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REVIEW ARTICLE

DESIGN AND DEVELOPMENT OF WELDING FIXTURE AND MANIPULATOR

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ABSTRACT

Fixtures are essential elements of production processes as they are required in most of the automated manufacturing, inspection, and assembly operations. For supporting and clamping the work piece, device is provided. Frequent checking, positioning, individual marking and non-uniform quality in manufacturing process are eliminated by fixture. This increase productivity and reduce operation time. Fixture is widely used in the industry practical production because of feature and advantages. In industrial ergonomics a manipulator is a lift assist device used to help workers lift, maneuver and place articles in process that are too heavy, too hot, too large or otherwise too difficult for a single worker to manually handle. As opposed to simply vertical lift assists (cranes, hoists, etc.) manipulators have the ability to reach in to tight spaces and remove workpieces.

INTRODUCTION

Welding fixtures are normally designed to hold and support the various components (workpieces) to be welded. Fixture is a device for locating, holding and supporting a work piece during a manufacturing industry (SampathRao, ?). It is necessary to support them in a proper location which is capable of preventing distortions in workpieces during welding. For this the locating elements need to be placed carefully, clamping has to be light but firm, placement of clamping elements has to be clear of the welding area and the fixture has to be quite stable and rigid to withstand the welding stresses. With the aid of manipulator the welding fixture on which the rooftop will be placed is rotated for welding purpose. After necessary welding operations being performed, the fixture is rotated back to its original position. Then the rooftop is unclamped and unscrewed from its fixture in order to get lifted by the crane to be placed on the train top. For carrying out these operations appropriate design and functioning of this mechanism is of prime concern.As a result of complex alignment and positioning equipment are important as they are required in nearly all research andmanufacturing processes (Martin, ?).

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Materials and Components

Steel specified by SAE (Society of Automobile Engineers) and AISI (American Iron and Steel Institute) classification and standards.eg. SAE 1020 first two digit indicate the class to which the steel belongs, the last two digit indicate carbon contain.SAE 1015 is plain carbon steel which is highly ductile and is used for press work and for fixture. Thus out of many types of steel used for manufactring we have choosen plain carbon steel while designing and manufacturing as it is robust, cheaper than other steels and easily available.

Our finalized design is a product of the several different ideas and components originally created in the design phase.

- **Manipulator:-** In industrial ergonomics a manipulator is a lift assist device used to help workers lift, maneuver and place articles in process that are too heavy, too hot, too large or otherwise too difficult for a single worker to manually handle. As opposed to simply vertical lift assists (cranes, hoists, etc.) manipulators have the ability to reach in to tight spaces and remove workpieces.

- **Gears:-** Gears used are spur gears or straight-cut gears are the simplest type of gear. They consist of a cylinder or disk with the teeth projecting radially, and although they are not straight-sided in form (they are usually of special form to achieve constant drive ratio, mainly involute), the edge of each tooth is straight and aligned parallel to the axis of rotation. These gears can be meshed together correctly only if they are fitted to parallel shafts.

- **Brake Motor:-** A Motor is a device that creates motion. It usually refers to an engine of some kind. It may also specifically refer to Electric motor, a machine that converts electricity into a mechanical motion. Brake motor consists of an induction motor coupled to a disk brake, forming an integrated compact and robust unit. The brake used is sturdy with few moving parts and minimum of maintenance. This type of motor is mainly used in applications requiring quick stop and positive action and stand still like conveyors, gear reducers, machine tools etc. The motor used in our project is 1.5 HP with a rotational speed of 0.5 rpm as per our application.
- **Gear Box:-** The gear box used in our project work is a BOX type 5 inch worm and worm wheel gear box. It comprises of series of worm gear units made with die cast aluminium housing from size 25 upto 90 and cast iron for the size 110, 130, & 150. Two taper roller bearings are mounted on the worm shaft improving the mechanical resistance to the axial thrust generated by the worm wheel. The housing has been designed using parametric 3-D CAD software supported by symmetric analysis of the thermal dissipation capacity and structural resistance to deformation under the effect of working loads. The housing has been optimized to maximize the draining of water or liquid in the event of gear box being subjected to splashing or washing, thanks to the adoption of auto lubricated bearings on the output gear.
- **Bearing :-** Bearing is a machine element that constraints relative motion and reduces friction between moving parts to only the design motion. The design of bearing provides free linear of the moving part or free rotation aroung the fixed axis. Bearing used in our project is single deep groove bearing no. 6206 having a basic static capacity of 1000 Kgf and basic dynamic capacity of 1.30 Kgf. The maximum rotational speed for the bearing is 13000 rpm.
- **PLC :-** The main concept of this research is implementation of a control system, by using an intelligent device, which controls the fixture so that manipulation of job becomes easy.A Programmable Logic Controller, PLC, is an electronic device used for Automation of industrial processes, control of machines and automation of factory assembly lines implying that PLC is an industrial computer which has multi-purpose use in order to handle complex parts and processes safely (Jagtap, ?).

