Design and Development of Fixture for Installing Car Front Seats

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Abstract— **Fixtures are devices utilized in industries for installation, inspection and assembly operations. This paper describes about design and development of fixture for installing car front seats, during car assembly process. After careful study of assembly components, two concepts of fixtures were designed. Among these concepts the best concept is developed based on pros and cons of two concepts. The detail modelling of the selected concept is done by using 3D software, NX Unigraphics 7.5 and analized using ANSYS. Based on the detail design, 2D draft drawings are generated and supplied for manufacturing of the fixture. The implementation of the fixture is able to reduce the cycle time by 40 percent. Finally the total cost incureed to develop fixture is eatimates.**

Keywords—Assembly components, Car front seats, Fixture design.

I. INTRODUCTION

Seats are important components of a car on which driver and traveler spends most of their time. Car seats consist of front and rear seats. Figure 1 shows different parts of a car seat. Front seats and rear seats are assembled in same assembly line at single stage. [1-2-3]
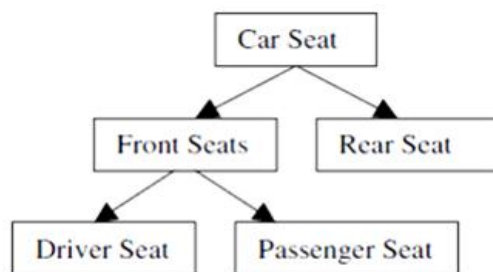

Figure 1: Types Of Seats

Following are the most commonly types automobile seats
1.   Fixed bus 2. Bench seat 3. Foldable seats
4.   Bucket seats 5. Pedestal bucket seats
6.   Child seats and 7. Booster seats

Front seats are assembled manually which leads to human fatigue, wastage of labour force and scratches on the car. Industrial automation has increased in recent years and more efforts have been incorporated to achieve efficient and flexible manufacturing. The development of front seat assembly fixture eliminates the undesirable effects. [4].

In this paper seat installation fixture is designed for assembling front seats in to a car. During manually assembly process, operator's faces difficulties to position front seat in to car on battery box, which leads to fouling of seat component like legs, with the battery box and interior parts such as dash board, and inner board panel of a car. Resulting scratches/damage to battery box and other components. Also according to ergonomic standards an operator can lift maximum weight of 18 Kgs, as seat weighs around 33kgs.

II. CONCEPT GENERATION

Concept generation involves the identification of the requirements and new concepts are generated based on the requirements, the generated concepts are explained below:

A.   Concept 1

Table 1: List of Components In Concept 1

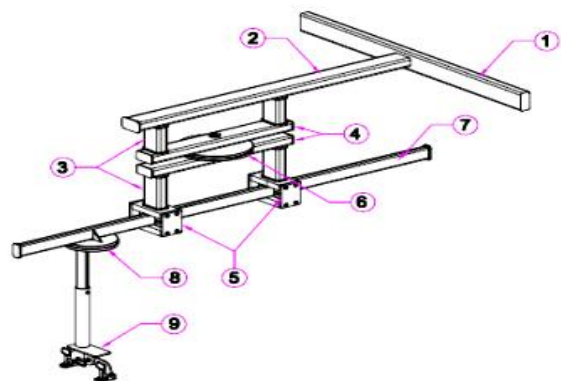| S.I. no	Name of components
1,2,3,4	RQ tube 80x40x2.5mm
5	Bearing and roller system
6	Bearing and rotary round plate system
7	RQ tube 50X25X2.5MM
8	Bearing and rotary round plate system
9	Seat assembly holding and handling system

