Design And Analysis Of Dedicated Fixture With Chain Conveyor Arrangement For Multistage Special Purpose Machine

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ABSTRACT

It is required to fix typical shape engine components on conveyor while performing cleaning operation. In conveyorised multistage washing machine, to fix these typical shape components is very difficult. Hence these components need dedicated fixturing with poke-yoke to avoid accidents inside the zone on conveyor. This project gives feasible solution on conventional roller chain conveyorised arrangement with dedicated moving fixture with conveyor for the tractor components like rear axle career, bull gear and shaft of a tractor model. This arrangement will be widely used for numerous cleaning purposes owing to its effectiveness for high production volume, reliable and durable performance.

Keywords: Dedicated fixture, chain conveyor, automation, process simulation.

1. Introduction

1.1 Project background

For automobile industry it's very difficult job to clean the engine component in the assembly line before assembly of the engine to obtain the required Millipore value. Hence in automotive, aviation, auto ancillaries and other industries automated washing machines are highly demanded to save the time, man power and to improve washing and drying quality.

The conventionally using conveyor in production line is worldwide known, but in special purpose machine conveyors are needed with special design and parameter for its operational feasibility. In this automated moving fixture arrangement fixturing parameters like V pads, vertical rods, mounting pads, etc. moves along with chain roller conveyor and reach at multiple station with stop and go operation with given speed by gear box.

Speed can be control by VFD (Variable Frequency Drive) gear box motor is used in the system, selected by considering required speed as per the production rate and number of components to be operated in machine per shift.

1.2 Problem statement

In an industry, it is required to clean engine component rear axle career, bull gear, and shaft of tractor engine in assembly line. It is very difficult to fix and clean these components on conveyor. Hence automated washing machine with fixture on conveyor is highly needed. Hence dedicated fixture for these components and chain conveyor to reach these components at various workstations is designed.

1.3 System legends

The travelling of components from one station to another should be operation oriented. Following important legends are considered to design planning the system as objectives.

i) To design fixture for auto moving components (Rear axle career, Bull gear and shaft).
ii) To design chain and sprocket arrangement with proper guiding rollers.
iii) To calculate required torque, pulling load, speed
iv) To mount fixture on conveyor by considering movability on forward and return side of conveyor.
v) To select the sensors.
vi) To select the material
vii) To select the mechanical components like bearing, bushes, keys, circlips, etc.

2 Literature review

2.1 Fixture

Fixtures are important in both traditional manufacturing and modern flexible manufacturing system (FMS), which directly affect machining quality, productivity and cost of products. The time spent on designing and fabrication fixtures significantly contributes to the production cycle in improving current product and developing new products.

Therefore, great attention has been paid to study of fixturing in manufacturing (Thomas and Ghadhi, 1986)[8].

2.1.1 Dedicated Fixture

Since dedicated fixtures are commonly used in mass production, dedicated fixtures design are usually applied the fixture construction is perfectly designed for specific operation. As part of machining tooling, the application of dedicated fixture has greatly contributed to the development of automated manufacturing system. Therefore dedicated fixture designs are specially designed for each specific operation, with special consideration of fixture structure, auxiliary support, and other operational properties. Moreover, the operations can be conducted quickly and the tolerance requirement can easily assured in the operation. The problem involving in dedicated fixture application includes the flexibility and long lead time required to designed and fabricate the fixture. When product design change like the shape and the size changes he dedicated fixture are usually not longer useful and scrapped. Today a flexible fixture is desired to a certain extent in order to design variations of the products (Taufif Bin Zakaria, 2008)[2]..

2.1.2 Fixture Design Methods:

Jeng and Gill (1997) formulated a fixture design problem in hierarchical design structure. Mervyn et al. (2003) presented an internet-enabled fixture design system by the use of XML file format. Rios et al. (2005) and Alarcon et al. (2010) developed and presented KBE (knowledge based engineering) application for, modular fixture design. Hunter et al. (2006) presented a functional design approach in which the functional requirements and constraints are considered as an input to the fixture design process. Wang and Rong (2008) and Sun and Chen (2007) presented the case based reasoning method to provide a computer aided fixture design solution. Perremans (1996) developed an expert system for automatic fixture design **2.2 Chain Conveyor**

A chain conveyor is a type of conveyor system for moving material through production lines. Chain conveyors utilize a powered continuous chain arrangement, carrying a series of single pendants. The chain arrangement is driven by a motor, and the material suspended on the pendants is conveyed. Chain conveyors are primarily used to transport heavy unit loads, e.g. pallets, grid boxes, and industrial containers. These conveyors can be single or double chain strand in configuration. The load is positioned on the chains; the friction pulls the load forward. Many industry sectors use chain conveyor technology in their production lines. The automotive industry commonly uses chain conveyor systems to convey car parts through paint plants. Chain conveyors also have widespread use in the white and brown goods, metal finishing and distribution industries. Chain conveyors are also used in the painting and coating industry, this allows for easier paint application. The products are attached to an above head chain conveyor, keeping products off of the floor allows for higher productivity levels.[4]

2.2.1 Roller chain

Flexure joints in roller chain contain pins that pivot inside the roller bushings. The pins are usually press fitted into the pin link plates, and roller bushings are press fitted into roller link plates, as shown in figure1.The ANSI standard for single pitch roller chain is B29. A free-turning roller encircles each bushing to provide rolling engagement and contact with sprocket teeth. The distance between flexing joints in roller chain is the pitch, which is the basic designation for different chain sizes. Larger pitch indicates larger links with higher load ratings. Although a small pitch chain carries fewer loads, it offers smoother, quieter operation than a chain of larger pitch (Power transmission design)[5]. Figure 3.2 shows the schematic of roller chain.

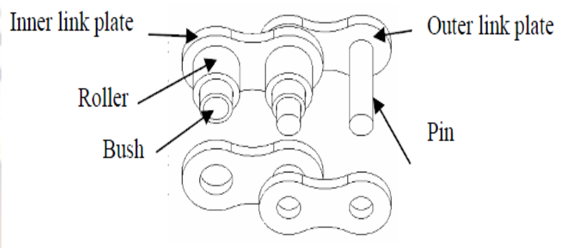


Fig.3.1 Schematic of roller chain link (Shoji Naguchi, et.al, 2009)[10]

3. Design of Fixture

3.1 Fixture Design Criteria

The following design criteria must be observed during the procedure of fixture design:

- Design specifications
- Factory standards
- Ease of use and safety
- Economy

3.2 Fixture locating principle

One of the principal purposes of a fixture is to locate the work piece surfaces for performing a different operation. This is usually done with respect to a number of factors to be considered such as the reference datum, supporting Surfaces, features those are likely to obstruct the tool movement or access direction, etc. In general, the following Surfaces should be distinguished:

Active surfaces

These are surfaces to be machined, ***i.e.*** surfaces which are subjected to the action of cutting tools.

Supporting and locating surfaces

These are surfaces by means of which the work piece is to be located with respect to set-to-size cutting tools.

