

A Systematic Approach for Conceptual Design of Fixtures for Assembly Process in Line

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Abstract

To stand apart in today's globalized world and to survive cutthroat competitions, manufacturers are in dire need to find ways to reduce production times and cost. This generation is more conscious about cost reduction, which leads one of the construction equipment industries to come up with a new model of Double drum compactor machine (DD) for their customers. The aim of the project is to increase the efficiency of workstation, minimizing the failures and thereby increasing the productivity in the assembly line. In order to obtain the productivity and reducing the time taken, some fixtures design is required for assembly line. In this paper, the concept of fixture design has been obtained by using SOLID EDGE software along with load calculations with mechanical formulas.

Keywords: *Compactor, Fixture, DD, SOLID EDGE*

INTRODUCTION

Compactors is required that efficiently and effectively compact varying soils and aggregates in applications such as highways, utilities, water retention structures, as well as in large residential, commercial and industrial site preparation. As a result, compaction becomes easier, more efficient and more effective.

Double drum compactors are very versatile performer, providing flexibility to handle varying conditions, widths and applications, from roadways and large parking lots to airport runways.



Fig 1 Working of paver and double drum

It gives complete control in choice of amplitudes, frequency and more. The result is a smooth, finished mat achieved with less passes and more profitability.

Solid Edge

A 3D CAD history based parametric feature and synchronous technology solid modeling software. It runs on Microsoft Windows and provides solid modeling, assembly modeling and drafting functionality for mechanical engineers, designers and drafters. Through third party applications it has links to many other Product Lifecycle Management (PLM) technologies.

Solid Edge is a portfolio of affordable, easy-to-use software tools that address all aspects of the product development process – 3D design, simulation, manufacturing, design management and more, thanks to a growing ecosystem of apps. Solid Edge combines the speed and

simplicity of direct modeling with the flexibility and control of parametric design – made possible with synchronous technology.

LITERATURE REVIEW

Sang Hoon Kong et al [1] has discussed in detail about the process planning for the assembly line with the help of agent-based collaborative engineering system. This study will help to encourage coordination and cooperation among the workers who wish to perform a task together.

Jinsong Bao et al [2] has mentioned about the problem faced during the more weight and thin-walled structure assembly which leads to the assembly deformation. In this study, the author introduced Virtual Assembly Fat Model (VAFM) which integrates geometry and non-geometry information when being created during assembly processes. This paper helps to study more complex model and the

evolution of the model in future. Djordje Vukelic et al [5] have explained the possibilities aided by computer application in fixture design process. In this paper, the author developed a fixture design which completely satisfies set requirements with the help of Computer-aided fixture design (CAFD) system development. Ali Keyvani and Fredrik Danielsson [6] have described how to combine an existing modular fixture design with process planning and simulation tools for the design of modular fixtures within the process-planning phase. Modification of the traditional design/planning strategies should be considered to gain the most from these tools.

ASSEMBLY PROCESS FOR DD

Road machinery is a mixed model and conveyorised assembly line. The assembly line consists of total 9 no of feeders and 7 no of stations. Three types of product flows in this line which are required to build a road:

- Double drum Compactor
- Single drum Compactor
- Pneumatic tire roller
- Paver is a bay built model which also plays a role in road building.
- Assembly process for new Double drum:

- a) In feeder 1, Swivel frame sub assembly, bearing fixing, dust seal fixing, steering cylinder sub assembly, link plate bearing assembly and hose routing in front frame and in station 1, swivel casting & link rod assembly, machine SL # plate fixing, machine SL # engraving, steering cylinder assembly will be done.
- b) In feeder 2, Rear frame sub assembly, bearing fixing, tightening of articulation joint bolt and in station 2, rear & front frame integration, hose routing, dust seal fixing to link plate, relocating frames on trolley will be done.
- c) In feeder 3, Engine sub assembly, propulsion pump assembly, vibration pumps assembly, fan mounting, engine mounting bracket assembly, engine oil filling and electrical connections and in station 3, engine mounting, battery assembly, radiator assembly, hose connections and routing will be done.
- d) In feeder 4, Cowling sub assembly, cowling foam fixing, pre-cleaner assembly and in station 4, cowling assembly and hose connections routing will be done.

