

# Design, Modification and Concept Generation of Fixture to mount Sub-assemblies from the Hydraulic Excavator Bucket

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**Abstract:** *In this paper, an attempt has been made to Design, Modify and Generate concepts to mount the sub-assemblies from the Hydraulic Excavator Bucket component onto a Fixture to perform Welding on the sub-assemblies. Techniques suggested in this paper help in saving Cycle time per Job and also help in reducing the Man hours, which might otherwise have been spent on manual Welding of all the Sub-Assemblies, by making the process Automatic.*

**Keywords:** Hydraulic Excavator Bucket, Fixture, Sub-Assembly, Isometric view, ANSI Drawing, Welding, Cycle time per Job

## 1. Introduction

Hydraulic Excavators are heavy construction equipment consisting of a boom, arm, bucket and cab on a rotating platform (known as the "Revolving frame"). The Revolving frame sits atop an undercarriage with tracks or wheels. All movement and functions of a hydraulic excavator are accomplished through the use of hydraulic fluid, with hydraulic cylinders and hydraulic motors [12]. Excavators are also called diggers, mechanical shovels and 360-degree excavators [12].

Applications of Hydraulic Excavators are:

- Digging of trenches, holes, foundations
- Material handling
- Brush cutting with hydraulic attachments
- Forestry work
- Demolition
- General grading/landscaping
- Heavy lift, e.g. lifting and placing of pipes
- Mining, especially, but not only open-pit mining
- River dredging
- Driving piles, in conjunction with a pile driver

A few notable manufacturers of Hydraulic Excavators are:

- Caterpillar Inc.
- John Deere
- J. C. Bamford (JCB)
- Komatsu Limited
- Larsen & Toubro (L&T)
- Orenstein & Koppel (O&K)
- Poclain
- Volvo Construction Equipment

The model we have based our concept generation upon is a sturdy, rugged and reliable hydraulic excavator incorporating advanced features based on extensive field experience. Its high indigenous content including key hydraulic components ensures increased availability and low operating cost [6].

The Hydraulic system provides optimum conversion of engine power into hydraulic power at the bucket. The heavy lift mode provides increased lifting capabilities and High digging force [2], [3]. The Technical specifications are as given below:

**Table 1:** Technical Specifications of a Hydraulic Excavator

<i>Make</i>	Cummins
<i>Power (SAE J 1349)</i>	320 HP
<i>Engine speed</i>	1900 rpm
<i>Hydraulic system</i>	Variodyn
<i>Optional Equipment</i>	Clamshell

Out of the major components which make up the Hydraulic Excavator, the Bucket component is the one which is of interest in this paper. A bucket is a specialized container having an inner volume which could be attached to the end of the arm of an excavating machine. It is a bulk material handling component. Excavator buckets are made of solid steel and have teeth protruding from the cutting edge, to disrupt hard material and avoid wear and tear of the bucket [8]. The Bucket of the Hydraulic Excavator is a Heavy duty bucket of 2.3 m<sup>3</sup> capacity fabricated with wear resistant C45 plates and provided with complete hard facing, extra reinforcements and with the wear plates fixed to the rear bottom of the bucket [4].

The Hydraulic Excavator Bucket is primarily made up of three Sub-Assemblies and also a few other components. These three Sub-Assemblies undergo a lot of machining and manufacturing processes before being fitted into the final stage thus, resulting in the shape of the Bucket [5]. Welding is a crucial stage during the Sub-Assembly manufacturing and is defined as an arc welding operation that uses a lead wire and a trail wire that are connected to two different power sources.

## 2. Objective

The Primary Objective of the paper is to represent in impeccable detail, both the indigenously generated concepts

on how to mount the Sub-Assemblies onto the Fixture. The paper also contains the Design of various other intermediate components and how it is used in the fulfilment of the primary objective. Also, an approximate material Cost-Estimation and comparative Cycle time per Job prediction of both the concepts are carried out individually on a small scale.