Clamping surfaces

Clamping surfaces are subjected to the clamping forces for obtaining invariant location. Clamping surfaces are usually not finish-machined surfaces as clamping marks could damage the finish.

Datum surfaces

Datum surfaces are reference surfaces where the dimensions are to be maintained and measured.

Free surfaces

Free surfaces are surfaces not involved in the set-up for the particular operation. (An advance treatise on fixture design)[7]

3.3 Clamping Principles

3.3.1 Basic Principles of Clamping

3.3.3.1 Orientation of Locators vis-a-vis Clamping Force

It is necessary in all clamping devices that the clamping forces hold the workpiece in its located position and should not cause any positional displacement or excessive distortion under the action of the clamping forces. Clamping forces should be directed towards supporting and locating elements on overhanging or thin sections of the workpiece. In addition, the force should be transmitted to the rigid sections of the body frame of the fixture. Cylindrical workpieces located in V-blocks can be clamped using another Vblock, making a 4-point clamping, or clamped in a 3-jaw chuck, in a 3-point clamping configuration. The latter is usually more common, especially in turning operations.

3.3.3.2 Effect of External Forces on the Clamping Action

Clamping elements can be classified in accordance with their force-deflection characteristics. There are two broad sub-divisions, viz.:

Type I: clamping elements in which the elastic deformation increases with clamping force, such as screws, levers, cams, etc.,

Type II: clamping elements in which the clamping force assumes a constant value independent of the elastic deformation at the contact surfaces such as fixtures operated with hydraulic or pneumatic pressures.

Within the elastic region, clamping elements based on elastic deformation, i.e.Type I clamps, would exhibit a linearly increasing clamping force in proportion to the deformation of the clamping element, if the workpiece or the locator is assumed to be rigid. If the workpiece or locator deforms, it will cause a relaxation of the clamping element and the clamping force will decrease. A limiting case arises when the clamping is lost and the force becomes zero.In Type I1 clamps, the clamping force remains constant at pre-set values and isindependent of workpiece and locator deformation. This type of clamping device istherefore more reliable and would not relax over time.

3.4 Restrictions on the Degrees of Freedom of a Workpiece

A workpiece, just like any free solid body, has twelve degrees of freedom.

- Six rectilinear displacements along the mutually orthogonal co-ordinate axes (+X, -X, +Y, -Y, +Z, -Z)
- Six angular displacements with respect to the same axes
  - Clockwise around X axis (CROT-X)
  - Anticlockwise around X axis (ACROT-X)
  - Clockwise around Y axis (CROT-Y)
  - Anticlockwise around Y axis (ACROT-Y)
  - Clockwise around Z axis (CROT-Z)
  - Anticlockwise around Z axis (ACROT-Z)

During a set-up, it is necessary to restrict certain degrees of freedom so as to locate and orient the active surfaces with respect to the cutting tools. Since supporting or restricting surfaces may vary from the true geometrical shape, especially on rough-machined surfaces or cast blanks, it is desirable that the workpiece be located with respect to the point supports.

It's Important to restrict all the twelve degrees of freedom except the three transitional degrees of freedom (-X, -Y and -Z) in order to locate the work piece in the fixture. So, nine degrees of freedom of the work piece need to be restricted.

By using the 3-2-1 method as shown below:

Rest the work piece on three non-collinear points of the bottom surface (XY), and then we will be able to restrict the +Z,CROT-X, ACROT-X, CROT-Y and ACROT-Y degrees of freedom. Now, rest the work piece at two points of side surface (XZ), and you will be able to restrict the +Y and ACROT-Z degrees of freedom. Now, rest the work piece at one point of the adjacent surface (YZ), and you will be able to restrict the +X and CROT-Z degrees of freedom.

So, we can successfully restrict nine required degrees of freedom by using the 3-2-1 principle of fixture design.

3.5 Design and Development of Fixture

3.5.1 Fixture design for Rear Axle Carrier

The rear axle carrier of tractor for which fixture element is to be designed is as shown in figure 3.2.

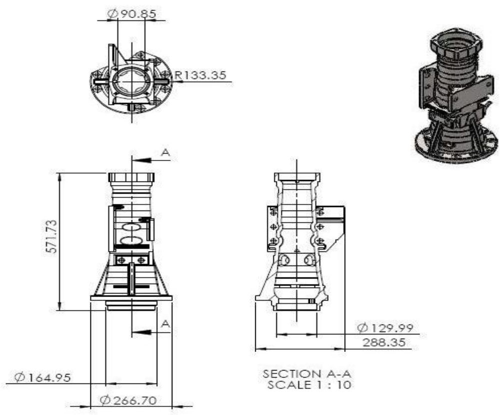


Fig. 3.2 Rear axle Carrier

Dedicated fixture component for the rear axle carrier consist of two pairs of resting pads. The pads are mounted vertically. Pad's height is considered by the operation oriented inputs so that further processes should not affect by fixturing and locating the component, since uniformity is to be considered for all components in process of the machine. The resting pads are as shown in figure 3.3.

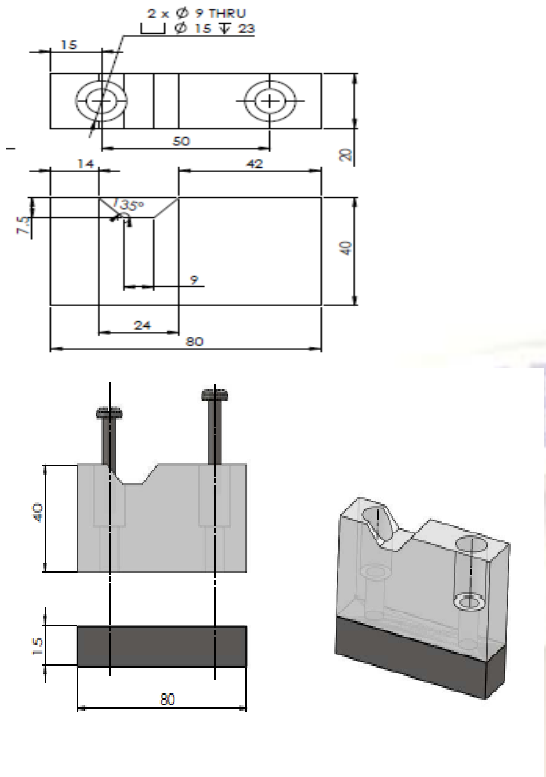


Fig 3.3. UHMW Resting pad

The fixture element to locate the rear axle carrier is designed by considering the shape and size of the rear axle carrier, as shown in figure 3.4