Design Procedure

The complete planning, design and documentation process for a fixture can be carried out systematically in 3 phases based on application which are design pre planning, fixture design, and design approval (Erik K. Henriksen, ?).
The steps considered during designing are as follows:-

- Analytical design for fixture.
- 3 - D Modeling in SOLIDWORKS Wildfire 5.0
- Fixture assembly.

Analytical design for fixture

It is included that design of base plate, base v block, threaded block, supporting v-block, clamp, hexagonal bolt with washer, supporting pin. 3D Modelling in SOLIDWORDS.

It is included that generating of 3D model of all details part of fixture like base plate, blade, shim, spacer, bolts, riser, etc.

Fixture assembly

It is included that assemble of all the detailspart of fixture step by step is carried out.

Approach to fixture design

- Analysis of the work piece drawing.
- Identification of candidate elements (machined surfaces for locating, possible clamps positions, important regions of work piece, tool path, possible tool interference points, etc.).
- Support, location, clamping, base, guiding, fasteners taken in consideration.
- Methodology (modular, vice, v-block, point surface, angular structure, multi work piece clamping, 3-2-1 principle etc.).
- Identification of solutions (successful sequence of local solutions and creation of a more work pieces)
- Fixture design.
- Building of assembly.

Design Calculations

Calculations of Spur gear

For the given pair of spur gear,
Pitch Circle Diameter (P.C.D.) of pinion, d_p = 150mm
Pitch Circle Diameter (P.C.D.) of gear, d_g = 700mm

Based on standard selections, Standard Module, m = 6mm for gear pair

From the above information we can calculate the following parameters: -

- Width (b)= 10m = 10 * 6 = 60mm
- Teeth of pinion (Z_p)= d_p / m = 150/6 = 25
- Teeth of gear (Z_g)= d_g / m = 700/6 = 117
- Center distance (C.D)= (d_p +d_g) / 2 = (700+150) / 2 = 425mm
- Addendum (h_a) = 1m = 1 * 6 = 6mm
- Dedendum (h_f) = 1.25m = 1.25 * 6 = 7.5mm

Now, Check whether Pinion or Gear is weaker Ultimate tensile strength for Pinion, $(S_{ut})_p$= 600 MPa
for Gear, $(S_{ut})_p g$ = 300 MPa

Deformation Factor (c) = 11000 N/mm^2 ;

Power P =7.5 KW;

