DESIGN OF CNC MILLING FIXTURE FOR AN ALUMINUM AEROSPACE COMPONENT

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ABSTRACT

Over the past century, manufacturing has made considerable progress new machine tools, high-performance cutting tools and modern manufacturing processes enable today's industries to make parts faster and better than ever before. Although work holding methods have also advanced considerably, the basic principles of clamping and locating are still the same. In traditional machining fields or modern flexible manufacturing systems, the work piece holding is the first issue of the machining operation to be confronted. Fixtures are the special production tools which make the standard machine tool, more versatile to work as specialized machine tools. Fixture design is a critical manufacturing activity in the production cycle and has great effect on product quality, lead time, and cost targets, and labour skill requirements in product manufacturing. This paper gives detailed description on designing a Milling fixture so that milling operation is performed properly to obtain required dimension for an aluminum component used in an aerospace application. It also includes the detailed result of analysis done for the assembled fixture, to know the behavior of the component against the operating load.The proposed fixture is designed to adopt cost effective manufacturing process so that it can be machined easily with a lesser time and in turn it saves the machining time and manufacturing cost.

Keywords: Design; Fixture; CNC Milling; Aluminum; Aerospace Conponent:

INTRODUCTION

Over the past century, manufacturing [01] has made considerable progress new machine tools, high-performance cutting tools and modern manufacturing processes enable today's industries to make parts faster and better than ever before. Although work holding methods have also advanced considerably, the basic principles of clamping and locating are still the same. In traditional machining fields or modern flexible manufacturing systems, the work piece holding is the first issue of the machining operation to be confronted. To ensure the machining accuracy of specific dimensions, it is necessary to correctly determine the position

of the work piece related to the cutting tool and immobilize this correct position during entire machining operation. Fixtures are the production tool used locate and hold a work piece in position during manufacturing process. Fixtures are used to manufacture duplicate parts accurately. Fixtures vary in design from relatively simple tools to expensive, complicated devices. Fixtures also help to simplify metalworking operations performed on special equipments.Fixtures play an important role on reducing production cycle time and ensuring production quality. Therefore to reduce production cost, fixture design, fabrication and its testing is critical.

Milling machine may be defined [02] as the type of machine in which the metal is removed by causing the job to be fed against a revolving cutting tool called the milling cutter. The horizontal milling machine spindle machine is very strong and powerful kind of machine. Multiple varieties of cutter are attached to the equipment to side, form, and face, to shape and remove materials. This equipment is commonly used to remove several materials using different cutter forms. It is used if vertical spindle machine is not appropriate to a specific job. Normally axis of rotation of feed given to the workpiece. Milling operation is distinguished from other machining operations on the basis of orientation between the tool axis and the feed direction, however, in other operations like drilling, turning, etc. the tool is fed in the direction parallel to axis of rotation. The cutting tool used in milling operation is called milling cutter, which consists of multiple edges called teeth. The machine tool that performs the milling operations by producing required relative motion between workpiece and tool is called milling machine. It provides the required relative motion under very controlled conditions.

J.C Trappey and C.R Liu [03] have established Fixturing techniques and methodology including the supporting and locating principles and clamping principles. Haiyan Deng and Shreyes N. Melkote [05 have described that the systematic approach for analyzing the dynamic stability of a fixtured workpiece during machining. In machining, fixturing stability refers to the ability of a fixture to fully restrain a workpiece that is subjected to dynamic cutting forces. Djordje Vukelic, Branko Tadiac and Peter Krizan [04] have presented and verified system for computer-aided fixture design is presented and verified. This system comprises methods and techniques for fixture design. The structure of this system is based on modular principle, and uses data base and knowledge base. Zhang fa-ping, Lu ji-ping, Yan yan Sun, hou-fang and Shahid [06] have mentioned that a framework to curb the machining errors based on the deformation of workpiece-fixture system is provided.

FIXTURE

Work holding in manufacturing is the immobilization of a part (workpiece) for the purpose of allowing a fabrication or an assembly process to be carried out on it. The term fixture is also commonly used to describe work holding. Design of work holding devices normally falls within the domain of expertise of tool designers, who decide what fabrication or assembly tools to use as well as what fixtures to employ. The overall objective is to increase productivity through increased rates of manufacturing: utilize tools with appropriate lengths of life and fixtures with optimum accuracies. A fixture [07] is a device for locating, holding and supporting a work piece during a manufacturing operation. Fixtures are essential

elements of production processes as they are required in most of the automated manufacturing, inspection, and assembly operations. Fixtures must correctly locate a work piece in a given orientation with respect to a cutting tool or measuring device, or with respect to another component, as for instance in assembly or welding. Such location must be invariant in the sense that the devices must clamp and secure the work piece in that location for the particular processing operation. There are many standard work holding devices such as jaw chucks, machine vices, drill chucks, collets, etc. which are widely used in workshops and are usually kept in stock for general applications.