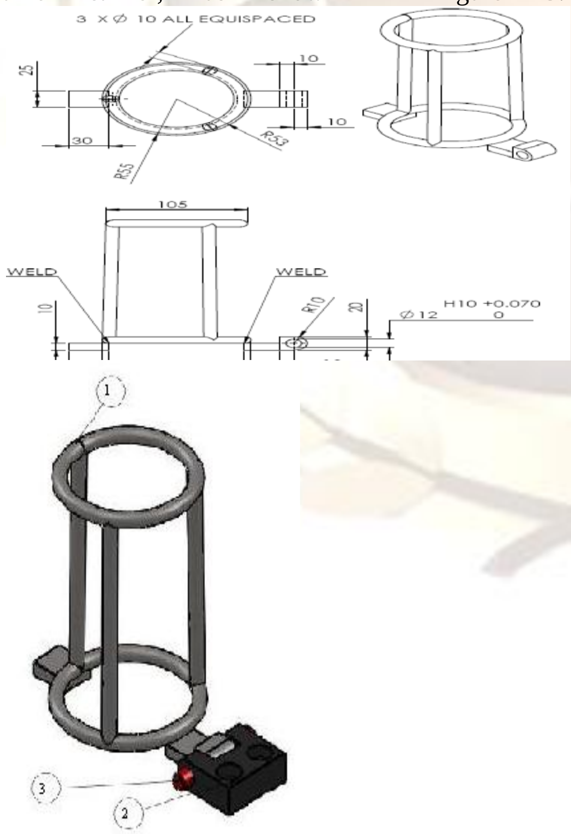


Fig 3.4 . Fixture element for Rear axle carrier

(1) Locating ring, (2) Hinge block, (3) Hinge pin

Above designed fixture elements to hold the rear axle carrier, are then mounted on holding plates which are fixed on the chain, as shown in figure 3.5.

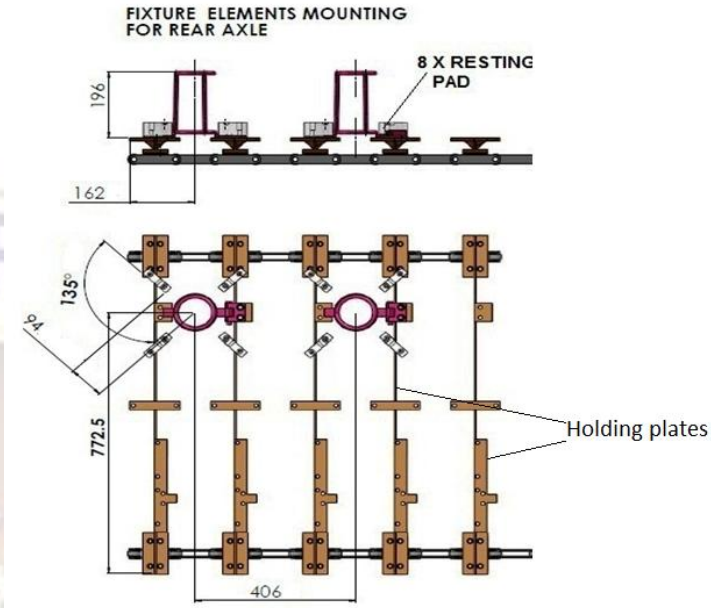


Fig 3.5. Mounting of fixture elements on mounting plates

While executing the cleaning operation on respective workstations, the component, rear axle carrier will be hold by designed fixture as shown in figure 3.6.

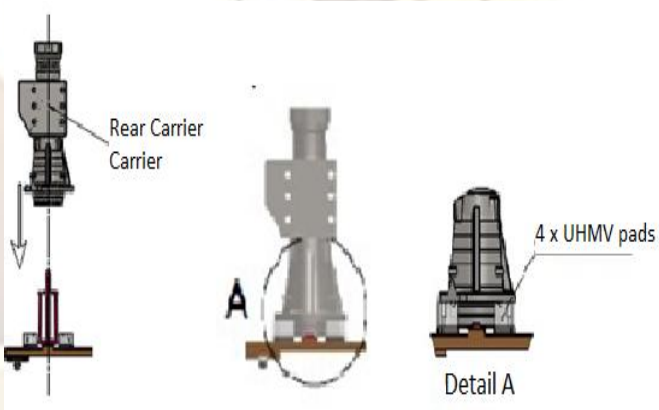


Fig 3.6. Holding of rear axle carrier on fixture elements

3.5.2 Fixture design for Rear Axle Shaft

The rear axle shaft of a tractor engine for which a holding device i.e. fixture element is to be designed, is as shown in figure 3.7.

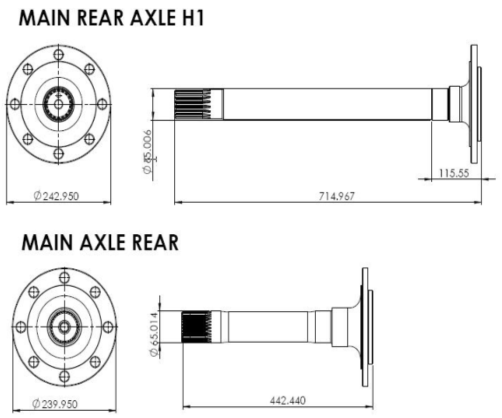


Fig 3.7. Rear Axle Shaft of Tractor Engine

Dedicated fixture component for the rear axle carrier consist of two V rods of different height. The V rods are selected to minimize the area of contact between rod and shaft. The rods are mounted vertically on holding plates. V-rod's height is considered by the operation oriented inputs so that further processes should not affect by fixturing and locating the component, since uniformity is to be considered for all components in process of the machine. The V rods (V rod – 1 and V rod – 2) are as shown in figure 3.8.

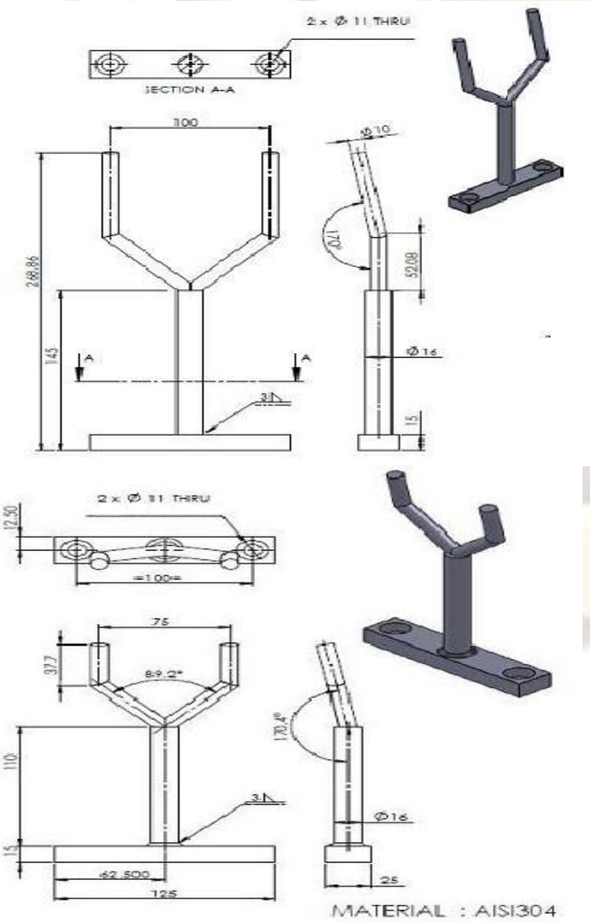


Fig.3.8. Fixture elements for holding Rear Axle Shaft (i) V Rod – 1 , (ii) V Rod – 2.