### 3. Concept One

The Isometric view of the Sub-Assembly is as shown below:

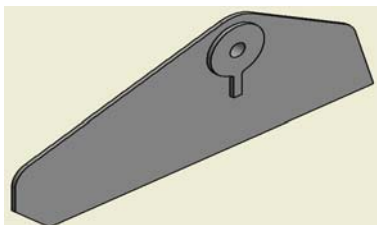


Figure 1: Isometric view of Sub-Assembly [11]

This Sub-Assembly is the one which is mounted onto the Fixture and is used in the forthcoming Concept One and Concept Two. It has a very simple design and its thickness varies from 20 mm to around 34 mm. A lot of machining processes is carried out in bringing the final shape as seen in the Isometric view. The geometry that resembles a circle, which is seen protruding from the side of the Sub-Assembly is the sub-component that is to be welded onto the Sub-Assembly. This is the primary reason the two indigenous concepts are developed in order to hold and firmly clamp the Sub-Assembly onto the Fixture while this Welding of the sub-component is taking place on the Sub-Assembly. Another important component is the L-Block (L-1 Block) and the L-Block without Sub-Assembly Bolt hole (L-2 Block) which are as shown:

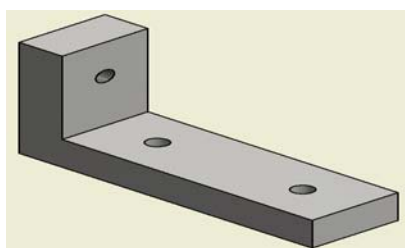


Figure 2: Isometric view of L-Block (L-1 Block)

This indigenously designed component is used in the process of clamping the Sub-Assembly by accommodating the Sub-Assembly Bolt through it. It is firmly fixed to the Fixture base using two Bolts. A Washer is used to disburse the compression of the nut or bolt smoothly. This lessens the possibility of damage and offers a flat space for the nut or bolt to stay in one place.

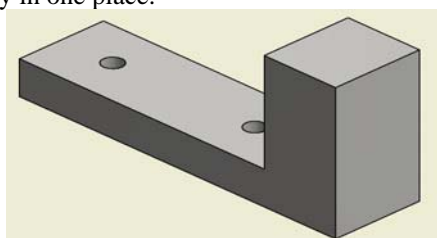


Figure 3: Isometric view of L-Block without Sub-Assembly Bolt hole (L-2 Block)

This is the same as the L-1 Block in design although its dimensions are altered for higher strength. It is used as a support onto which the Sub-Assembly would be pressed against while the Sub-Assembly Bolts are being tightened. Notice that this L-Block does not contain the Sub-Assembly Bolt hole which not only improves the strength of the L-Block but also cuts down the manufacturing and machining cost. It also helps in reducing the overall Cycle time per Job since only Two Sub-Assembly Bolts are used for clamping the Sub-Assembly compared to using four Sub-Assembly Bolts on both the L-Blocks which would have been a poor design. The final six components used in the creation of Concept One are:

Table 2: Description of the components

Part Number	Component Name	Quantity used
Part 1	Fixture	1
Part 2	L-Block (L-1 Block)	2
Part 3	L-Block without Sub-Assembly Bolt hole (L-2 Block)	2
Part 4	Standard M22 Bolt	8
Part 5	Washer	10
Part 6	Sub-Assembly Bolt	2

The three views of the ANSI Drawing and the Isometric view of the fully assembled concept are as shown below:

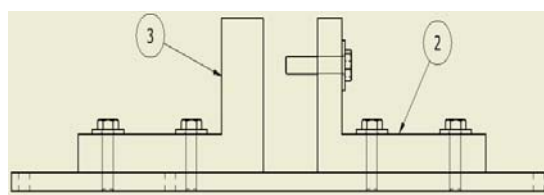


Figure 4: Front view of Concept One

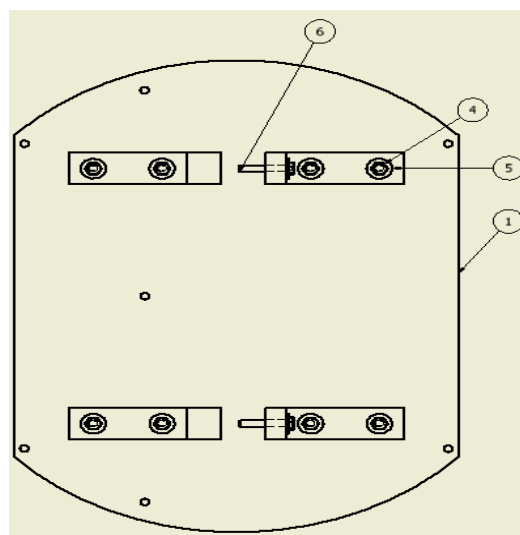


Figure 5: Top view of Concept One

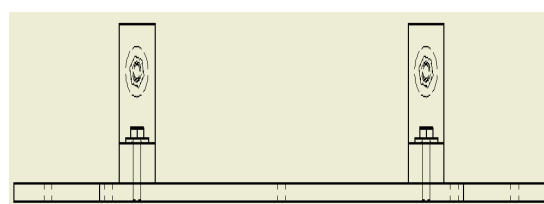
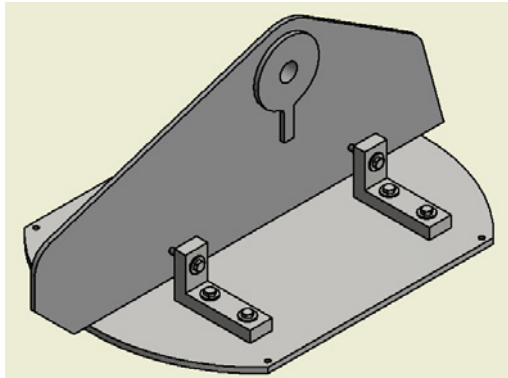


Figure 6: Left Profile view of Concept One



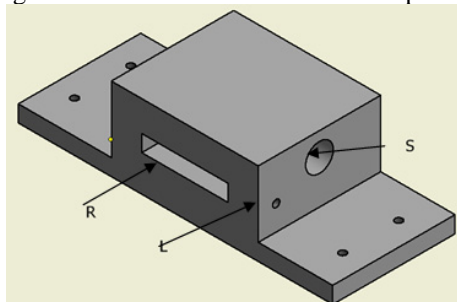
**Figure 7:** Isometric view of Concept One with Sub-Assembly mounting [11]

The following are the steps involved in assembling the individual components in creating the final concept and its working:

- The Original Fixture design is modified such that a total of eight threaded holes of Diameter 22 mm is to accommodate the four L-Blocks
- Two L-1 Blocks are placed on the surface of the Fixture on one side, while the other two L-2 Blocks are placed on the opposite side such that the Bolt hole axis of L-1 and L-2 Blocks is co-axial with the respective hole's on the Fixture
- Eight Washers are used on the eight Bolt holes of the four L-Blocks and the rest two Washers on the Sub-Assembly Bolt holes of the L-2 Blocks
- Next, all the eight Bolts are bolted onto the Four L-Blocks and is firmly locked in position because the threading present on the Bolt is a Right hand Thread and the Bolt holes have a Left hand Thread thus, accommodating the Bolts. The Washer lies in between the base of the Bolt head and the surface of the L-Blocks to prevent wear and tear to both the components
- Finally, the Sub-Assembly Bolts are bolted into position onto the two L-2 Blocks. The depth/travel of the Sub-Assembly Bolt through the L-2 Block depends on the thickness of the Sub-Assembly which we intend to place and clamp firmly in between the two L-Blocks

#### 4. Concept Two

To begin with, the Housing which encloses the Rack, Pinion and Locking mechanism is shown below and explained:

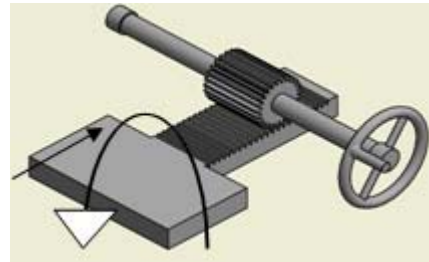


**Figure 8:** Isometric view of Housing

It consists of a Shaft hole (S), Lock hole (L) and Rack slot (R). The Shaft hole houses the Shaft which consists of the Bearings acting as the support structure for the Shaft and the Pinion Gear. The Lock hole has a Left hand threading and

thus allows the Locking mechanism to act on the Rack. Finally, the Rack slot is a dedicated space for the inward and outward motion of the Rack through the Housing.

The Crucial Mechanism in this Concept is the indigenously developed Rack and Pinion arrangement as shown:

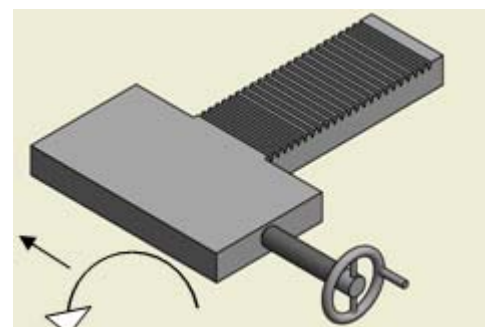


**Figure 9:** Isometric view of Rack and Pinion mechanism [9]

This mechanism resembles a conventional Rack and Pinion setup wherein, the rotation of the pinion gear causes its teeth to mesh with the teeth of the Rack and thus linear motion of the Rack takes place. When the direction of rotation of the Pinion changes, the linear motion of Rack occurs in the opposite direction. In our idea, clockwise rotation of the carriage wheel rotates the Pinion gear clockwise through the shaft and causes the Rack to move outwards from the Housing thus, clamping the Sub-Assembly. Conversely, counter-clockwise rotation of the carriage wheel causes the Pinion to rotate counter-clockwise which produces a linear inward motion on the Rack which, as a result travels inside the Housing and de-clamps the Sub-Assembly.