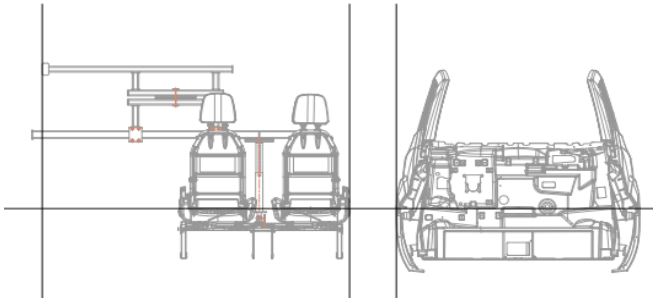Figure 2: Isometric View of Concept 1

Figure 3: Assembly of Front Seat By Concept 1

In this concept, the seat assembly fixture is employed to assemble the seat into a car. The fixture is made of mild steel and C45 steel materials, consists of two rotary round plate systems and roller bearings. The rotary plates rotate about 360 degrees, which rotates the entire setup and the other plate is located at seat handling arrangement. The roller bearings, carries a load by placing rolling elements (such as balls or rollers) between two bearing rings. The relative motion of the pieces allows the round elements to roll. To make the concept simple, fixture is divided into two portions, namely upper and lower. The upper portion is fabricated with rectangular tube of size 80x40x2.5mm and welded to a superstructure at 90 degrees along its length. In lower portion, the pneumatic cylinder is connected to sliding rectangular tube of size 50x25x2.5 mm through a rotary plate and seat handling system is attached to lower end of the pneumatic cylinder. During operation, the operator unlocks pin of seat trolley and withdraws the seat and places it on platform and raised to a required height by hand winch mechanism, attached to platform as shown in Figure 3. To lift the seat from platform, lower portion of fixture is rotated to 5-15 degrees about superstructure; further pneumatic cylinder is actuated, to which the clamp attached handles the seat about its CG point of seat. Then lower Portion is rotated to 80-110 degrees about superstructure. The operator slides the seat in forward direction, such that seat is assembled at desired position. To perform this operation only two operators are required.
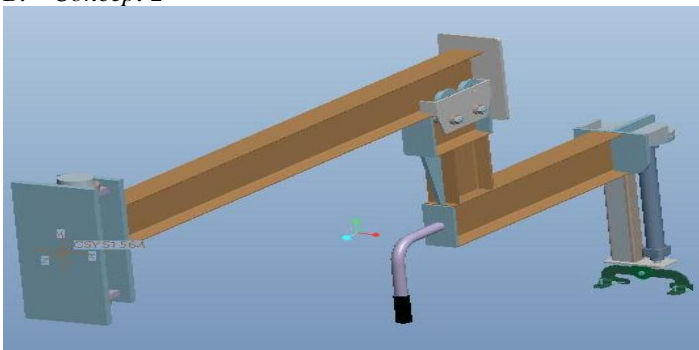
B. *Concept 2*

Figure 4: 3d Model of Fixture

The main difference between concept1 and this concept2 is that, the fixture is fabricated using I-beam cross section and is welded to a frame which is fastened to super structure, whereas in concept1 fixture is build using rectangular tubes. The fixture operation is similar as in the case of concept1. Seat assembly fixture is made of mild steel and C45 steel materials. A rectangular tube is provided at the bottom of frame to support the fixture where one end is fastened to frame and other end is fastened to floor/grouted. Setup consists of a rotary round plate at free end, bearing arrangement attached at fixed end, a push-pull travelling trolley provides the sliding movement to lower portion along the beam and pneumatic cylinder attached to rotary plate system which rotates the seat. Figure 4 shows the isometric view of concept 2.
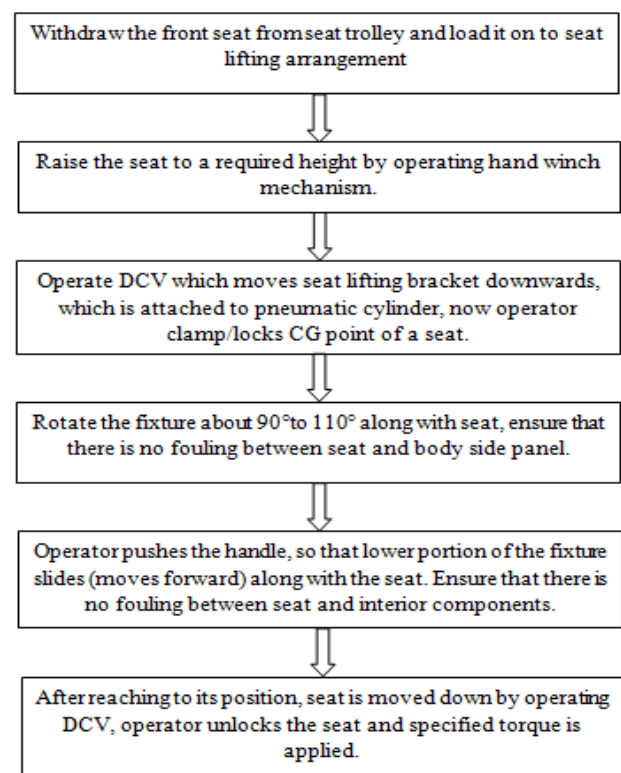

Figure 5: Process Methodology of Concept 2

III. CONCEPT SELECTION

Concept selection is the process of evaluating concepts with respect to identified requirements and other criteria, comparing the relative strengths and weaknesses of the concepts, and selecting one or more concepts for further investigation, testing, or development. Concept selection method is carried out based with reference to Karl T. Ulrich and steven D, Eppinger had described few methods for choosing a concepts [5-6-7]. In which concept selection based pros and cons is employed.