Material of V Rod 1 and V Rod 2 is AISI 304.

Quantity required in one fixture set –

V rod – 1 = 2 Nos.

V rod – 2 = 2 Nos.

Maximum weight of –

V rod – 1 = 0.70 kg

V rod – 2 = 0.5 kg

The mounting of V rod – 1 and V rod – 2 on holding plates and also the holding of shaft on the designed fixture elements is as shown in figure 3.9 and figure 3.10. The fixture elements i.e. V rods are fixed on the holding plate by the means of M10 head socket head cap screw (15 mm).

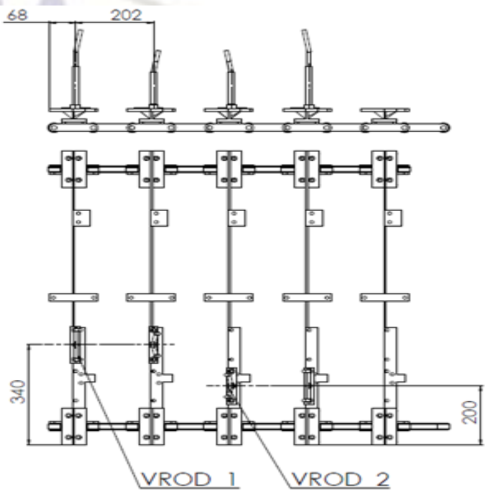


Fig. 3.9 Mounting of fixture elements on holding plates

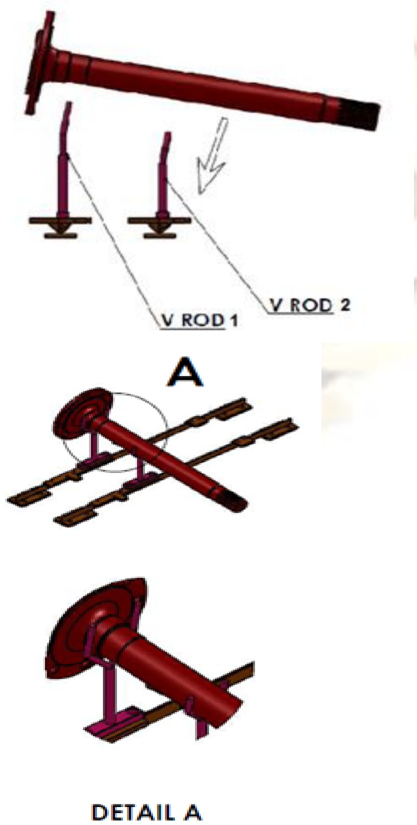


Fig. 3.10 Mounting of rear axle shaft on fixture elements.

3.5.3 Fixture Design for Bull Gear

Bull gear of the tractor engine to be hold to clean before going to assembly section, is as shown in figure 3.11.

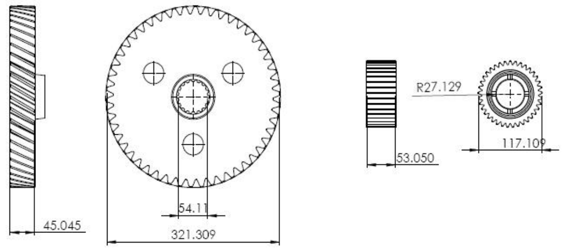


Fig 3.11 Bull gears

By considering the geometry of the bull gears, a fixture element, to hold the gears while performing the cleaning operations in assembly line to avoide accidents in conveyor zone, is designed and drafted as follows.

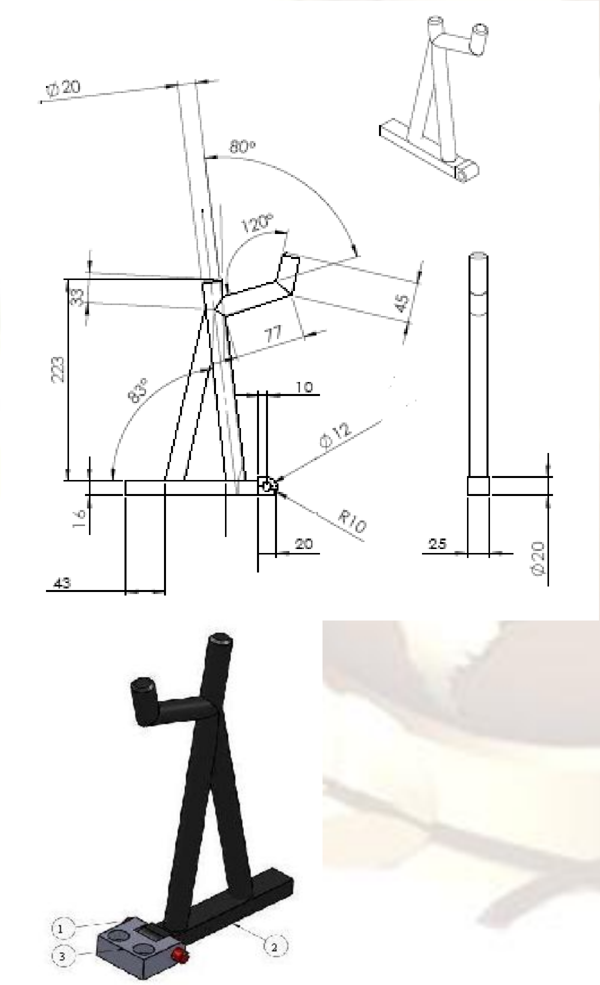


Fig 3.12 Fixture element to hold Bull gear of tractor

(1) Hinge pin, (2) Fixture element rods, (3) Hinge block.

The designed fixture element is fixed on the holding plates. The bull gears will be held by this fixture element so as to avoide movements of gears while performing the cleaning of gears, to avoid accidents inside the conveyor zone.

As seen above, the different fixture elemnts for rear axle carrier, rear axle shaft and bull gears are designed by considering the geometry of these components. The details of these fixture elements are as given below.

- Material of fixture elements (except resting pads) is AISI 304.
- Quantity required for one fixture set –
  - UHMW resting pads = 08 nos.
  - Fixture elements for rear Axle Carrier = 02 nos.
  - V rod – 1 (for rear axle shaft) = 02 nos.
  - V rod – 3 (for rear axle shaft) = 02 nos.
  - Fixture elements for bull gears = 02 nos.

These designed fixture elements should move with chain conveyor. Hence its needed to mount these fixture elements on chain conveyor. To mount these fixture elements on chain conveyor, a holding plate is designed by considering the geometry and location of fixture elements on chain conveyor. The holding plate is as shown in figure 3.13.