A special constructional feature of the shaft is that it is basically made of two halves - one half shaft consists an end with an incremental diameter increase at the end which arrests the lateral movement of the shaft and the other half shaft has a Carriage wheel which is Interference fitted to its other end. The free end of the two shafts are interference fitted into the Pinion gear thus completing the mechanism.

Next, the Locking mechanism is explained in explicit detail and its Isometric view is as shown below:



**Figure 10:** Isometric view of Lock and Rack arrangement

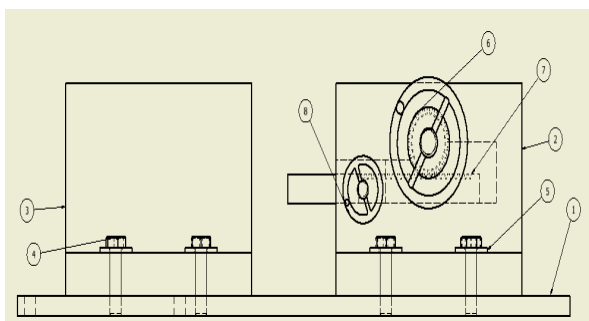
A simple mechanism which involves the clockwise rotation of the Carriage wheel which engages the linear forward motion of the Lock screw thus locking the Rack in its current position and consequently, a counter-clockwise rotation causes a linear backward retraction releasing the Rack from its locked state.

Lists of all the components used in the creation of Concept Two are tabulated below:

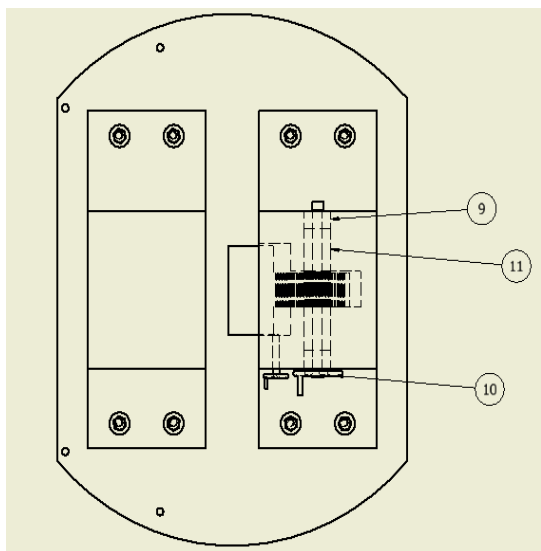
**Table 3:** Description of the components

Part Number	Component Name	Quantity used
Part 1	Fixture	1
Part 2	Housing	1
Part 3	Support	1
Part 4	Bolt	8
Part 5	Washer	8
Part 6	Pinion	1
Part 7	Rack	1
Part 8	Lock screw + Carriage wheel	1
Part 9	Bearing	2
Part 10	Shaft + Carriage wheel	1
Part 11	Shaft	1

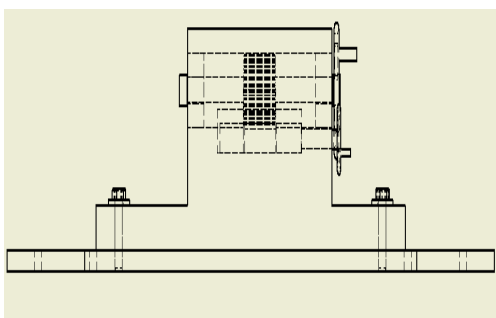
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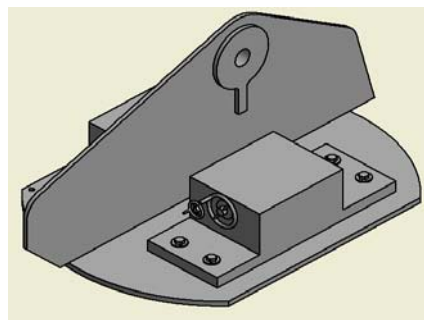
**Figure 11:** Front view of Concept Two