- e) In feeder 5, Control console sub assembly, steering wheel assembly, seat mounting, pedestal sub assembly, facial plate assembly and in station 5, control console assembly, console platform assembly, turbocharger hump hose assembly, ROC (cooler) assembly, pedestal assembly will be carry out.
- f) In feeder 6&7, Water tank sub assembly, water pumps assembly, water spray bar assembly, water sensor harness assembly, diesel and hydraulic tanks sub assembly and in station 6, water tank assembly, rear drum assembly and railings assembly will be done.
- g) In feeder 8, Eccentric with bearing housing assembly and mounting, vibration motor mounting, drum oil charged, drum hand wheel assembly, drum shock mounts assembly and propeller shaft assembly will be done.
- h) In feeder 9, Eccentric parts cleaning in the washing machine, eccentric assembly, carrier assembly, carrier plate assembly and drum drive motor assembly will be done.

- i) In station 7, ROPS assembly, silencer assembly, charging of Hydraulic oil, diesel and coolant, front and rear lights mounting, front drum mounting, hose and harness connection will be done. Finally the machine is ready to go for flushing and TDI.

FIXTURE CONCEPT

A fixture is a work-holding or support device used in the manufacturing industry. Fixtures are used to securely locate (position in a specific location or orientation) and support the work, ensuring that all parts produced using the fixture will maintain conformity and interchange ability. Using a fixture improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the requirement for skilled labor by simplifying how work pieces are mounted, and increasing conformity across a production run.

A fixture's primary purpose is to create a secure mounting point for a work piece, allowing for support during operation and increased accuracy, precision, reliability, and interchangeability in the finished parts. It also serves to reduce working time by allowing quick set-up, and by smoothing the transition from part to part.

It frequently reduces the complexity of a process, allowing for unskilled workers to perform it and effectively transferring the skill of the tool maker to the unskilled worker. Fixtures also allow for a higher degree of operator safety by reducing the concentration and effort required to hold a piece steady.

Economically the most valuable function of a fixture is to reduce labor costs. Without a fixture, operating a machine or process may require two or more operators; using a fixture can eliminate one of the operators by securing the work piece.

Already double drum compactor is running in assembly line but the new machine (DD) requires some fixtures since the design of machine is different from the old one.

Places where fixture design is required:

- Fixture to rest front frame for bearing insertion
- Fixture to rest link rod for bearing insertion
- Fixture to lift swivel casting along with articulation pin for assembly

- Fixture to rest swivel casting in line for link rod assembly.

ANALYSIS AND DESIGNING

A. Fixture to rest front frame for bearing insertion



Fig 2 Existing fixture for front frame

For front frame this fixture is presently there some modification has been done for bearing insertion. It is suggested to put two hooks in the circled area of fig 1.2, so that the hooks can go inside the hole in the frame as circled in the fig 1.3 and hold the frame firmly when force is applied to drive the bearing inside on the front part of the frame. It is a cost saving proposal since no new fixture is required.

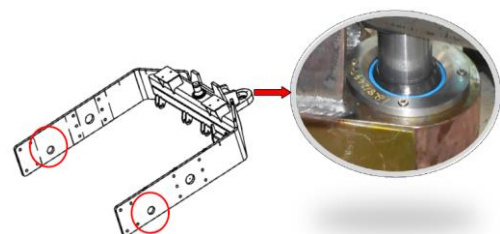


Fig 3 Hooks to be inserted in front frame to drive the bearing inside [3]

Fixture to rest link rod for bearing insertion

Link rod is required to link the two articulation pins which in results the integration of frames. The total weight of link rod is 55 kg, for this it has been decided to give a portable fixture since there is limited space available in feeder area. It needs space for bearing balls to

move freely as the force is applied to drive the bearing inside from up. So it is suggested for two small hollow cylinders of 40 mm width and diameter is of the link rod hole 120 mm and a measured connecting rod to make the complete fixture. It is very cost efficient design and consume very less space as it can be separate and keep in a place.