Out of two concepts, concept 2 is finalized due to following reasons. [10]

Cons of concept 1:
- Fixture is developed by using rectangular tubes. Since load carrying capacity is less, hence concept 1 failed.
- Rectangular tube of dimension 80x40x2.5mm got bend, when the fixture is load with a seat.
- In concept 1 there no provision to rotate the fixture to desired angle.
- Fixture is projecting out from the superstructure, which may cause accidents to operators, while performing work.

Pros of concept 2:
- In concept 2 is developed using I beam, which have more load bearing capacity.
- In concept 2 has a provision to rotate to a desired angle.
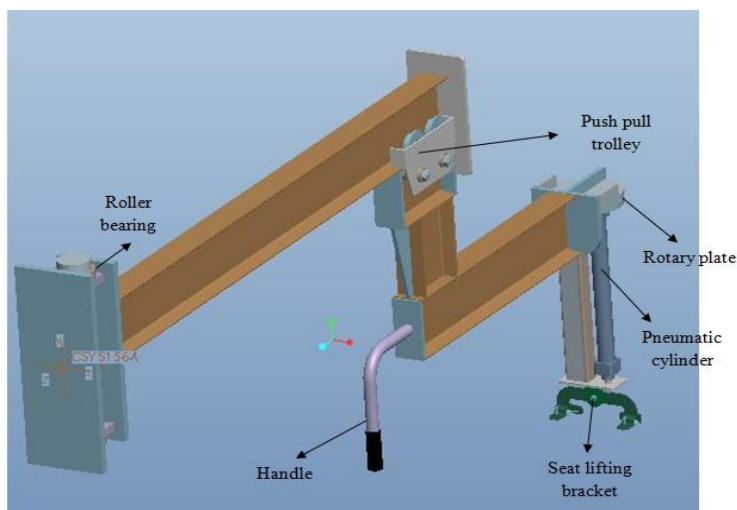
IV. DETAILED DESIGN

Figure 6: Fixture For Installing Front Seats Into a Car
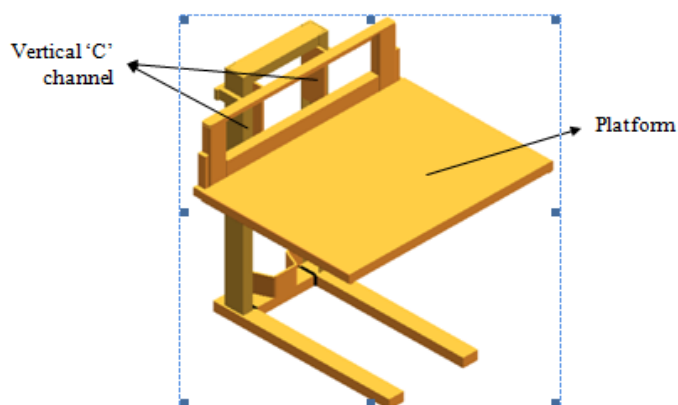
V. COMPONENTS OF FIXTURE

A. Seat lifting arrangement:

Figure 7: Seat Lifting Arrangement

Seat lifting arrangement consists of platform, hand winch mechanism and rope arrangement. The main function of seat lifting arrangement is to lift the seat from lower level to required height. The seat to be lift is placed on the platform. The Platform is raised by operating hand winch mechanism which is fixed between the vertical 'C' channels. The Rotary motion of hand winch lifts the platform from ground level to required height through rope arrangement, connected between platform and hand winch.