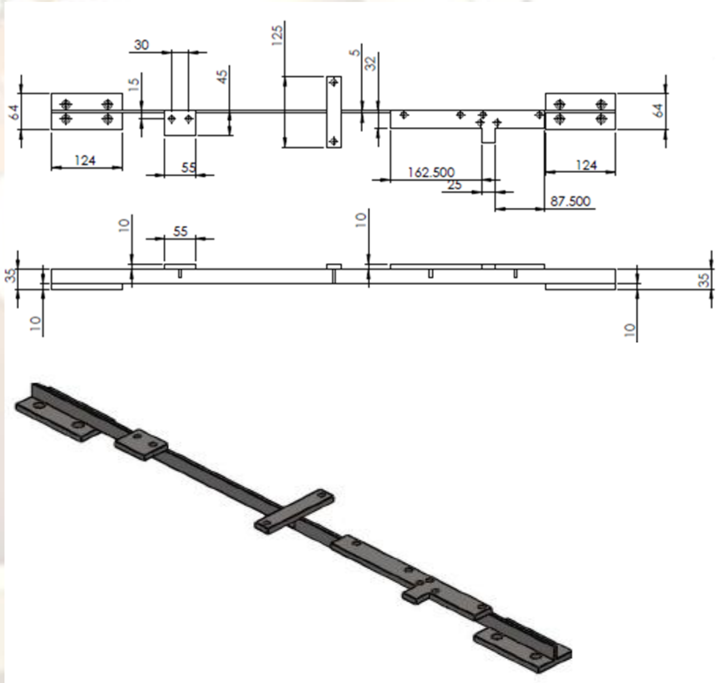


Fig. 3.13 Detailed View of Fixture elements holding plate

For one fixture tray, five numbers of holding plates are required. They are fixed on chain to make a fixture tray, as shown in figure 3.14. The holding plates are mounted on chain conveyor by means of M8 head socket head cap screw (15 mm). Total 8 numbers of screws are required to mount one holding plate.

Details of holding plate:

Material = AISI 304

Total number per fixture set = 05 nos.

Weight = 3.3 kg

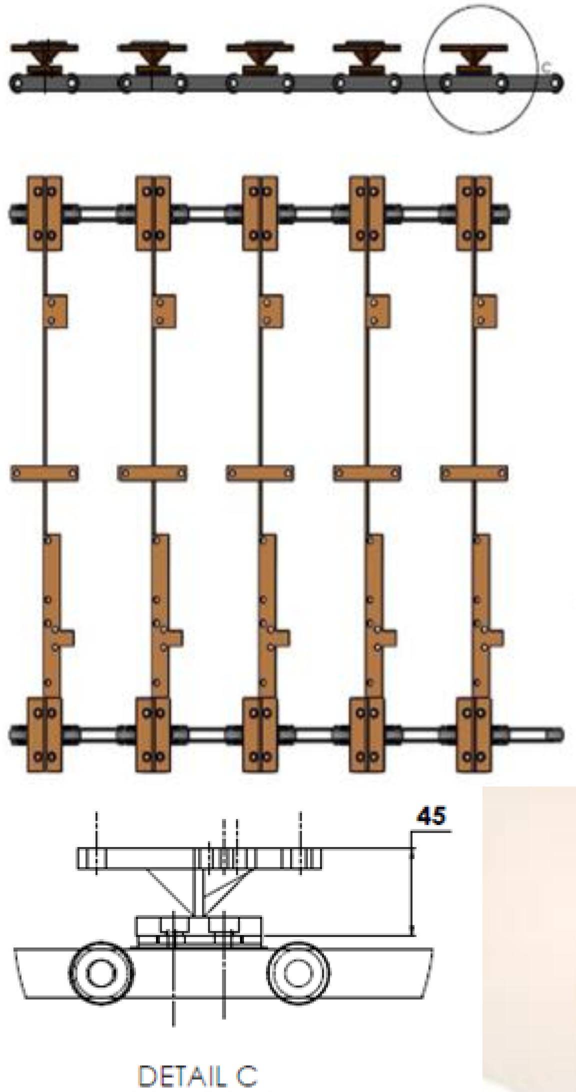


Fig. 3.14 Mounting of fixture elements holding plates on chain conveyor

4. Analysis of Fixture

The static analysis of the designed fixture elements has been done using analysis software "Ansys -V11".

4.1 Static analysis of resting pad

The resting pads, on which the rear axle carrier is to be mounted analysed to find the stresses and strains developed due to load of component. The shear stress developed in the resting pad is as shown in figure 4.1.

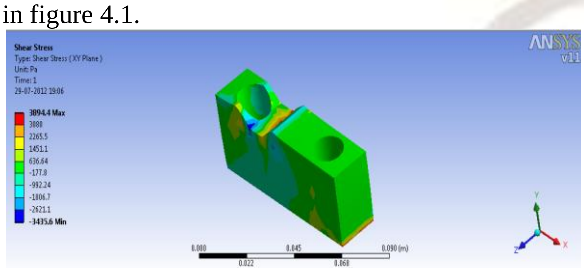


Fig. 4.1 Shear stress developed in resting pad

From the above figure, it is clear that the minimum shear stress developed in resting pad is - 3.4356 Mpa and it can be maximum upto 3.8944 Mpa.

4.2.1 Shear strain

Shear strain developed in the resting pad is as shown in figure 4.2.

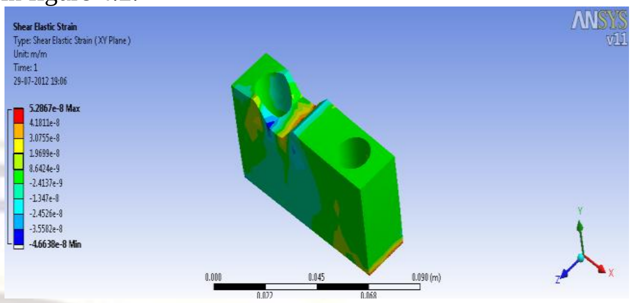


Fig. 4.2 Shear strain developed in resting pad

It can be seen that, the shear strain developed in the resting pad due to weight of the rear axle carrier ranges from 5.2861 * 10^{-8} max to -4.6638 * 10^{-8}.

4.1.2 Equivalent shear stress and equivalent shear strain

Figure 4.3 shows the equivalent shear stress developed in resting pad. It is seen that the maximum equivalent shear stress value is 12.56 Mpa. The maximum value of equivalent shear stress can be reduced by providing fillet to the edge where the maximum equivalent stress is developed. The value of equivalent shear strain developed ranges from 0.3822 Mpa to 12.5635 Mpa.

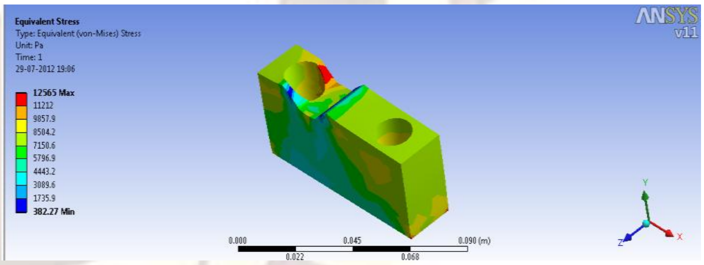


Fig. 4.3 Equivalent stress developed in resting pad

Similarly, the figure 4.4 shows the equivalent elastic strain developed in resting. It ranges from 1.9807 * 10^{-9} to 6.5105 * 10^{-8}.