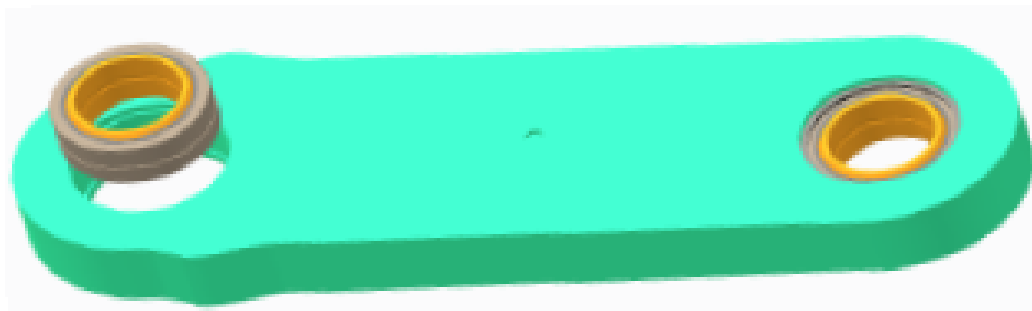


Fig 4 Snapshot of link rod

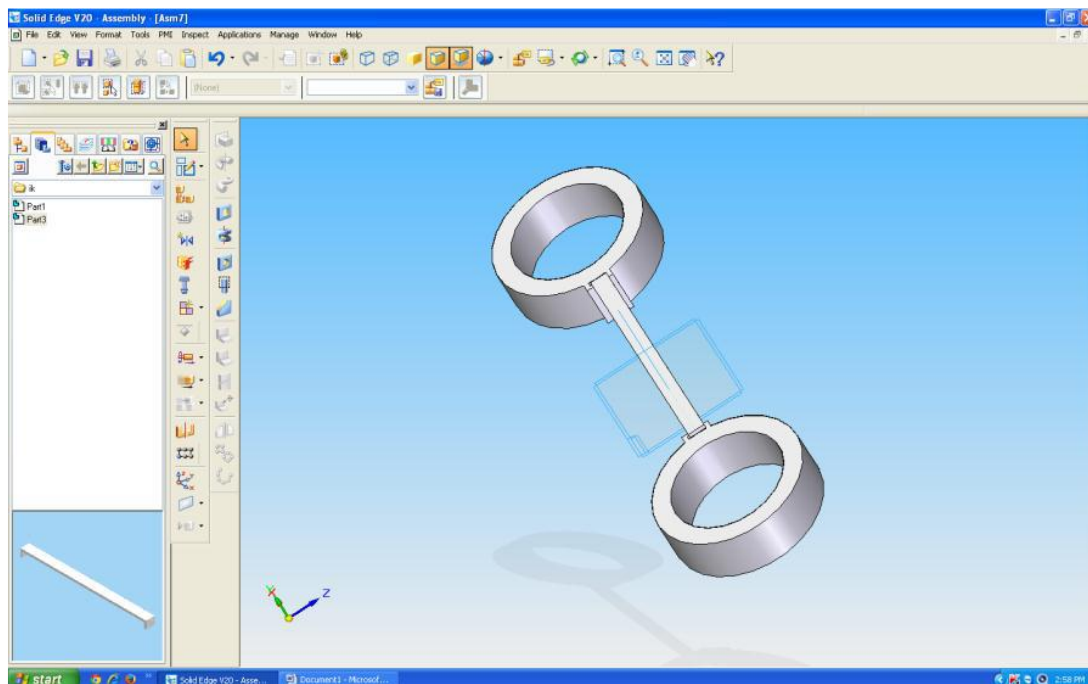


Fig 5. Fixture to rest link rod in SOLID EDGE

Fixture to lift swivel casting along with articulation pin for assembly

It has been observed that after insertion of articulation pin it is getting difficult to lift the sub assembly to the main line. One

fixture has been designed which will hold the swivel casting with the help of M20 bolt and two fixed hook to lift the sub assembly from top.