A. *Classifications of Fixtures*

Fixtures are classified into two general classes:

- Manufacturing tooling
- Assembly tooling

Manufacturing tooling consists of those devices, which are used, in producing individual parts, e.g., when the ends of the connecting rod are to be faced by straddle milling. This type of fixture is used for holding the connecting rod during the milling process. Assembly tooling consists of those devices, which are used to hold the work and guide the tools for the parts being assembled. The centre section of the wings of airplane is assembled in a special jig in which parts are held in placed, drilled together and riveted. The assembly jig is so built that the components could fit together when located and so that no measurement is ever made and no blue print is ever referred by the workers assembling the wings. These types of fixtures are designed by a group of highly skilled workers and may be used less skilled labors.

B. *Elements of Fixtures*

Generally, all fixtures consist of:

- **Locating elements:** These position the work piece accurately with respect to the tool guiding or setting elements in the fixture.
- **Clamping element:** These hold the work piece securely in the located position during the operation.
- **Tool guiding and setting elements:** These aids are used in guiding or setting of the tools in correct position with respect to the work piece, e.g., drill bush guide the drills accurately on to the work piece. Milling fixtures uses setting blocks for correct positing of milling cutters with respect to work piece.

C. *Fixtures in Manufacturing*

Fixtures provides a means of manufacturing any desired number of parts to desired tolerances because they set the relationship between the work and the machine tool to do so they are equipped with means for.

- Locating the work
- Clamping the work
- Supporting the work

- Holding all the elements together in a rigid frame work
- Guiding the tool(in case of jigs)
- Fastening and positioning the unit on the machine tool(in case of fixtures) because of these characteristics jigs and fixtures posses several distinct advantages in manufacturing, in that they
    - Ensure the interchangeability and accuracy of parts manufactured.
    - Minimize the possibility of human errors.
    - Permit the use of unskilled labors.
    - Reduces manufacturing time.
    - Allow production of repeat orders without retooling.

FIXTURE DESIGN

Fixtures are the production tool [08] used locate and hold a work piece in position during manufacturing process. The Purpose of this is the correct relationship and alignment between the cutter, or other tool and the work piece must be maintained. To do this, a fixture is designed and built to hold, support and locate work piece to ensure that each work piece is machined within the specified limits. A fixture should be securely fastened to the table of the machine upon which the work is done. Fixture planning is to conceptualize a basic fixture configuration through analyzing all the available information regarding the material and geometry of the workpiece, operations required, processing equipment for the operations and the operator. It plays an important role on reducing production cycle time and ensuring production quality.

Fixture is designed using the software SolidWorks. The material for fixture is Mild Steel ST42. Here, component passes through 4 faces. The component is having machining activities on 4-axis horizontal milling machine. The machine used for this operation is MIKRON UMC600 having controller Hiedenhain. So 4-axis Horizontal milling machine is used to hold and locate the fixture plate and it is located on rotary table. Fixture plate contains two units:

- Top plate
- Base plate

Top plate is assembled with base plate, surface grinding is done for top plate. If the surface grinding is done for top plate without assembling with the base plate, then there will be no parallelity between top plate and machine bed. It is case hardened to avoid scratches and damages during consequent location of component