B. Hand winch mechanism

Figure 8: Hand Winch

Hand winch consists, set of spur gears and works on gear reduction mechanism. It has a handle to which driver gear is attached and is meshed with driven gear which is large in diameter compared to driver. Hand winch arrangement is connected to lifting platform and is employed to lift the platform on which front seat is placed. The rotary motion of gear/handle is converted into vertical lift of the platform.
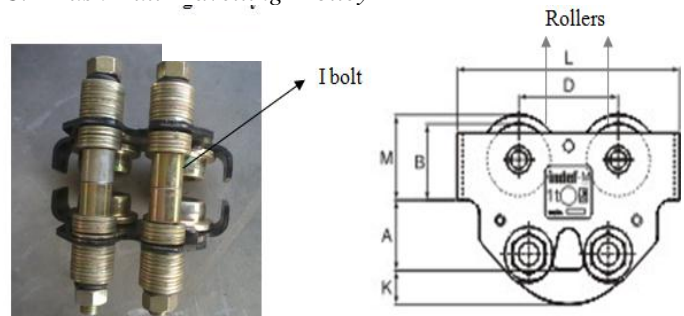
C. Push-Pull Travelling Trolley

Figure 9: Hand Winch

Push pull travelling trolley is employed to slide the lower portion of fixture. This setup consists, two sets of rollers which roll on the web of upper portion of the fixture. As rollers rolls along web, the lower portion moves to and fro. The setup is fastened to lower portion using I bolt. The Upper and lower portion of the fixture is made of I beam structure.

D. Roller Bearing:
It carries load by placing rolling elements (such as balls or rollers) between two bearing rings. The relative motion of the pieces cause the round elements to roll resistance with very little and with little sliding movement. In the project, a set of

roller bearings are employed and connected to the upper portion of fixture.
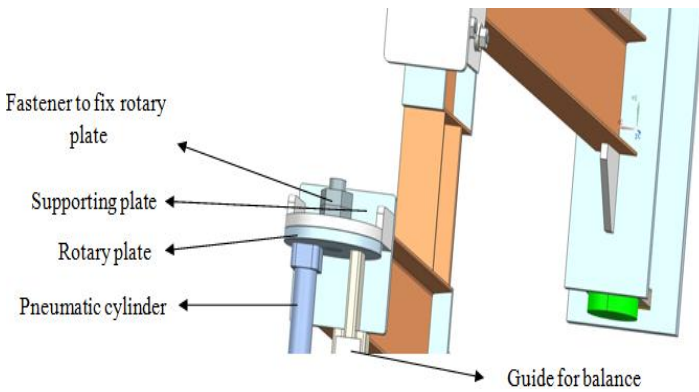
E.   Rotary Plate

Figure 10: Rotary Plate

The rotary plate is made of C45 steel material. During assembly process, rotary plate rotates the seat to a required angle, which is fastened to supporting plate with a clearance of 1mm. Threading is done at desired position of rotary plate to fasten the end of pneumatic cylinder.

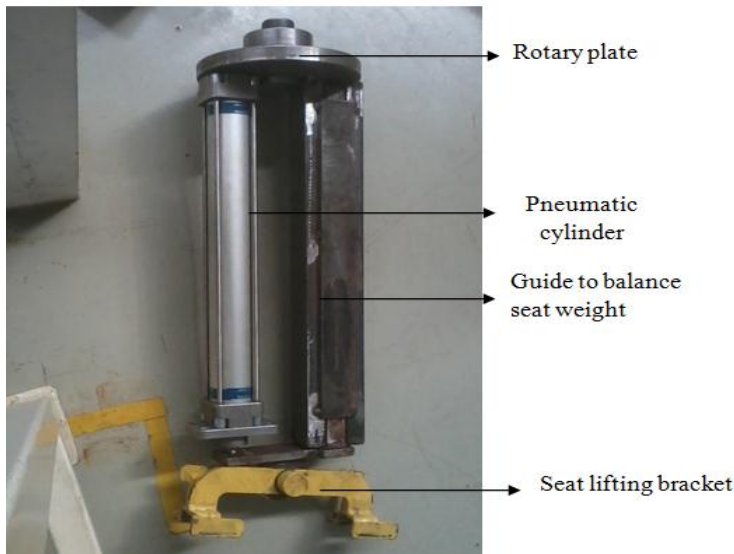F.   *Pneumatic Cylinder with Bracket*

Figure 11: Double Acting Pneumatic Cylinder with Bracket

These are mechanical devices, which use the power of compressed gas to produce a force in a reciprocating linear motion. They are also known as air cylinders. In the setup one pneumatic cylinder is employed. One end of the cylinder is fastened to rotary plate, and other end is fastened to seat lifting bracket.

