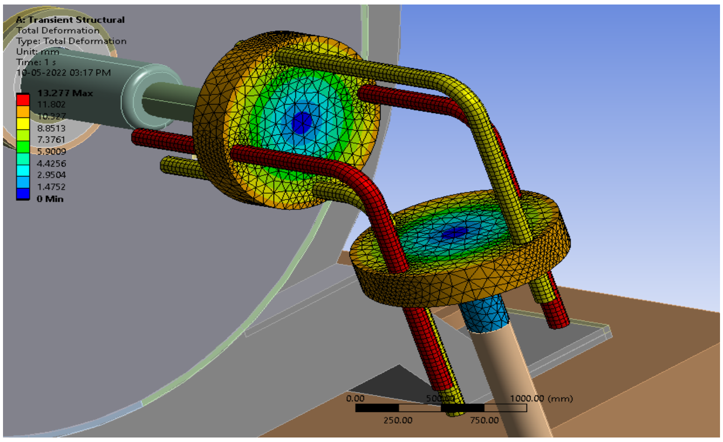

Fig. 5.5 Deformation Analysis on The System

The states the deformation analysis and the stress induced in the parts of the mechanism when the operation is stimulated as shown in Fig. 5.5.

In total deformation same like equivalent stress loads are applied on the work piece. But max permissible stress is applied on the 1 and 3 rod and yellow and green colour indicates the allowable permissible stress. It is applied on 2 and 4 rod which is 10.42 and max is 13.272 as shown in the graph.

It is observed that maximum deformation occurs when the pins are at the $43^{o} – 47^{o}$ and at opposite side of the system. Due to the reciprocating motion more vibrations are generated during the operation. The system in safe under the conditions. The stress which is bending in nature is being developed in the elbow links and the value of the stresses developed will vary with the rotational speed of the shaft. It is observed that the hub remains constant and safe throughout the operation and the elbow links will deform with time.

From the present study the results obtained are:

1) The design is safe, no speed losses occur while transmitting the power from input to output shaft.
2) When the same design is takes into consideration and applied in the real-world conditions the product failed.
3) More noise is produced when compared to another transmission devices.

4) Jamming and lack of moment occur if the elbow links used are less than 3.

5) Increase in number of elbow links will make the mechanism smoother.

6) The elbow link surface needs to be very smooth to reduce friction and vibrations in the mechanism, this will also help in increasing the life span of the mechanism

7) The pins must be odd in number for smooth and correct operation.

8) The material used to make elbow joints is stainless steel mostly.

9) The design of the system is easy but every wrong step in the system will show a big impact while fabricating the product.

10) Alternate mechanisms need to be preferred at least where the losses are negligible like.

5.2 BEVEL GEAR

Bevel gear is designed in Creo and imported as STEP file into Ansys to carry stress and deformation test. The surfaces are given some thickness to convert the surface body into solid body and the thickness of the surface is given as 0.5m.

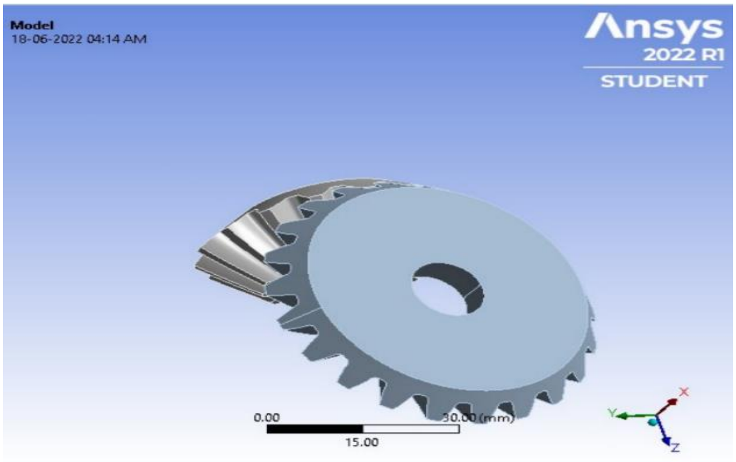

Fig. 5.6 Bevel Gear After Importing into Ansys

The motor and other bodies are hidden to make the analysis easy as it takes more time to mesh and analyse every part. The co-ordinate system is kept unchanged, unlike remaining systems global coordinate system is used where X-axis data is [1,0.0], Y- axis co-ordinates are [0,1,0] and Z-axis coordinates are [0,0,1]. During the setup process the default tolerance is used that is 0.2mm between moving parts, the material considered is structural steel in the Ansys software. The environment temperature is kept as 22^{o} throughout the process as shown in Fig. 5.6.