Calculations:

a) Center of gravity of swivel casting

Table 1 Calculation for center of gravity for swivel casting with pin [4]

Component	Volume (V)	Centroidal distance (y)	V
Rectangle	$l*b*w = 450*258*30 = 3483000$	$30/2 = 15$	52245000(+)
Trapezium	$(a+b)*h/2*w = 4889229$	$225 - (a^2+b^2+ab)/3(a+b) = 159.8$	781298794.2 (+)
Circle	$\pi/4*d^2*h = 2333194.89$	188.5	439807237 (+)
Semicircle	$\pi/8*d^2*h = 2960637$	$181 + 4r/3\pi = 215$	638536955 (+)
Triangle	$1/2*b*h*w = 3398337.5$	$261/3 = 87$	295655362.5 (-)
Isosceles triangle (2 nos.) $h = \sqrt{(100^2 - (188.54)^2/4)} = 33.4$	$1/2*a*h*w = 374685.3$	180	67643354 (+)
Total	12495404.8		1859674292

$$\begin{aligned} Y(\text{bar}) &= \Sigma (V*y) / \Sigma V \\ &= 1859674292 / 12495404.8 \\ &= 148.8 \end{aligned}$$

b) Force exerted by swivel casting along with articulation pin

$$\begin{aligned} F &= ma \\ &= w * g * (v - u) / t \\ &= w * g * d / t^2 \\ &= 94 * 9.81 * 1500 / 17^2 \\ &= 4786 \text{ N} \end{aligned}$$

Where,

w = weight of the sub assembly

g = gravitational force = 9.81 N/mm²

d = displacement of the sub assembly = 15m

t = time taken to lift the sub assembly to 15m = 17 minutes

Load taken by bolt M20 [3]:

$$\begin{aligned} P &= \pi / 4 * (d_c)^2 * \sigma_t \\ &= \pi / 4 * (16.933)^2 * 830 \\ &= 186911 \text{ N} \end{aligned}$$

Where d_c = core diameter of bolt = 16.933 (Coarse threads)

σ_t = Tensile strength = 830 N / mm²

c) Factor of safety = 186911 / 4786 = 39

Since factor of safety is 39 we can lift sub assembly with the M20 bolt, maintaining the center of gravity as 148.8 mm.

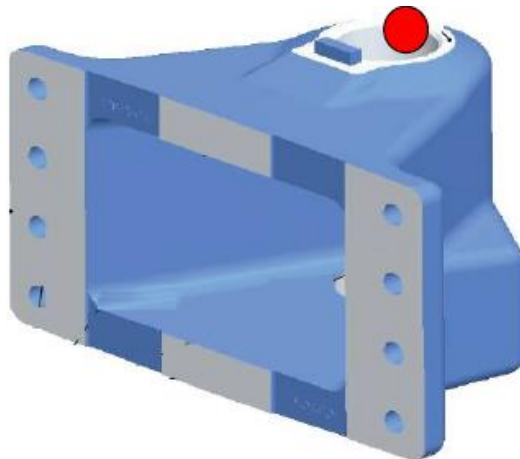


Fig 6 Red mark showing the C.G of swivel casting



Fig 7 Lifting of modeled swivel casting along with articulation pin without fixture at mule

At the mule in proto shop, there was no fixture as such to lift the sub assembly of swivel casting along with articulation pin so the design of the swivel casting has been changed and some side portion of the casting has been removed. By removing the material some space has been formed

to put the nylon strap and lift the sub assembly. This issue has observed in the mule and the fixture was designed for actual assembly line keeping all the issues in mind.