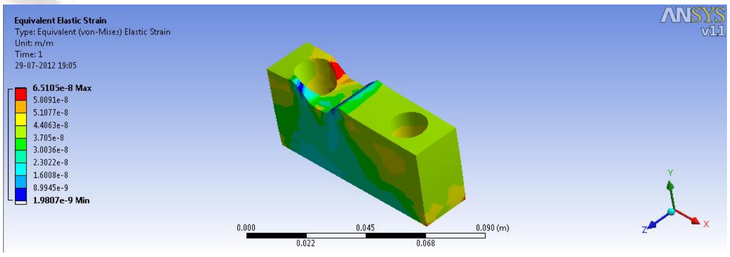


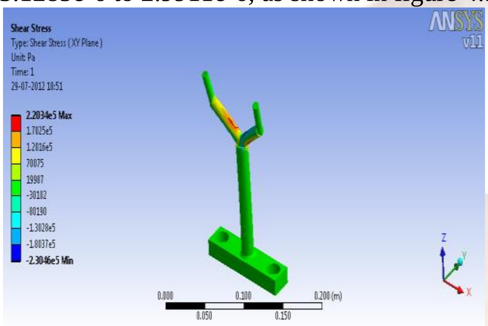
Fig. 4.4 Equivalent elastic strain inresting pad

The values of stress and strains developed in the resting pad are summarised as follows.

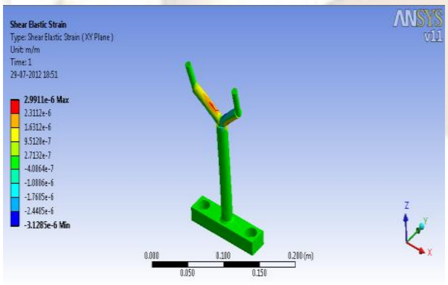
Object Name	***Equivalent Elastic Strain***	***Equivalent Stress***	***Shear Elastic Strain***	***Shear Stress***
Minimum	1.9807e-009 m/m	382.27 Pa	-4.6638e-008 m/m	-3435.6 Pa
Maximum	6.5105e-008 m/m	12565 Pa	5.2867e-008 m/m	3894.4 Pa

4.3 Satic analysis of V rod

A ststic analysis is carried out on the fixture element for shaft i.e. V rod. It is found that the value of shear stress ranges from -2.304e5 Pa to 2.2034e5 Pa And the value of shear strain rnages from -3.1285e-6 to 2.9911e-6, as shown in figure 4.5.



(I)Shehear stress



(ii) Shear Strain

Fig. 4.5 Shear stress and Shear Strain developed in Vrod

The equivalent stress and strain distribution in the V rod is as shown in figure 4.6. And figure 4.7 respectively.

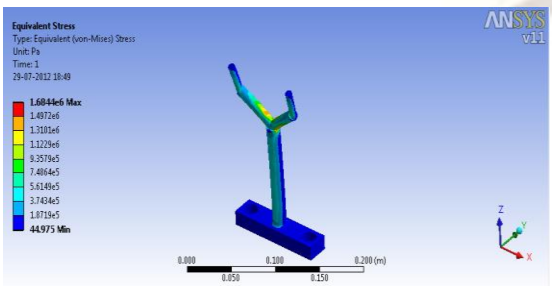


Fig. 4.6 Equivalent stress developed in V rod

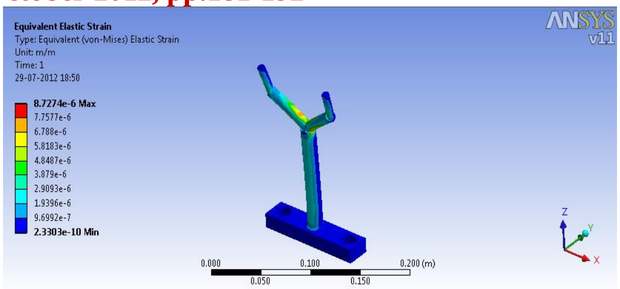


Fig. 4.7 Equivalent strain in V rod

The results of static analysis of V rod are summarised as follows.

Object Name	Equivalent Stress	Equivalent Elastic Strain	Shear Elastic Strain	Shear Stress
Minimum	44.975 Pa	2.3303e-010 m/m	-3.1285e-006 m/m	-2.3046e+005 Pa
Maximum	1.6844e+006 Pa	8.7274e-006 m/m	2.9911e-006 m/m	2.2034e+005 Pa

4.4 Static analysis of Gear Fixture elements

The analysis is carried on the gear holding fixture element. The equivalent stresses developed in the element is as shown in figure 4.8.

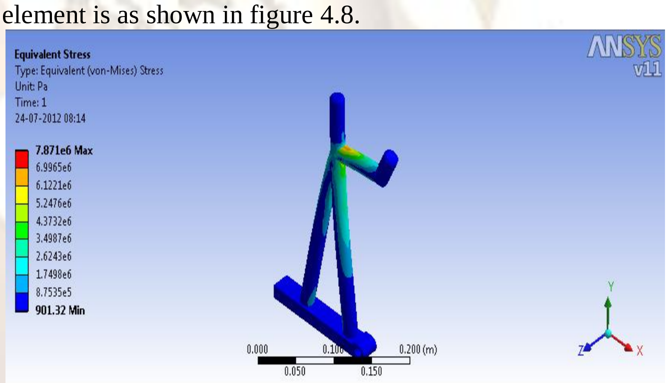


Fig. 4.8 Equivalent stress developed in gear fixture rod

Similarly, the dirstbution of equivalent strain is as shown in figre 4.9.

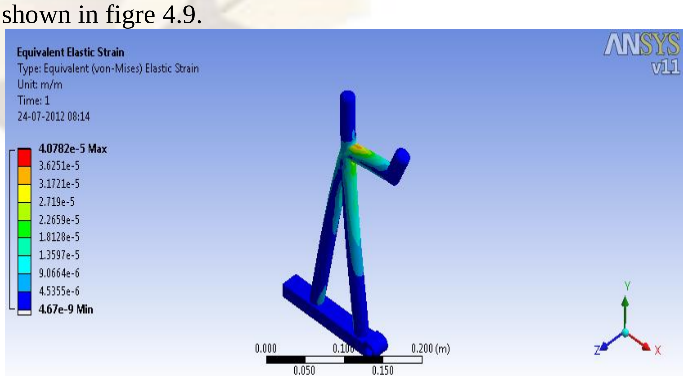
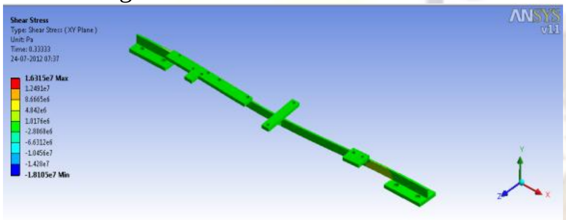


Fig.4.9 Equivalent strain distrubution in gear fixture.