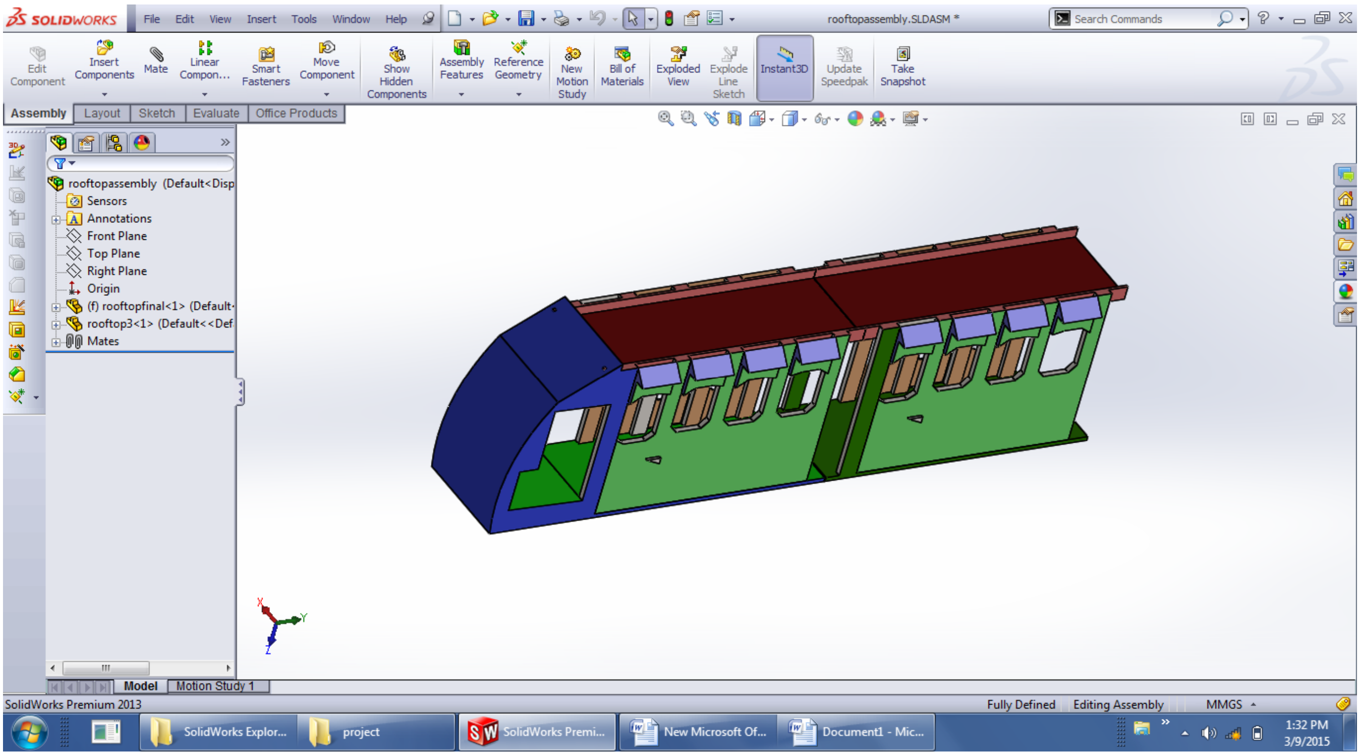


Figure . Rooftop of railway

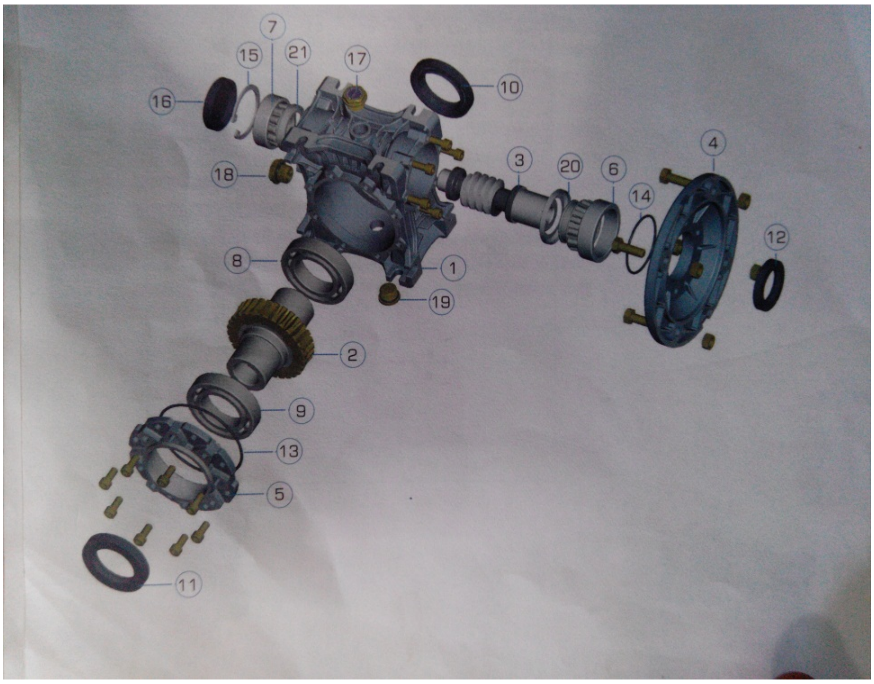


Figure . Exploded view of Brake Motor

Factor of safety, FOS = 2.5;