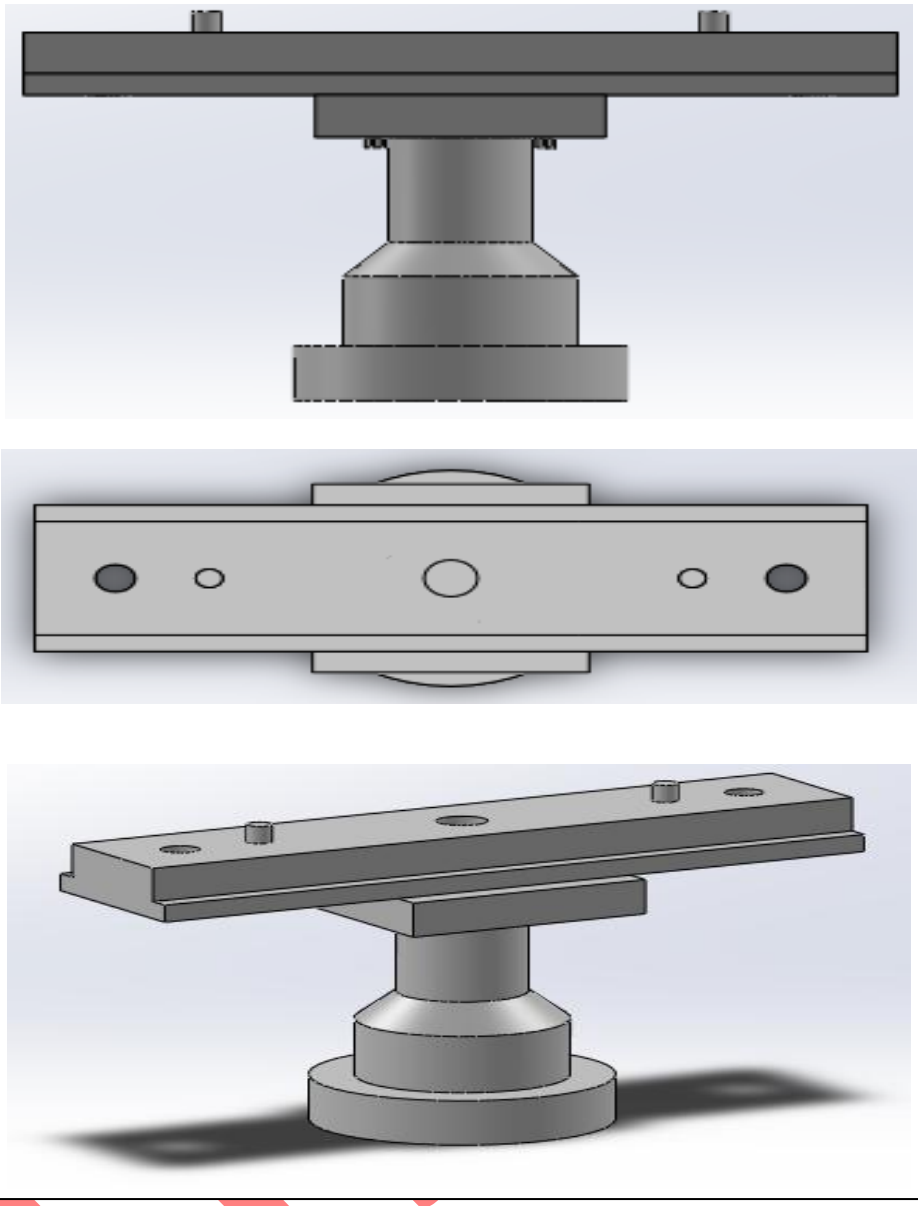

Figure 1. Different Views of Fixture.

COMPONENT DETAILS

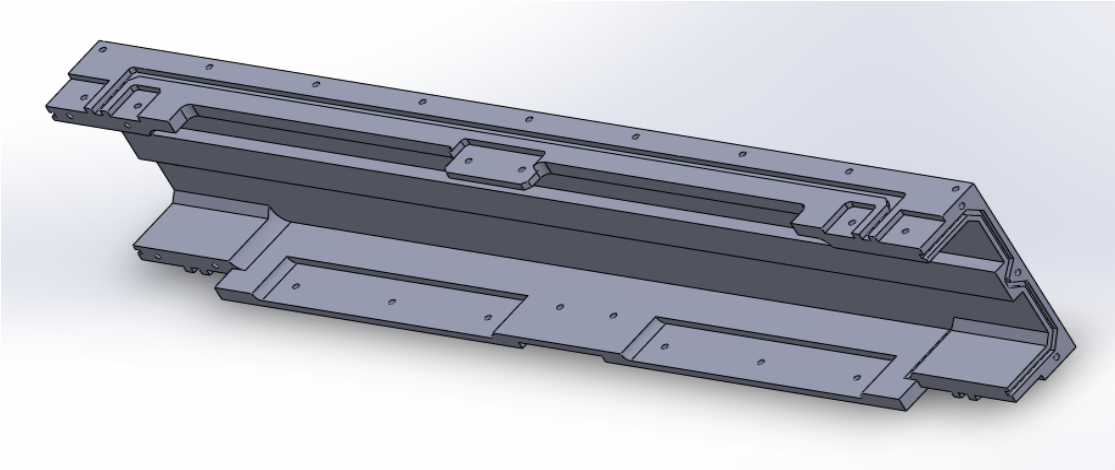

Figure 2. Aerospace Component.