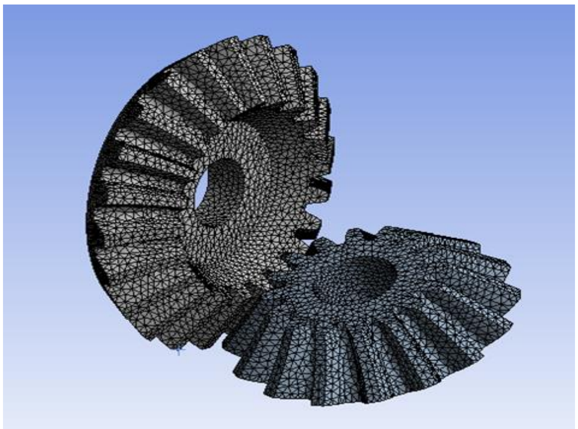

Fig. 5.7 Meshing on Bevel Gear

The meshing is the process of dividing the hole geometry into small pieces which are in triangle shape. The meshing process is carried on using default settings which has a growth rate of 1.5 and maximum element size of 52.05mm. it is allowed to have very fine mesh at the joints and at the corners, the elbows have uniform mesh throughout the surface and the area at the holes and around the holes the mesh is generated very finely. The number of elements in this mesh is 37002 and nodes are 8370, nodes are the connecting points between the mesh elements as shown in Fig. 5.7.

The state of the connection is fully defined, the type of connection is detected automatically by the software which is Trajectory. The bodies are considered as frictionless bodies to avoid complications

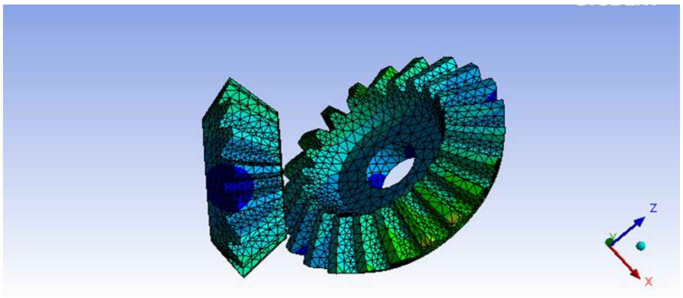

Fig. 5.8 Total Deformation of Bevel Gear

The gears are set to rotate freely around its axis, one of the gears is allowed to rotate at the speed of one degree per second. After the analysis the maximum deformation is displayed as 31.137mm as shown in Fig. 5.8.

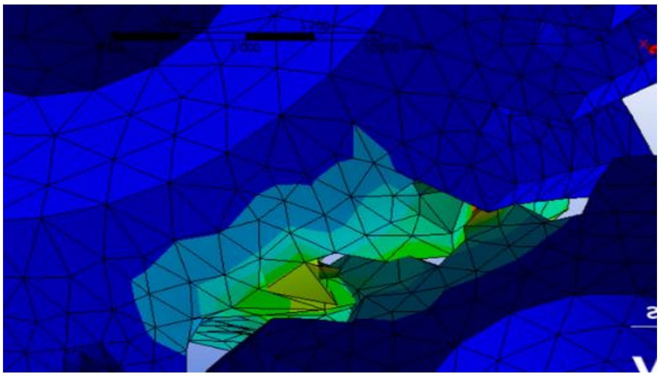

Fig. 5.9 Stress Induced in The System

The equivalent stress is the maximum stress at the yield point, in Ansys the test is carried out by calculating stress values on every element and dividing them into 9 counter plots which indicate maximum and minimum stress elements on the element the blue plot indicates least or minimum stress on the element and the red indicates maximum stress on the body. The maximum stress that can be induced into the system is 746.60Mpa as shown in Fig. 5.9.

5.3 WORM GEAR

Worm gear is designed in Creo and imported as STEP file into Ansys to carry stress and deformation test. The surfaces are given some thickness to convert the surface body into solid body and the thickness of the surface is given as 0.5m. The motor and other bodies are hidden to make the analysis easy as it takes more time to mesh and analyse every part. The co-ordinate system is kept unchanged, unlike remaining systems global coordinate system is used where X-axis data is [1,0.0], Y- axis co-ordinates are [0,1,0] and Z-axis coordinates are [0,0,1]. During the setup process the default tolerance is used that is 0.2mm between moving parts, the material considered is structural steel in the Ansys software. The environment temperature is kept as 22^{o} throughout the process as shown in Fig. 5.10.

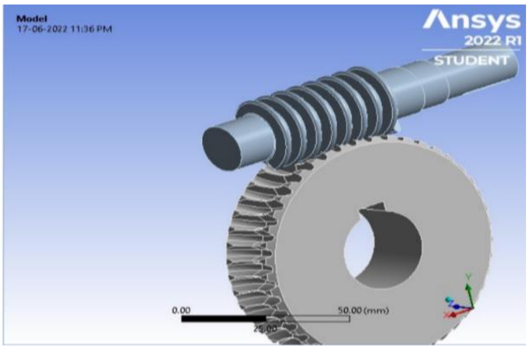

Fig. 5.10 Worm Gear After Importing into Ansys

The meshing is the process of dividing the hole geometry into small pieces which are in triangle shape. The meshing process is carried on using default settings which have a growth rate of 1.5 and maximum element size of 52.05mm. it is allowed to have very fine mesh at the joints and at the corners, the elbows have uniform mesh throughout the surface and the area at the holes and around the holes the mesh is generated very finely. The number of elements in this mesh is 74115 and nodes are 123800, nodes are the connecting points between the mesh elements as shown in Fig. 5.11.