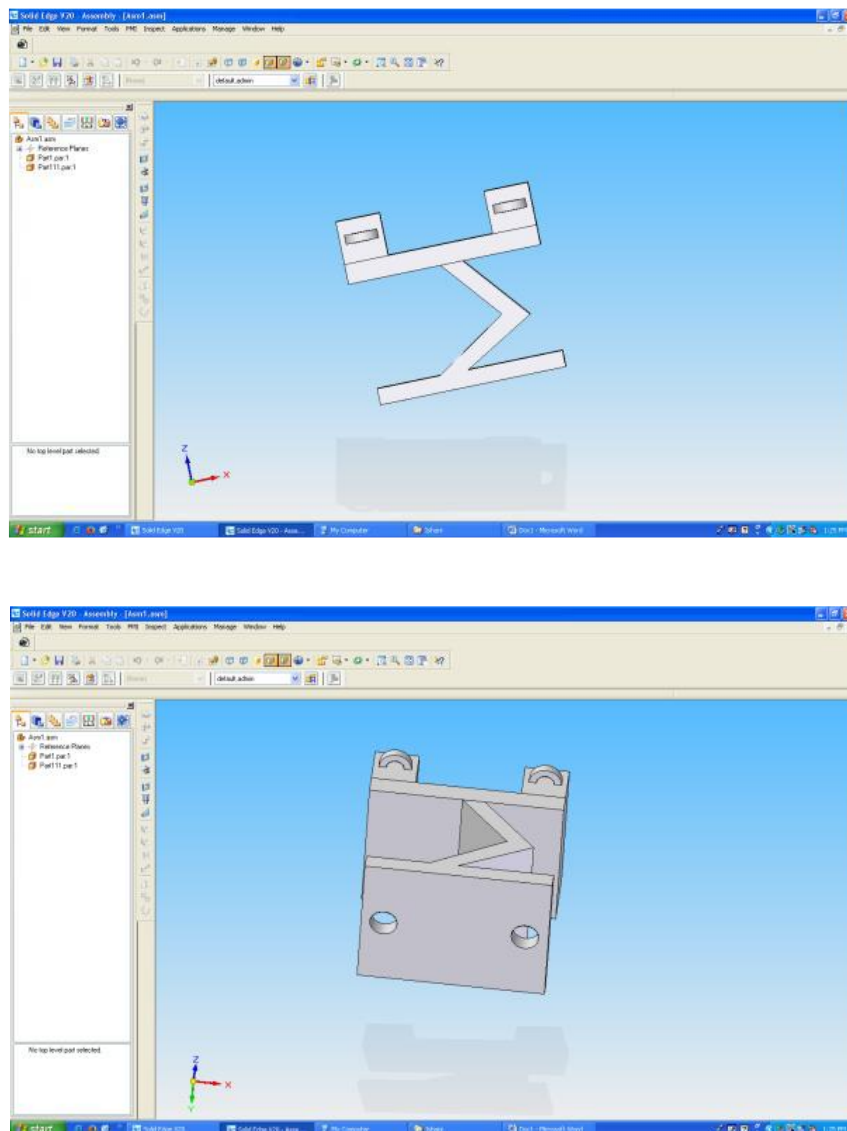


Fig 8 Fixture to lift swivel casting along with articulation pin

Fixture to rest swivel casting in line for link rod assembly.

To assemble link rod with the rest portion of machine parallelism comes into picture, the two pins need to be parallel to each other and perpendicular to the link rod. In mule it has been observed that after assembling swivel casting it is getting tilted without any external support as the surface is not plane, and to put link rod both the pins should be parallel to each

other. And to make the articulation pin perpendicular to the link rod one fixture in needed to make it straight. It is suggested for this scissor jack in fig 5.8, as it can be used in very less time. Pneumatic gun and compressed air is also available in the assembly line for other operations and it can be used to operate this scissor jack also. It will take less time for operators to adjust the height.

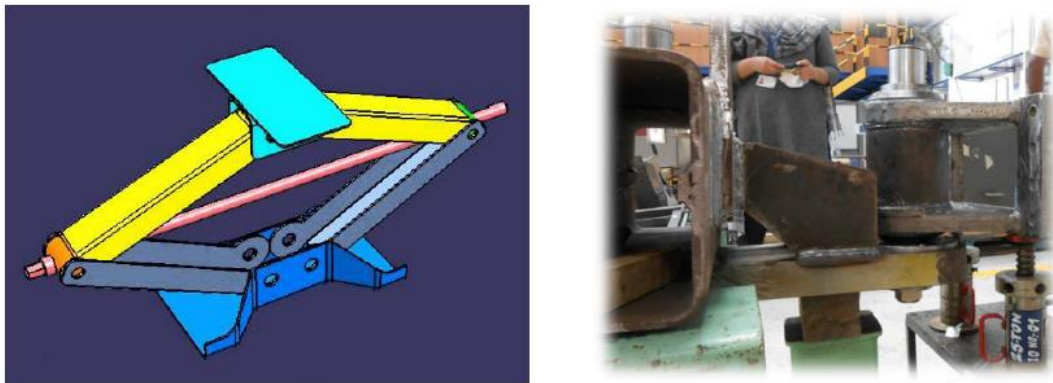


Fig 9 Fixture to rest swivel casting for parallelism (left)

Fixture to lift link rod for assembly

After fixing the parallelism of two shafts, now this link rod need to be inserted in these two pins. But for lifting we need a fixture which will maintain the center of gravity of the link rod since we need to hammer the link rod for inserting link rod into the pins.