This component is used in aerospace. The component is made up of Al IS 54300 having a minimum tensile strength of 49 MPa

Table I. Component Details.

Name	***Aerospace Component***
Material	***Aluminum IS 54300***
Component weight	***1Kg***
Material size	***410×84×43.7 mm***
Melting temperature	***933.47 K (660.32 °C, 1220.58°F)***
Boiling point	***2740.15 K (2467 °C, 4472.6 °F)***
Quantity	***110***
Accuracy	***± 0.1 mm***
Density	***2.70 g/cm^3.***

A. Component Material (Aluminum IS 54300)

Aluminum is found primarily in bauxite ore. Pure aluminum is soft, silvery, ductile of the poor metal group of chemical elements, which is corrosion resistant, light weight and high electrical conductivity. It has the symbol Al and atomic number 13. The metal is used in many industries to manufacture a large variety of products and is very important to the world economy. Structural components made from aluminum and its alloys are vital to the aerospace industry and very important in other areas of transportation and building. It is widely used for foil and conductor cables, but alloying with other elements is necessary to provide the higher strengths needed for other applications.

B. Material Properties

- Aluminum is a soft, lightweight metal with normally a dull silvery appearance caused by a thin layer of oxidation that forms quickly when the metal is exposed to air.

- Aluminum oxide has a higher melting point than pure aluminum. Aluminum is nontoxic (as the metal), nonmagnetic, and nonsparking.
- It has a tensile strength of about 49 MPa in a pure state and 400 MPa as an alloy.
- Aluminum is about one-third as dense as steel or copper; it is malleable, ductile, and easily machinable and castable.
- It has excellent corrosion resistance and durability because of the protective oxide layer.
- Aluminum mirror finish has the highest reflectance of any metal in the 200-400 nm (UV) and the 3000-10000nm (far IR) regions, while in the 400-700 nm visible range it is slightly outdone by silver and in the 700-3000 (near IR) by silver, gold, and copper.
- It is the second-most malleable metal (after gold) and the sixth-most ductile. Aluminum is a good thermal and electrical conductor

MANUFACTURING OF THE COMPONENT

A. Manufacturing by using Vice

Vice is a device that analyses all the available information regarding the material and geometry of the workpiece, operations required, processing equipment for the operations and the operator. Following are the steps to be considered in manufacturing of component with Vice.

Table II. Manufacutirng using Vice.

Setting	***Process***
1a	***Pre-tooling***
1b	***Deburring***
2a	***Conventional Milling***
2b	***Deburring***
3a	***CNC Milling***
3b	***Deburring***
4a	***CNC Milling***
4b	***Deburring***
5a	***CNC Milling***
5b	***Deburring***
6a	***CNC Milling***
6b	***Deburring***
7a	***CNC Milling***
7b	***Deburring***
8a	***CNC Milling (Scooping)***
8b	***Deburring***
9	***Inspection***

B. Manufacturing using Fixture

Fixture is used to hold the component during manufacturing. There are only 6 steps required for the completion of one component. Here, component passes through 4 faces. The component is having machining activities on 4-axis horizontal milling machine. The machine used for this operation is MIKRON UMC 600 having controller Hiedenhain. So 4-axis Horizontal milling machine is used to hold and locate the fixture plate and it is located on rotary table.

Table III. Manufacutirng using Fixture.

Setting	***Process***
1a	***Pre-tooling***
1b	***Deburring***
2a	***Conventional Milling***
2b	***Deburring***
3a	***CNC Milling***
3b	***Deburring***
4a	***CNC Milling (1st Setting) 0º***
4b	***CNC Milling (2nd Setting) 90º***
4c	***CNC Milling (3rd Setting) 180º***
4d	***CNC Milling (4th Setting) 270º***
4e	***Unloading of Component***
4f	***Deburring***
5a	***CNC Milling (Scooping)***
5b	***Deburring***
6	***Inspection***

C. *Comparison of Vice and Fixture with parameter Time*

Table IV. Coparison Table.