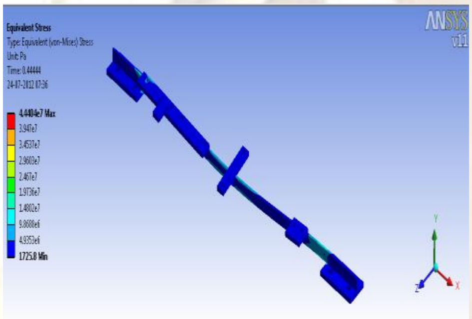
The result of analysis of gear fixture rod is summarised as follows.

Object Name	*Equivalent Stress*	*Shear Stress*	*Equivalent Elastic Strain*	*Total Deformation*
Minimum	901.32 Pa	-3.6142e+006 Pa	4.67e-009 m/m	0. m

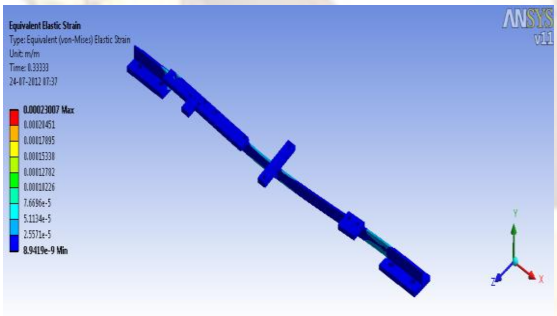
The fixture are mounted on a holding plate. The holding plate is analysed to find out the validation of the plate. The shear stress, Equivalent stress, equivalent strain and deformation of the plate is as shown in figure 4.10.



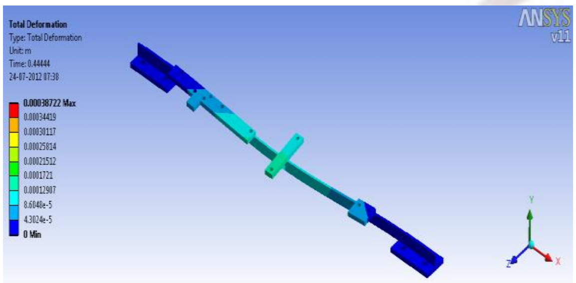
(i) Shear stress developed in holding plate



(II)Equivalent Stress



(iii) Equivalent Strain



(iv)Total deformation

Fig. 4.10 Static analysis result of Holding plate.

The result of analysis of holding plate are as follows.

Object Name	*Equivalent Stress*	*Shear Stress*	*Equivalent Elastic Strain*	*Shear Elastic Strain*	*Total Deformation*
Minimum	1725.8 Pa	-1.8105e+007 Pa	8.9419e-009 m/m	-2.4577e-004 m/m	0. m
Maximum	4.4404e+007 Pa	1.6315e+007 Pa	2.3007e-004 m/m	2.2148e-004 m/m	3.8722e-004 m

5. Design of chain conveyor

5.1 Design Calculations of Chain Conveyor

5.1.1 Weight of the components

Table 5.1: Weight of the components to be carried

Sr. No.	**Comp.**	**Wt./ Comp. (kg)**	**No. of Comp / Fixture tray**	**Total Wt. of Comp (kg)**
1	Rear Axle Career	26.4	2	52.8
2	Shaft	22.6	2	45.2
3	Bull Gear	7.8	2	15.6
	TOTAL		**6**	**113.6**

Total weight of components on one fixture tray = 113.6 kg

Maximum number of fixture tray on conveyor at a time = 06

Total weight of component at a time on conveyor = 113.6 x 6 = 681.6 kg ~ 700 kg.

5.1.2 Weight of fixture elements and other components on chain conveyor

- Weight of fixture for Rear axle carrier = 1.05 * 2 = 2.10 kg.
- Weight of fixture for shaft
  V rod 1 = 0.71 * 2 = 1.42 kg
  V rod 2 = 0.72 * 2 = 1.44 kg
- Weight of Gear holding fixture = 0.97 * 2 = 1.94 kg
- Weight of fixture elements holding plate = 3.3 kg.
  Total number of holding plates on 1 fixture tray = 5
  Weight of total holding plates = 3.3 * 5 = 17.5 kg

Hence,
Total weight of one fixture tray = 24.4 kg
Total number of fixture tray = 6
Weight of fixture tray = 24.4 * 6 = 146.4 kg
Hence,

- Total weight of fixture elements and other components = 681.6 + 146.4 = 828 ˜ 830 kg.

5.2 Selection of chain

From the catalogue of ANSI roller chain, Chain no. 64B-1 is selected. The specification of the chain are as follows.

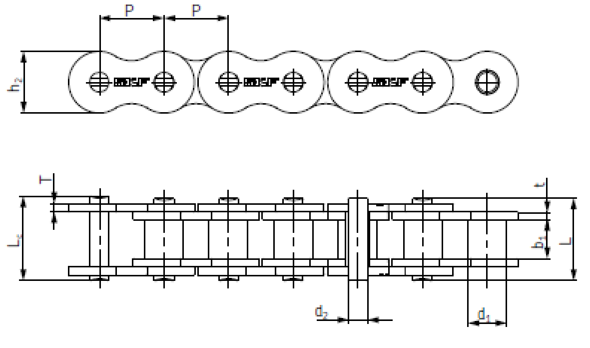


Fig 5.1. Schematic of roller Chain

Chani No. 64B -1
Pitch of the chain (P) = 101.6 mm
Roller diameter, d_1 (max) = 63.5 mm
Width between inner plates, b_1 (min) = 60.96
Pin diameter, d_2 (max) = 39.40 mm
Pin length, L (max) = 130.00 mm
Inner plate height, h_2 (max) = 90.17 mm
Plate thickness, t (max) = 15.00 mm
Weight per meter = 6.5 kg/m

Other input parameter Parameters
Chain speed (v) = 4 m/min
Select number of teeth on sprocket (z) = 13

5.3 Analytical calculations of Chain Conveyor

- **Pitch circle diameter of sprocket**

$$PCD = \frac{P}{\sin\left(\frac{\pi}{z}\right)}$$

PCD of sprocket (D_p) = 425 mm = 0.425 m.

Sprocket outside diameter (D_o) = D_p + 0.8 d
Where, d = Roller diameter
$d = \frac{5}{8} \times \text{Pitch} = \frac{5}{8} \times 101.6 = 63.5$ mm
Do = 425 + (0.8 × 63.5) = 475.8 mm
Inner width i.e. minimum distance between roller link plate = $\frac{5}{8} \times \text{Pitch}$
= 63.5 mm

$$\text{Pin diameter} = \frac{5}{16} \times \text{Pitc}$$

= 31.75 mm
Thickness of link plate = $\frac{1}{8} \times \text{Pitch}$
$= \frac{1}{8} \times 101.6$
= 12.7 mm
Centre distance ≤ 80 × pitch
Hence,
Maximum centre distance = 80 × 101.6
= 8128 mm
= 8.128 m
But due to the space availability, let us consider centre distance (C) = 5000 mm = 5 m.