Calculations

a) Center of gravity of link rod.

Table 2 Calculation for center of gravity for link rod [4]

Component	Volume (V)	Centroidal distance (x)	V * x
Hemisphere	$\frac{2}{3} \cdot \pi \cdot r^3 =$ $\frac{2}{3} \cdot \pi \cdot (100)^3 =$ 2094395	$100 - 3r/8 = 62.5$	130899687 (+)
Cylinder	$\pi/4 \cdot d^2 \cdot h =$ $\pi/4 \cdot (120)^2 \cdot 63 =$ 712513	$40 + d/2 = 100$	71251321 (-)
Rectangle	$l \cdot w \cdot h = 425 \cdot 63 \cdot 200$ $= 5355000$	$100 + 425 - l/2 = 312.5$	1673437500 (+)
Triangles (2 nos.)	$\frac{1}{2} \cdot b \cdot w \cdot h =$ $\frac{1}{2} \cdot 12 \cdot 67.5 \cdot 63 =$ 25515	$100 + 37 + 67.5 - 67.5/4 =$ 187.6	4787252 (+)
Triangles (2 nos.)	$\frac{1}{2} \cdot b \cdot w \cdot h =$ $\frac{1}{2} \cdot 12 \cdot 89 \cdot 63 = 5607$	$100 + 37 + 67.5 + 89 - 89/4 =$ 263.8	1520899 (+)

Cylinder	$\pi/4*d^2*h =$ $\pi/4*(120)^2*63 =$ 712513	100+425 = 525	374069437 (-)
Hemisphere	$2/3*\pi*r^3=$ $2/3*\pi*(100)^3=$ 2094395	625-3r/8 = 587.5	1230457739 (+)
Total	5971422		1859234294

$$X(\text{bar}) = \Sigma (V*x) / \Sigma V$$

$$= 1859234294 / 5971422$$

$$= 311.3 \text{ mm}$$

b) Force exerted by link rod while lifting

$$F = ma$$

$$= w * g * (v - u) / t$$

$$= w * g * d / t^2$$

$$= 55 * 9.81 * 1500 / 15^2$$

$$= 3597 \text{ N}$$

Where,

w = weight of the sub assembly

g = gravitational force = 9.81 N/mm²

d = displacement of the sub assembly = 15m

t = time taken to lift the sub assembly to 15m = 17 minutes

u = initial velocity = 0

Load taken by eye bolt M12 [3]:

$$P = \pi / 4 * (d_c)^2 * \sigma_t$$

$$= \pi / 4 * (9.858)^2 * 800$$

$$= 61060 \text{ N}$$

Where d_c = core diameter of bolt = 9.858 (Coarse threads)

σ_t = Tensile strength = 800 N / mm²

c) Factor of safety = 61060 / 3597

= 17

Since factor of safety is 17 we can lift link rod with the M12 eye bolt, maintaining the center of gravity as 311.3 mm.

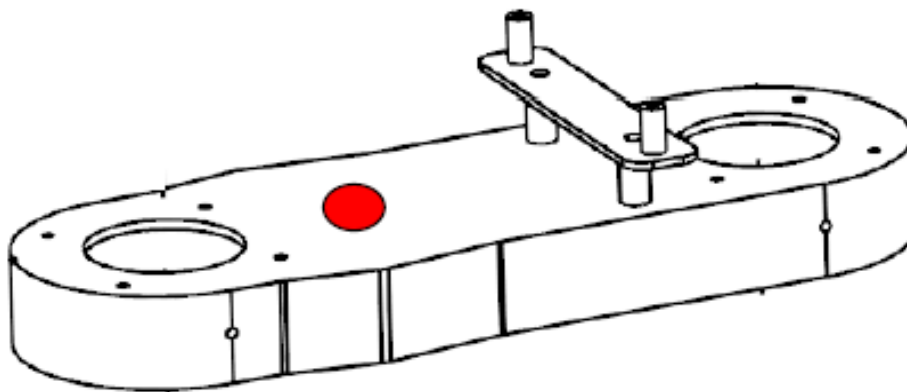


Fig 10 Showing center of gravity of link rod



Fig 11 Nylon strap used to lift link rod at mule

At mule in proto shop, the link rod was lifted with the help of nylon strap as no fixture was there at that time. It is a risky process if the link rod gets slipped it can cause a serious injury to the operator. After observing this issue in proto shop, I have come up with a new design of fixture. Where the tapped holes on the link rod

will be connected to the tapped holes of the fixture with the help of M12 bolts and one square bar has been welded down the fixture to avoid bending at the time of lifting. After bolted one eye bolt will be inserted at the C.G to lift the fixture perpendicular to the plane.