Tool	***Vice***	***Fixture***	***Difference***
Total Time	***27 ½ Hrs***	***24 ½ Hrs***	***3 Hrs***

RESULTS AND DISCUSSIONS

By considering the manufacturing using vice, vice is a device that analyses all the available information regarding the material and geometry of the workpiece, operations required, processing equipment for the operations and the operator. The vice requires 9 steps to complete one component. The overall manufacturing time (including setting time) is 27 ½ Hrs for one component. Proposed Method of Manufacturing using fixture. Fixture is used to hold the component during manufacturing. There are only 6 steps required for the completion of one component. Here, component passes through 4 faces. The component is having machining activities on 4-axis horizontal milling machine. The machine used for this operation is MIKRON UMC 600 having controller Hiedenhain. So 4-axis Horizontal milling machine is used to hold and locate the fixture plate and it is located on rotary table. The overall manufacturing time (including setting time) is 24 ½ Hrs for one component.

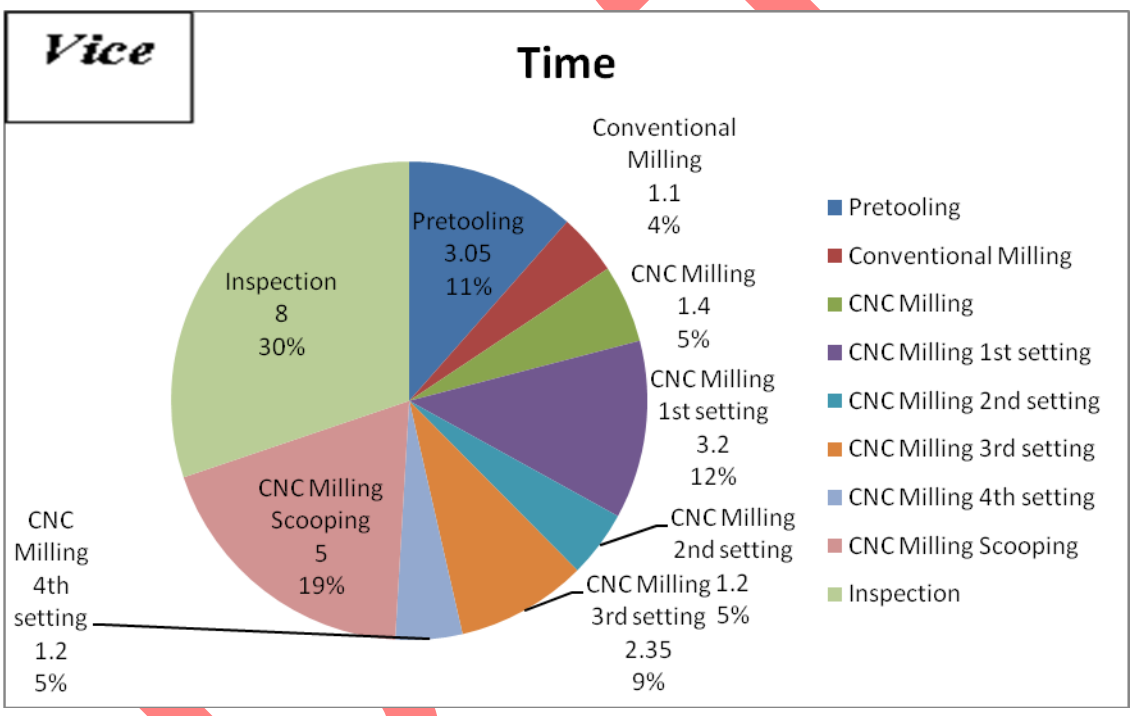

Figure 3. Pie Chart for Vice considering Time.