G.   *DCV Valve*

Hand **5/2** Directional Control lever operated valves are particularly suitable for use in installations where no electrical control is allowed in that area.These valves are mainly used to control the direction of movement and retain pneumatic cylinders by virtue of spring returns are de-tented (de-tented: stays in position when lever is released and untill the lever is moved again).

VI. FINITE ELEMENT ANALYSIS OF FIXTURE AND SEAT LIFTING BRACKET

A.   Analysis of fixture when its lower portion is at extreme length.

B.   *Material Properties of Fixture*

The materials chosen for this analysis is Structural A36 Steel Alloy and C45 steel. The relevant material properties, from Reference [44-45] are summarized below in Table 2.

Table 2: Fixture Material Properties

Properties	A 36 Mild steel	C45 Steel	Units
Young's modulus	2e5	2.1e5	Mpa
Poisson's ratio	0.3	0.3	-
Yield strength	250	353	Mpa
Ultimate tensile strength	460	620	Mpa

1.   *Geometry*

For the analysis of fixture, model is prepared using modelling software Unigraphics 7.5 the IGES or STP file is imported in ANSYS Workbench 13.0. Figure 12 shows the geometry of fixture, in ANSYS 13.0 workbench environment.
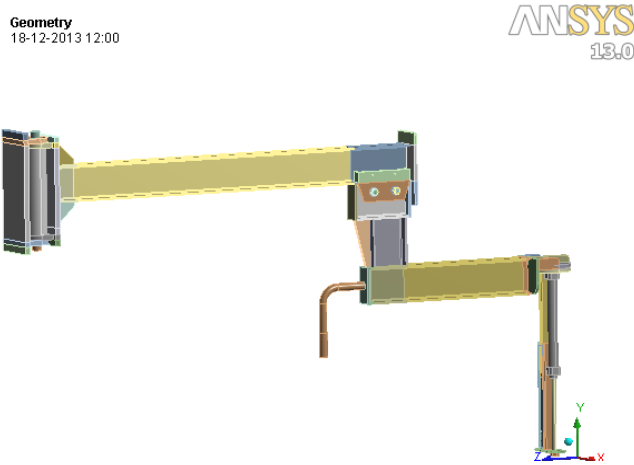
Figure 12: Geometry of Fixture

2. *Finite Element Model*

The model of fixture is mesh with Solid 186 tetrahedral and Solid 187 hexahedral element with 130900 numbers of nodes and 82108 total numbers of elements. The solid elements has three degree of freedom i.e. translation in X, Y and Z-directions. Figure 13 shows the meshed model of fixture.
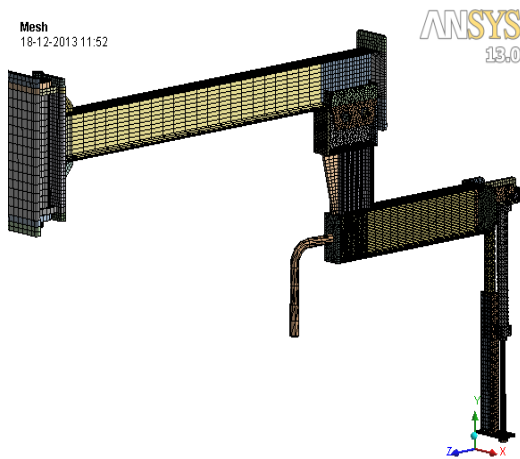
Figure 13: Meshed Model Of Fixture

Table 3: Meshing Details Of Fixture

Element Type	Solid 186,187/contact 174/Target 170
Nodes	130900
Elements	82108

3. *Boundary conditions*

Nodes of baseplate1 are constrained in all directions and nodes of baseplate2 are made to rotate only about Y-axis restricting it to 180 degree and all DOFs are arrested. Push pull travelling setup is free in Z direction to allow sliding movement and all other DOFs are fixed. A force of 324 N (which is indicated by red colour, the sharp edge of arrow shows the direction of force acting) is applied on cylinder arrangement in negative Y direction and other DOFs of cylinder are arrested. The rotary plate is made to rotate 360 degrees about Y axis and all other translation and rotational DOFs are constrained. The surface with violet colour shows the fixed support, in practice this surface is welded to frame, which intern fastened to superstructure of an assembly line. Figure 14 shows the boundary conditions considered for analyzing the fixture.
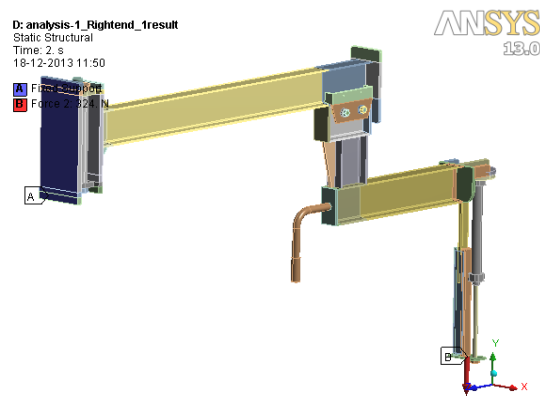
Figure 14: Boundary Conditions For Fixture