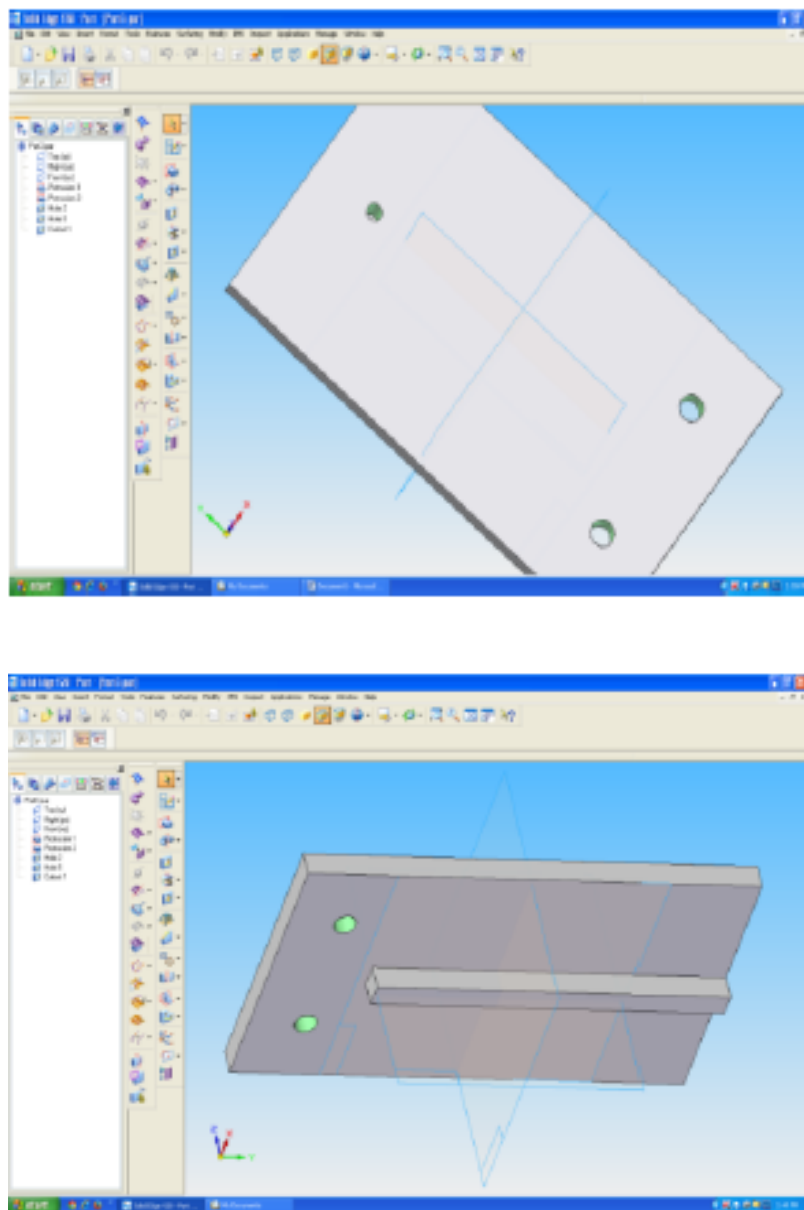


Fig 12 Fixture to lift link rod

CONCLUSION

At the mule of the prototype some processes needs fixture to carry out that activity as these concepts are new to the assembly line. Using SOLID EDGE it is been suggested some fixture concepts for that processes which has been accepted by the XYZ and will be used in the assembly process. The practical validation of this has to done in consultation with the management of XYZ.

ACKNOWLEDGMENT

I acknowledge Mr. Deepak Kumar and XYZ construction equipment for their immense support towards this project.

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