Sum of errors between meshing teeth (e) = 7.3 microns;

Velocity factor = 6 / (6+V) ; Lewis factor = 0.484 – 2.87 / z;

Thus,

$(\sigma_b)_p = (S_{ut})_p / 3 = 600 / 3 = 200$ MPa

$(\sigma_b)_g = (S_{ut})_g / 3 = 300 / 3 = 100$ MPa

Lewis form factor is

$Y_p = 0.484 - 2.87 / 25 = 0.3692$

$Y_g = 0.484 - 2.87 / 117 = 0.46$

Now,

$(\sigma_b)_p * Y_p = 200 * 0.3692 = 73.84$ MPa

$(\sigma_b)_g * Y_g = 100 * 0.46 = 46$ MPa

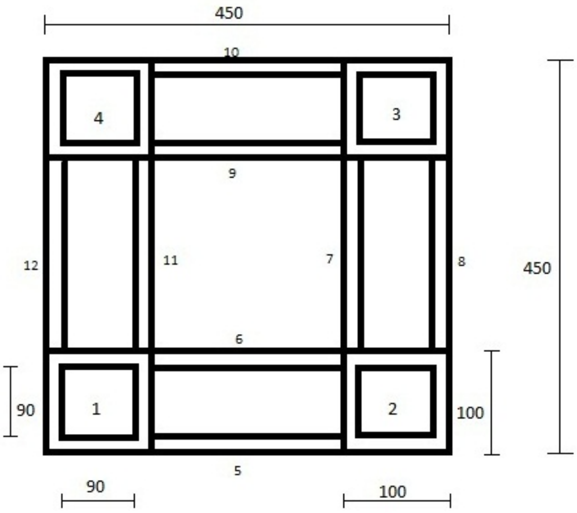
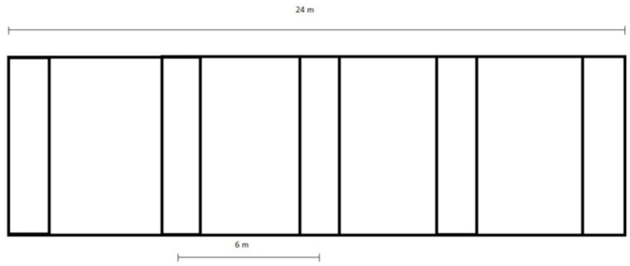


Figure 3. Rectangular Cross-section of Duct



Now,
Volume of Figure 5= 0.25 $(0.1^2 - 0.09^2)$ * 4 * 4 = 7.6 * 10^{-3} m^3

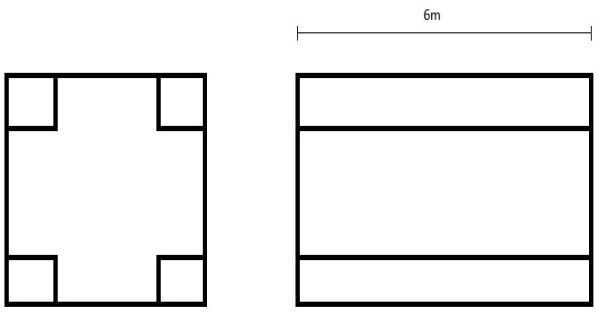
⇨ Mass of standing ducts = $Density_{carbon\ steel}$ * Volume
= 59.66 kg

Therefore,
Total mass of all ducts over 6m length= 357.96 + 59.66 = 417.62 kg
Total mass of all ducts over 24m length= 417.62 * 4 = 1670.48 + 1000 ←(UDL)
= 2670.48 kg