4. *Equivalent(von-Mises) Stress distribution*

The von Mises stress is used to perform the comparison of the FEA stress results. This allows for measuring stress at one single scalar variable. Examining the principal stresses or the stress states within different sections of the plate may provide additional information, for example show the different layers through the plate thickness in a state of compression or tension. Alternatively, the analysis can examine the stresses based on Cartesian coordinates. This would however increase the number of different stress variables (or directions) to examine and compare. Most structural evaluations are based on using the von Mises stress criterion for a convenient comparison with the material yield strength. Therefore, the stress results presented by this investigation are based upon the von Mises stress. Figure 15 shows the distribution of von-mises stresses induced within the fixture. Maximum stress of 14.456 Mpa is found at the portion of the rib.
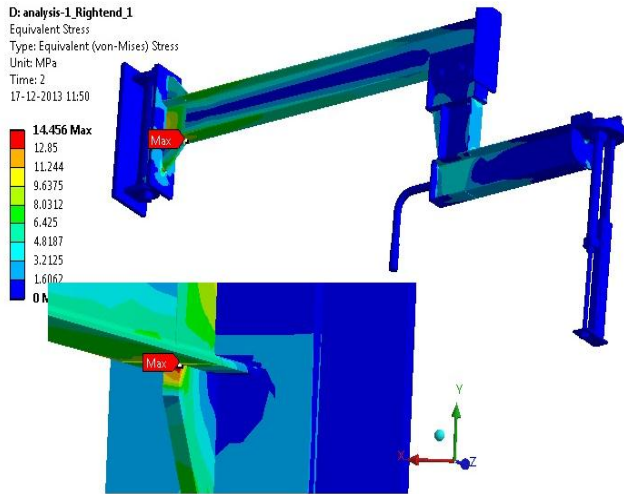
Figure 15: Von-Mises Stress Distribution on Fixture

5. Directional deformation (Y Axis)

The Directional deformation (Y Axis) of fixture is shown in Figure 16. The maximum static deformation of fixture is found to be 0.0030858 mm.
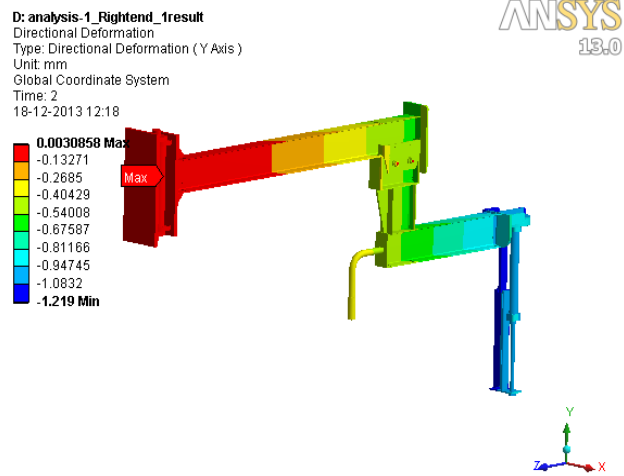

Figure 16: Directional Deformation of Fixture

C. Analysis of seat lifting bracket

Material Properties of Seat Lifting Bracket, the materials chosen for seat lifting bracket is Structural A36 Steel Alloy. The relevant material properties, from Reference [8- 9] are summarized below in Table 4.