Length of chain

$$L = 2C + \frac{N1 + N2}{2} + \left(\frac{N1 - N2}{4\pi^2 C}\right)^2$$

Where,
C = Centre distance = 5000 mm
N1 = Number of teeth on driven sprocket = 13
N2 = Number of teeth on driving sprocket = 13
Hence,
Length of chain = 23 m.

Weight of the chain
For the selected chain number 64B - 1, weight of the chain is 6.5 kg/m
Hence, Weight of the chain = 6.5 × 23
= 149.5 kg
~ 150 kg.

Total pulling weight = Weight of chain + Weight of components
= 150 + 830
= 980 kg
Maximum pulling weight = Total pulling weight × Coefficient of friction
In general, for rolling application, the coefficient of friction is considered to be 0.2.
Hence,
Maximum pulling weight = 980 × 0.2
= 196 kg.
Let, g = 10 m/s^2
Hence,
Maximum pulling weight = 1960 N.

Pulling Torque

$$\text{Required torque} = \text{Maximum pulling weight} \times \frac{PCD}{2}$$

= 416.5 Nm
Final output torque = required torque × Service factor
Let, Service factor = 1.5
Hence,
Final output torque (T) = 416.5 × 1.5
= 624.75 Nm ~ 625 Nm
Hence,
Pulling Torque = 625 Nm.

$$\text{Pitch between components (Pc)} = \frac{\text{Centre distance}}{\text{Number of fixture tray}}$$

Pitch between components (Pc) = 833.33mm
Time to travel pitch Pc = 13 sec.

$$\text{Required RPM} = \text{Pc} \times \left(\frac{60}{13}\right) \times \left(\frac{\text{Pitch}}{z}\right)$$

Where, z = number of teeth = 13
Hence,
Require RPM = 2.97 rpm
~ 3 RPM

$$\text{Horse Power (hp)} = \frac{2\pi nT}{45000}$$

$$\text{Horse Power (hp)} = 0.26\ \text{HP}$$

$$\text{Required Power (kW)} = \frac{\pi \times \text{Torque} \times \text{RPM}}{30000}$$

$$\text{Required Power (kW)} = 0.20\ \text{kW}$$

Hence,
Final output Torque (T) = 625 Nm
Final output RPM (n) = 3 rpm
Final output Horsepower (hp) = 0.26 HP
Required kilowatt (kW) = 0.20 kW.

5.4 Sprocket Parameter calculations

Pitch circle diameter of sprocket, PCD (D_p) = 424.5 m ~ 425 mm
Top diameter, $(D_o)_{max} = D + 1.25p - d_1 = 488.5$ mm
$(D_o)_{min} = D + p(1\text{-}1.6/z)\text{-}\ d_1 = 450.59$ mm

Hence, let us take top Diameter = 475 mm

Root diameter, $D_f = D - 2r_i$
Where, r_i = roller seating arrangement
$(r_i)_{max} = 0.505d_1 + 0.069(d_1)^{1/3} = 32.34$ mm
$(r_i)_{min} = 0.505d_1 = 32.06$ mm
Take $r_i = 32.3$ mm

Hence root diameter = 410.8 mm

Tooth flank radius
$(r_e)_{max} = 0.008d_1\ (z^2+180) = 117.3$ mm
$(r_e)_{min} = 0.12d_1 + (z+2) = 114.3$ mm

Take tooth flank radius = 115 mm
Roller seating angle (α)
$(\alpha)_{max} = [120 - (90^0/z)] = 113.08^0$
$(\alpha)_{min} = [140 - (90^0/z)] = 133.08^0$
Hence take
$\alpha = 125^0$
Tooth height above the pitch polygon
$(h_a)_{max} = 0.625p - 0.5d_1 + (0.8p/z) = 38$ mm
$(h_a)_{min} = 0.5(p - d_1) = 19.05$ mm
Hence
$h_a = 25.4$mm
Tooth width, $(b_f)_{max} = 0.95b_1 = 60.325$
~ 60.5mm
Where, $b_1 = 63.5$mm

6. Result and Conclusion

As discussed above, the dedicated fixtures are designed to hold the tractor components rear axle carrier, rear axle shaft and bull gear. the fixture elements are analysed to check the validation of the elements. The result of analysis is as follows.

1. Resting Pad

	Equivalent Elastic Strain	***Equivalent Stress***	***Shear Elastic Strain***	***Shear Stress***
Minimum	1.9807e-009 m/m	382.27 Pa	-4.6638e-008 m/m	-3435.6 Pa
Maximum	6.5105e-008 m/m	12565 Pa	5.2867e-008 m/m	3894.4 Pa

2. V rod (Fixture element to hold shaft)

	Equivalent Stress	***Equivalent Elastic Strain***	***Shear Elastic Strain***	***Shear Stress***
Minimum	44.975 Pa	2.3303e-010 m/m	-3.1285 e-006 m/m	-2.3046e+005 Pa
Maximum	1.6844e+006 Pa	8.7274e-006 m/m	2.9911 e-006 m/m	2.2034e+005 Pa

3. Fixture element for gear

	Equivalent Stress	***Shear Stress***	***Equivalent Elastic Strain***	***Total Deformation***
Minimum	901.32 Pa	-3.6142e+006 Pa	4.67e-009 m/m	0. m
Maximum	7.871e+006 Pa	2.0326e+006 Pa	4.0782e-005 m/m	2.8847e-005 m

4. Holding plate to hold the fixture elements on chain conveyor

Object Name	***Equivalent Stress***	***Shear Stress***	***Equivalent Elastic Strain***	***Shear Elastic Strain***	***Total Deformation***
Minimum	1725.8 Pa	-1.8105e+007 Pa	8.9419 e-009 m/m	-2.4577e-004 m/m	0. m
Maximum	4.4404e+007 Pa	1.6315e+007 Pa	2.3007 e-004	2.2148e-	3.8722e-004 m

			m/m	004 m/m	

From the above discussion, the designed dedicated fixtures will hold the components while execution of the washing operations safely.

Conclusion

As discussed above this project gives the suitable solution on the other conveyors to carry the components like Rear Axle Carrier, Bull Gear, shafts of tractor before going to assembly line. Also this project suggests the dedicated fixturing arrangement for these components.

Also it is concluded that, the design and development of SPM gives perfect idea towards the process forecasting, by which process can be modified and improved before building SPM in actual way.

SPM can be making effective by using these kinds of automated fixtures in the automation systems. Where Components are travelling by trolleys, by cranes, or conveyors to reach at operating stations this designed system can be use there by making the existing system valuable and time saving. Instead of using Robotics system in the special purpose operations this travelling fixture can do perfect job to handle the component and give stoppage at the desired station which can be build in effective cost.

It can be conclude that in fixturing process everytime not necessary to use fastening or clamping devices if the perfect Poka-yoke is selected by the design engineer.

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