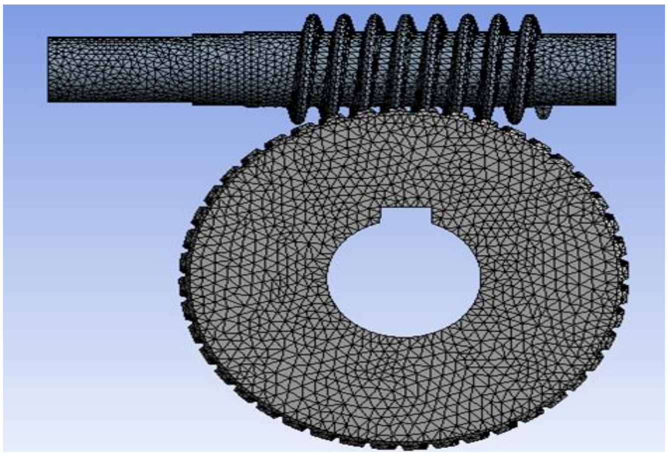

Fig. 5.11 Mesh on Bevel Gear

The state of the connection is fully defined, the type of connection is detected automatically by the software which is Trajectory. The bodies are considered as frictionless bodies to avoid complications

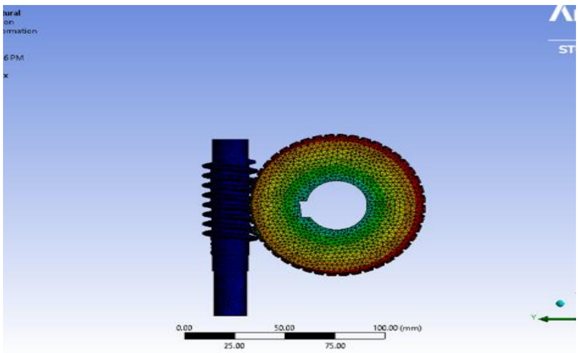

Fig. 5.12 Total Deformation of Bevel Gear

The gears are set to rotate freely around its axis, one of the gears is allowed to rotate at the speed of one degree per second. After the analysis the maximum deformation is displayed as 2.798mm as shown in Fig. 5.12.

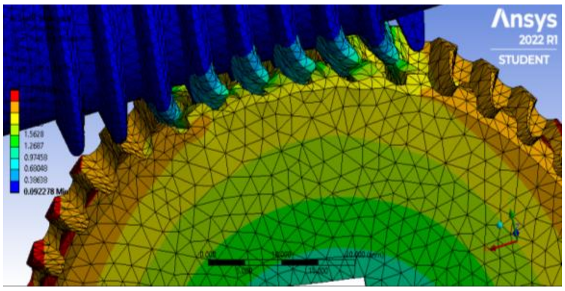

Fig. 5.13 Stress Induced in The System

The equivalent stress is the maximum stress at the yield point, in Ansys the test is carried out by calculating stress values on every element and dividing them into 9 counter plots which indicate maximum and minimum stress elements on the element the blue plot indicates least or minimum stress on the element and the red indicates maximum stress on the body. The maximum stress that can be induced into the system is 1149.4Mpa as shown in the Fig. 5.13.

CONCLUSION

The gear less transmission system is very helpful, efficient, maximum efficiency of gear less transmission can be up to 90% - 91%, but when it come to the real world there are some problems with the system. The elbow links need to be very smooth, the friction between the pins and the hub need to be very minimum and the alignment must be very accurate between the hub holes, diameter of the hub holes and number of pins selected, distance between the two hubs, bearing that support the shafts, surface roughness of the pins, diameter of the pins, the angle at which the pins are placed. In the fabrication of the model, it is not possible to fabricate with that accuracy to the metal that we selected which is stainless steel. In order to machine stainless steel special tool are required to process hard material. After fabricating the model due to the low accuracy, the gearless transmission model has been called off and when started looking for alternatives, we selected bevel gear mechanism and worm gear mechanism to transmit power at right angles. After analysis the worm gear transmits more power when compared to bevel and gearless mechanism. The worm gear mechanism can work under the maximum stress up to 1149.4Mpa, the bevel gear mechanism can work under the maximum stress of 746.6Mpa whereas the elbow mechanism can work only under the stress of 315.6Mpa. The deformation in

the elbow mechanism is more when compared to worm and bevel gear mechanism, the maximum deformation in elbow mechanism is 39.2mm whereas it is 2.18mm in worm gear and 3.92mm in worm gear mechanism. When stress and deformation values are considered elbow mechanism is not the greatest choice. It is concluded that if tools and machines are available which are possible to machine accurately, it is wise in choosing elbow mechanism which transmits power with 1:1 input and output ratio only if the machinery availability is of high accuracy and the machines available can process those materials and the stress induced in the system is low. The gears are available in different sizes these days. So, finding gears of different sizes are easy and fabrication is accurate. This makes the whole process easy. A right gear is selected to transmit power which can reduce overall loss during power transmission.

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