Table 4: Seat Lifting Bracket Material Details

Properties	A 36 Mild steel	Units
Young modulus	2e5	Mpa
Poisson's ratio	0.3	-
Yield strength	250	Mpa
Ultimate tensile strength	460	Mpa

1. *Geometry*

For the analysis of bracket, model is prepared using modelling software Unigraphics 7.5, the IGES or STP file is imported in ANSYS Workbench 13.0. Figure 17 shows the geometry of bracket, in ANSYS 13.0 workbench environment.
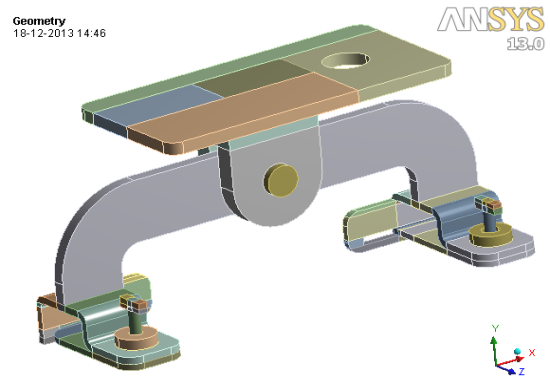

Figure 17: Geometry of Seat Lifting Bracket

2. *Finite Element Model*

The model of bracket is mesh with Solid 186 tetrahedral and Solid 187 hexahedral element with 54769 numbers of nodes and 37977 total numbers of elements as shown in table 5. The solid elements has three degree of freedom i.e. translation in X, Y and Z-directions. Figure 18 shows the meshed model of fixture.

Table 5: Meshing Details of Seat Lifting Bracket

Element Type	Solid 186,187/contact 174/Target 170
Nodes	54769
Elements	37977

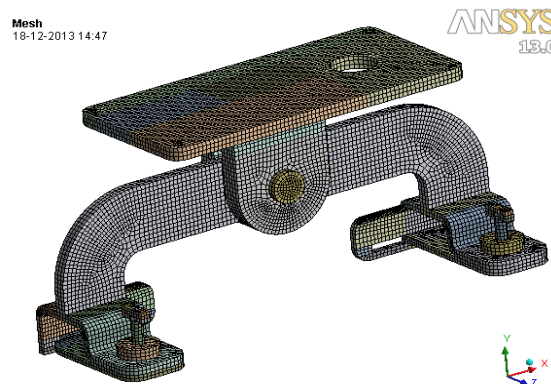Figure 18: Meshed Model Of Seat Lifting Bracket

3. Boundary conditions

A force of 162 N is applied at each end of the bracket as shown in Figure 19, which is indicated by red colour, the sharp edge of arrow shows the direction of force acting and the surface with violet colour shows the fixed support.
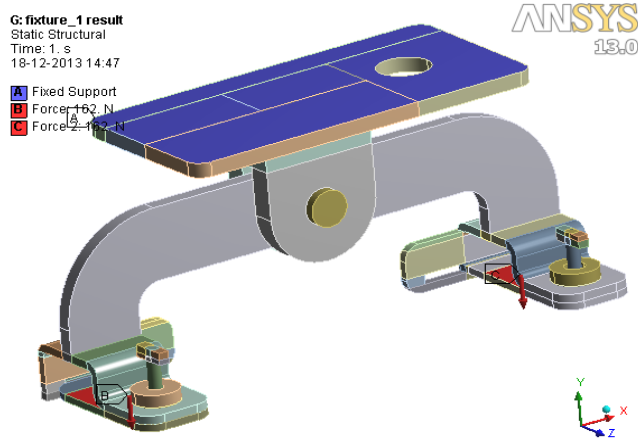

Figure 19: Boundary Conditions For Seat Lifting Bracket

4. Equivalent(von-Mises) Stress distribution

Figure 20 shows the distribution of von mises stresses induced within the bracket. Maximum stress of 30.158 Mpa is found at the hinged support, which is well below the yield strength of the selected material and hence we can assume that the structure is safe.
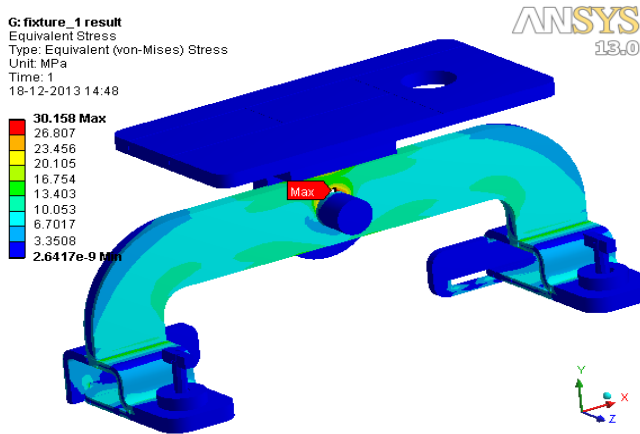

Figure 20: Von-Mises Stress Distribution On Bracket

VII. COST ESTIMATION

The total cost of the fixture involves several costs such as material cost, manufacturing (machining) cost, assembly cost, inspection cost. The total cost incurred for the fixture is tabulated below.