Figure 5. Duct for 24m length

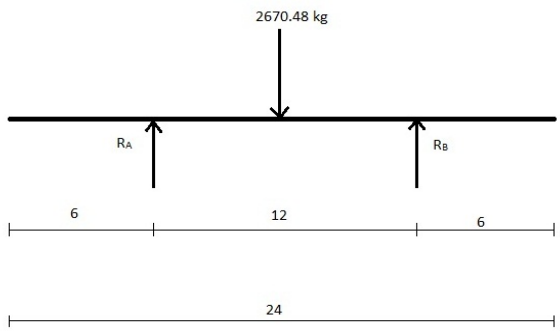
Table 1. Calculation of Moment of Inertia I for Figure 3

Sr.No.	Area	I_y	x	x-x'	I_{yy}
1	0.1^2-0.09^2 = 1900	2865833.33	50	-175	61053333.33
2	1900	2865833.33	400	175	61053333.33
3	1900	2865833.33	400	175	61053333.33
4	1900	2865833.33	50	-175	61053333.33
5	250 * 5 = 1250	6510416.67	225	0	6510416.67
6	1250	6510416.67	225	0	6510416.67
7	1250	2604.167	377.5	152.5	29072916.67
8	1250	2604.167	422.5	197.5	48760416.67
9	1250	6510416.67	225	0	6510416.67
10	1250	6510416.67	225	0	6510416.67
11	1250	2604.167	72.5	-152.5	29072916.67
12	1250	2604.167	27.5	-197.5	48760416.67
	Total				4.25 * 10^{-4} mm^4



Volume of Figure 4 (i.e. for 6m length ducts)= 6 * $(0.1^2 - 0.09^2)$
= 0.114 * 4 ducts
= 0.0456 m^3
Density = Mass / Volume
As $Density_{carbon\ steel}$ = 7850 kg/m^3
Therefore,
Mass = $Density_{carbon\ steel}$ * Volume
= 7850 * 0.0456
= 357.96 kg

Figure 4. Duct for 6m length



From Figure 6,
Considering Forces in x and y directions, we get,
R_A=R_B= 1335.21kg
From defection Diag.,
M=EI D^2y/Dx^2

⇨ EI D^2y/Dx^2=R_B (x) - 2670.48 (x-6)

Substituting the value of R_B in the above equation and Integrating and solving the equation,
EIy=-219.545x^3 + 8011.44 x^2 - 64522.8x + 0
Where, E=210 * 10^9 N/m^2
I=4.25 * 10^{-4} mm^4
Deflection, y = 24mm (downward)

Figure 6. F.B.D. of duct of 24m length

As $(\sigma_b)_p *Y_p < (\sigma_b)_g *Y_g$, gear is weaker than pinion in bending. So, the design is required based on gear.

Beam Strength of gear, $F_b= (\sigma_b)_g *Y_g *b*m= 46 * 60 * 6 = 16560$ N

Effective load on gear pair, $F_{eff}= (K_a * K_m * F_t) / K_v$
As $V = \pi d_p N_p / 60 = (\pi * m * Z_p * N_p) / 60$

$= (3.14 * 6 * 25 * 1440) / (60 * 10^3)$

=11.304 m/sec

Tensile Force, $F_t = P / V = 7500 / 11.304 = 663.48$ N

$K_v = 6 / (6+V) = 6 / (6+11.304) = 0.3467$

$K_a = 1.56$ and $K_m = 1$ (assume)

Therefore,

$F_{eff}=(K_a * K_m * F_t) / K_v = (1.56 * 1 *663.48) / 0.3467 = 2985.373$ N

Dynamic Load by Buckingham's Equation

$F_d = [21V(Ceb + F_t)] / [21V+ (Ceb + F_t)^{(1/2)}]$

⇨ $F_d=[21* 11.304(11000 * 7.3*10^{-3} *60 + 663.48)] / [21* 11.304 + (11000 * 7.3*10^{-3}*60 + 663.48)^{(1/2)}]$
⇨ $F_d =3631.97$ N

Design safety

$F_{eff} = (F_t)_{max} + F_d = K_a * K_m * F_t + F_d$

⇨ $F_{eff}=1.56 * 1 * 663.48 + 3631.97$
⇨ $F_{eff}=4667$ N

Therefore,

$FOS=F_b / Feff = 16560 / 4667 = 3.5483$

As available FOS of gear pair is higher than the required FOS; Design of gear pair is safe.