**Figure 12:** Top view of Concept Two



**Figure 13:** Left Profile view of Concept Two



**Figure 14:** Isometric view of Concept Two with Sub-Assembly mounting [11]

The following are the steps involved in assembling the individual components in creating the final concept and its working:

- The eight threaded holes of Diameter 22 mm of the Fixture is used to accommodate the Housing and Support components
- Eight Washer and Bolt combinations are used. The axis of the Washer and Bolt combination is co-axially aligned with the respective hole's on the Fixture to firmly secure the Housing and the Support onto the Fixture
- The Housing encloses the Rack and Pinion mechanism. The Rack directly rests on the Housing via the Rack slot while the Pinion is connected to two shafts one of which has a Carriage wheel to allow the operator to rotate the shaft and in turn the Pinion
- The two shafts are supported on the Housing with the help of one Bearing each. The diameter of the shaft is such that it passes through the internal diameter of the Bearing which allows rotation of the shaft while also acting as a support structure by holding the shaft in position
- Working – After the Sub-Assembly is placed in the gap between the Housing and the Support, The Carriage wheel is given a clockwise rotation which in turn rotates the Pinion in the clockwise direction and the Rack moves outwards in order to firmly clamp the Sub-Assembly. Lock screw is engaged to arrest the motion of the Rack. Post the Welding operation on the Sub-Assembly, the Lock screw is released and the Rack is retracted inwards by providing a counter-clockwise rotation to the Carriage wheel which in turn rotates the Pinion and causes the retraction of the Rack

## 5. Cost Estimation and Time Analysis

The Cost-Estimation of all the individual components of Concept One is as tabulated below:

**Table 4:** Cost Estimation of Concept One [10]

Component Name	No. of parts	Mass (Kg)	Cost (Rs/Kg)	Total Cost (Rs)
Fixture	1	277.873	135.46	37640.68
L-1 Block	2	18.82	135.46	5098.71
L-2 Block	2	18.969	135.46	5139.08
M22 Bolt	8	0.354	45.7	129.44
Washer	10	0.127	45.7	58.004
Sub-Assembly Bolt	2	0.476	45.7	43.51
Grand Total Rs.				48,109.424

The Cost-Estimation of all the individual components of Concept Two is as tabulated below:

**Table 5:** Cost Estimation of Concept Two [10]

Component Name	No. of parts	Mass (Kg)	Cost (Rs/Kg)	Total Cost (Rs)
Fixture	1	277.873	135.46	37640.68
Housing	1	354.902	135.46	48075.025
Support	1	394.016	135.46	53373.407
M22 Bolt	8	0.354	45.7	129.44
Washer	8	0.127	45.7	46.432
Pinion	1	6.097	135.46	825.9
Rack	1	15.93	135.46	157.89
Lock screw	1	0.514	45.7	23.49
Bearing	2	1.895	135.46	513.39
Grand Total Rs. 1,42,785.64				

Time analysis – The manual Welding process can easily be automated using the above mentioned concepts and it also helps in reducing the Cycle time per Job. Comparatively, although Concept Two is expensive, it is more time saving when implemented in an Industry employing mass production, since the Rack and Pinion mechanism is faster to use compared to the Sub-Assembly Bolt fastening present in Concept One.

## 6. Conclusion

The Design, Modification and Concept Generation of both Concept One and Concept Two have successfully been carried out. Also, the ANSI drawings of the Front view, Top view and Left profile view and the Isometric view along with the Sub-Assembly of both these Concepts are shown. Apart from the main Concepts, many other intermediate mechanisms like Rack and Pinion etc. have been shown in the paper which is used in either one of the Concepts. Finally, Cost-Estimation has been tabulated and Time analysis has been carried out which provides the feasibility of both these Concepts.

## 7. Future Works

Hydraulic Concept – In this, the clamping mechanism is actuated with a Hydraulic Piston-Cylinder arrangement. When the pump is actuated, the Hydraulic fluid is delivered to the Piston end of a Double acting Cylinder which in turn causes extension of the Piston rod which can be employed to clamp the Sub-Assembly. Conversely, the retraction of the Piston rod de-clamps the Sub-Assembly. Hydraulic locking mechanisms can be used to keep the Piston in place for the operation to be carried out. Magnetic Concept – A magnetic force of attraction induced by either an electro-magnet or a permanent magnet can be used for clamping and de-clamping action. This is achieved because of the Ferromagnetic properties of the Sub-Assembly material.

## 8. Acknowledgement

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