TABLE 6: TOTAL FIXTURE COST

SI . no	Description	Cost in Rs
1	Material cost	21600.3
2	Manufacturing cost	3820
3	Assembly cost	2000
4	Inspection cost	1000
Total		**28420.3**

VIII. CONCLUSION

1. By employing the front seat installation fixture, one operator is sufficient to install the front seat into a car.
2. The limitations that were observed during manual front seat installation process, such as fatigue to the operators, difficult to withdraw the seat to its position, cycle time, and fouling of seat with other components. All the above limitations have been overcome.
3. After installing the front seat assembly fixture, cycle time is minimized by 40 percent.

IX. ACKNOWLEDGEMENT

X. REFERENCES

1. Kamijo et al. (1982). Evaluation of seating comfort. *Society of Automotive Engineers Technical Paper* 820761.
2. Rakesh Singh, S.L. Ahirwar and Sunil Kumar Tiwari, "Designing of High Comfort, Reliable and Economical Driver Car Seat" *(IJETAE)* ISSN 2250-2459, www.ijetae.com Volume 3, Issue 10, October 2013.
3. G.Andreoni, F. Beverina, G. C. Santambrogio1 (2006), "The ergonomics of car driver seats". *Ergonomia IJE&HF*, Vol. 28, pp. 2, 113–123.
4. Chetan kumar maini "Development of a globally competitive electric vehicle in India" *J. Indian Inst. Sci.*, Mar.–Apr. 2005, 85, 83–95.
5. C.B. Bryant, RB Stone, DA. Mc adams, Daniel A; Kurtoglu Tolga and campbellm MI. "Concept generation from the functional basis of design" *International Conference On Engineering Design*. 2005:1702-1715.
6. K. Thriveni and Dr.B.JayaChandraiah. "Modeling and Analysis of the Crankshaft Using Ansys Software", *International Journal of Computational Engineering Research*, Vol, 03 Issue, 5.
7. M. A. Kumbhalkar, Umesh Nawghare, Rupesh Ghode, Yogesh Deshmukh and Bhushan Armarkar "Modeling and Finite Element Analysis of Knee Prosthesis with and without Implant", DOI: 10.13189, *ujcmj*.2013.010204.
8. Mr. Pulkeet Sharma, Mr. Nikhil Sohoni, Mr. Ketan Dawoo and Mr. Nakul Mahalle, "Design and development of car seat safety mechanism", *MSRIT* Bangalore.
9. Ceglarek, D., Li, H., Tang, Y., "Modelling and Optimization of Fixture for Handling Compliant Sheet Metal Parts," *ASME, J. of Manufacturing Science and Engineering,* Vol.123, No.3, pp.473-480, 2001.
10. Product Design and Development Karl T. Ulrich and Steven D. Eppinger *4th edition, Irwin McGraw-Hill,* 2008.
11. Mustafa bin Yusuf "Development of an automotive seat for ride comfort*" int. j. of automotive year* 2005 issue 74113.
12. P.V.Srihari, et.al. "Design and Development of an Assembly Fixture for Mounting a Circlip to the Piston'' *International Journal of Engineering Research and Applications (IJERA)* ISSN: 2248-9622 www.ijera.com Vol. 2, Issue4, July-August 2012, pp.1476-1479.[20]
13. Meridith Grimsley and Birmingham, Slide assembly fixture for rear hub assembly, *United States patent*, patent No. 7225516, (2007). [21]
14. Frank M Prucha and Birmingham, Ring assembly fixture, *United States patent*, Patent No. 2865091, (1958).[22]
15. Esa Hietikko. "Estimation of Manufacturing Costs in the Early Stages of Product Development Project" *International Journal of Modern Engineering Research* (IJMER) Vol. 2, Issue. 6, Nov.-Dec. 2012 pp-4673-4676.
16. K. Schreve, A. H. Basson. Small Volume Fabrication Cost Estimation Models for Embodiment Design. *R&D Journal* 2004 Vol 20, no. No 1 to 3.