Surface Hardness, $F_w= d_p * b * Q * K$

But, $d_p = 150$ mm ; b = 60 mm

$Q = 2Zg / (Z_g + Z_p) = (2 * 117) / (25 + 117) = 1.648$

Assume, $K = 0.16 * (BHN / 100)^2$

$F_w = 150 * 60 * 1.648 * 0.16 * (BHN / 100)^2$

But, $F_w = FOS * F_{eff}$

Hence, $2373.12 * (BHN / 100)^2 = 2.5 * 4667$

BHN = 221.7322

Various processes and machines used for our component

- **Gas cutting: -** Oxy-fuel cutting is a process that uses fuel gases and oxygen to weld and cut metals, respectively. Pure oxygen, instead of air, is used to increase the flame temperature to allow localized melting of the workpiece material (e.g. steel) in a room environment. A common propane/air flame burns at about 2,000 °C (3,630 °F), a propane/oxygen flame burns at about 2,500 °C (4,530 °F), and an acetylene/oxygen flame burns at about 3,500 °C (6,330 °F).
- **Arc welding:** - Arc welding is a type of welding that uses a welding power supply to create an electric arc between an electrode and the base material to melt the metals at the welding point. They can use either direct (DC) or alternating (AC) current, and consumable or non-consumable electrodes. Each weld on any component is welded using a specific welding process with the aid of highly focused electrode shielding gas, largedegree of control the welder has over the heat intensity leads to production of very strong and consistent welds.
- **Special purpose machine: -** Special purpose machines are designed to perform some specific applications which cannot be carried out using conventional machines. In our company the SPM is of the company SCHARMANN is used mainly for job setting and machining the components using operations like sizing, drilling, rimming, boring, finishing etc.
- **Vertical machining center: -** VMC used in our company is of the Hartford Company. It is very costly but serves its purpose to the fullest. Being economical it is widely used for large scale production of components. It is basically constituted of three components- the monitor where program is fed, keypad for feeding the program and the control panel for controlling the feed rate, RPM, start and stop of machine. For the machining purpose following are the codes which are written:-

Interpolation

```
(JCB/334/U1471);
;
(D80H7/D32.0/CUTTR;
G00 G90 G54 G80 G40 G1;
G54 Z200.0;
M03 S1200;
G52 X-710.0 Y0.0;
G00 X0.0 Y0.0;
G01 Z00.0 F1000;
X23.8;
G02 X23.80 Y0.0 Z-60.0 I-23.80 P120;
G02 I-23.80;
G01 X0 Y0;
Z-90.0;
X23.8;
G02 X23.8 Y0.0 Z-155.0 I-23.80 P130;
G02 I-23.80;
G01 X0 Y0;
G00 G90;
Z200.0;
M30;
%
```

Drilling:-

```
G00 G90 G54 G17 G40 G80 G60;
Z200.0 G54;
```

```
M03 S0150;
/ G51.1 X0;
G98 G85 X0.0 Y-300.0 Z-17.5 Q4.0 R4.0;
F50;
(D10H8);
X-737.2 Y-545.6;
X-397.2 Y-228.6;
X469.6;
X809.6 Y-545.6;
/M98 P40;
;
G00 G90;
Z200.0;
M30;
%
```

Milling:-

```
G91 G01 F700;
Z-1.0
X-40.0;
Z-1.0;
X040.0;
/ M01;
M99;
```

decrease in the deflection. Thus it is advisable to design a duct 100*100mm with 8mm thickness and 6mm chamfer. Bearing selection also plays a very important role and based on our application it is highly recommended to select single row deep grove ball bearing as they can sustain some axial load in either direction as well as radial loads, and the two raceway cross-sections are simple circular arcs which can be very precisely finished so that the bearings have low friction and very little noise or vibration. Several different cage designs are available with different characteristics and the choice depends upon the individual application

Acknowledgement

Inspiration and guidance are invaluable in every aspects of life, especially in the fields of academics, which we have received from our company Adroit Enterprises. We would like to thank them as they are responsible for the complete presentation of our project and also for the endless contribution of time, effort valuable guidance and encouragement given by professor S.N.Shindeto project work.

Conclusion

Conclusion is drawn on the basis of the information collected on each aspect of our project. It leads to a belief that if applied

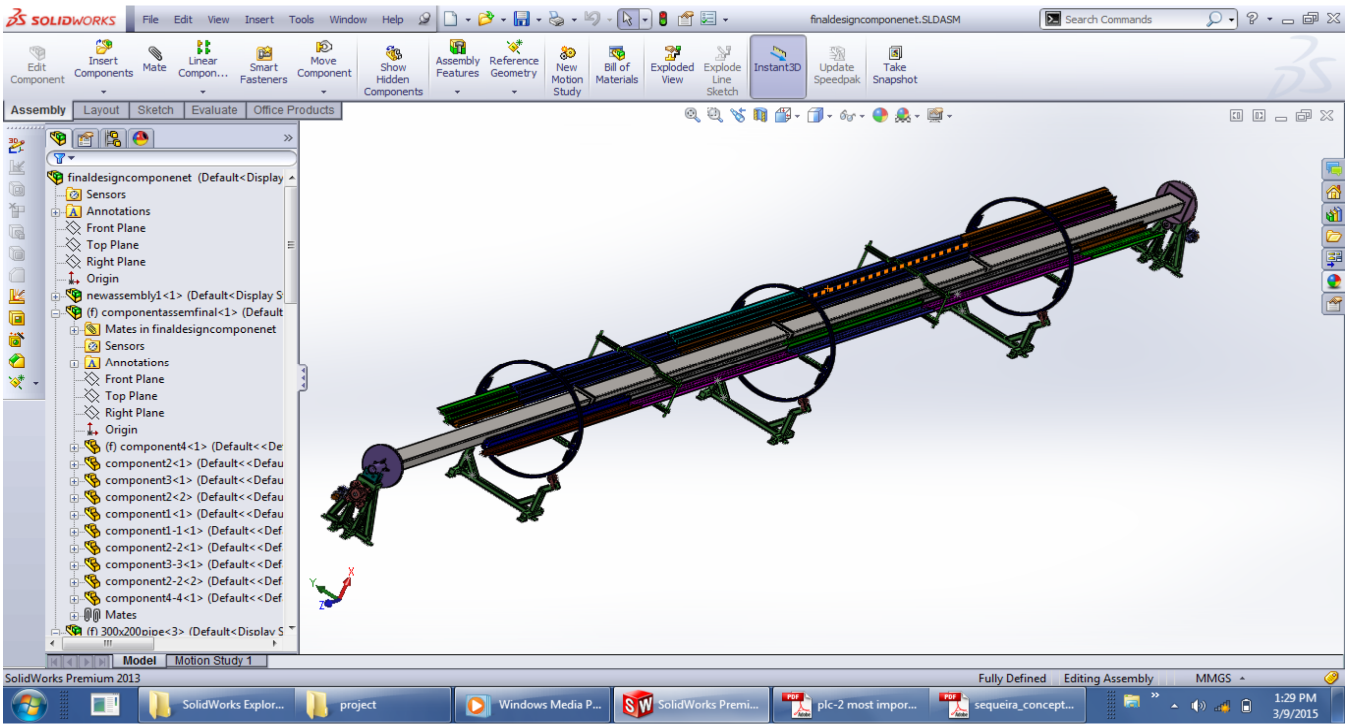


Figure 7. Final assembly of fixture

RESULTS

From the above design calculations the type of gear which we have chosen is spur gear because it has proportional Brinell hardness number, high power transmission efficiency, highly reliable and unlike belt drives have no slip condition. From the above bending condition the design of duct is not suitable, so it is required to take a plain rectangular duct with square cross section in order to reduce the bending below 10mm. By changing the cross section the inertia will change leading to

will create an even better machine than we have designed. The process of conducting operations related to welding fixtures and positioners helps in gaining a deeper understanding as well as effective project process. From finding a resource for research material to design updates of the part causes the task of accurately prototyping the real design difficult. It is important that the design satisfies all of the functional requirements and design parameters which were outlined at the start of the project. In order to meet the requirements of the fixture customization is done by making the clamping system very practical for various sizes and geometries. By also knowing the material selection a cost benefit analysis could be conducted to determine how cost effective the product is.

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