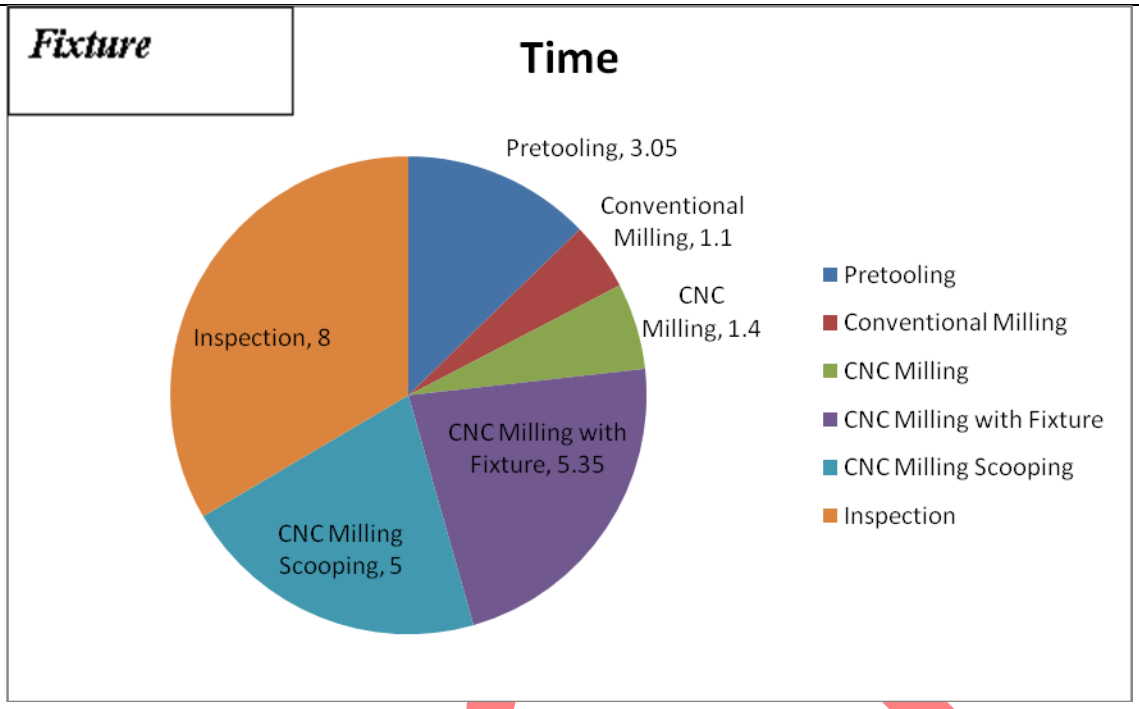

Figure 4. Pie Chart for Fixture considering Time.

Hence the following result is achieved using fixture.

- Total operating time required to machine one component is reduced to 3 Hrs. This is because the loading/unloading (i.e. handling and setup time) time of the component is considerably reduced by using Fixture.
- The fixture which is designed will reduce the human fatigue, lead time and hence increases the profits and the productivity.
- The overall quality of the machining was found to be much better than compared to the Vice.
- This is a batch production. In this we are producing 110 components. So, for total production the difference is 330 Hrs time.

CONCLUSIONS

The design of the fixture is simple, the loading and unloading of component is very easy. At a time all the operations such as milling, boring, drilling, tapping can be done in a single set up which in-turn decreases the handling and machining time. The fixture is designed with least number of components. Considering the dynamic forces over the component, analysis has been done; it shows the possible displacement, stress and deformed shape of the component. This indicates that the component will not get distorted during the milling operation.

By considering all the above mentioned facts, the proposed design of the fixture will meet the necessary requirements to achieve optimum production rate. The total operating time required to machine one component is reduced to 3 Hrs. This is because the loading/unloading (i.e. handling and setup time) time of the component is considerably reduced by using Fixture.

The fixture which is designed will reduce the human fatigue, lead time and hence increase the profits and the productivity. The overall quality of the machining was found to be much better than compared to the Vice.

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REFERENCES

[1] Y.G. Liao, S. J. Hu, "*An Integrated Model of a Fixture - Workpiece System for Surface Quality Prediction"*, Hayward Street, International Journal of Advanced Manufacturing Technology, Ann Arbor USA, 2001.

[2] Gorukle, "*Machining fixture locating and clamping position optimization using genetic algorithms"*, Uludag University, Bursa 16059, Turkey, 26th May 2005.

[3] J.C Trappey, C.R Liu, "*A Literature Survey of Fixture Design Automation"*, Purdue University, International Journal of Advanced Manufacturing Technology. West Lafayatte, U.S.A, Vol. 5, 1990.

[4] DjordjeVukelic, BrankoTadiac, "*A rule-based System for Fixture Design"*, Scientific Research and Essays, 16 November 2011.

[5] Haiyan Deng, Shreyes N. Melkote, "*Analysis of Fixturing Dynamic Stability in Machining"*, Monterey, California, USA, 24-28 July, 2005.

[6] Zhang fa-ping, Lu ji-ping, Yan yan Sun, hou-fang and Shahid, "*An Integrated Methodology for Workpiece-fixture System Stiffness Calculation and Error Control"*, Beijing 100081, International Conference on Measuring Technology and Mechatronics Automation, P.R.China, Vol. 2, April 2009.

[7] N.Kaya, F.Ozturk, "*Contact Analysis of Workpiece – Fixture",* Gorukle, Bursa 16059 Turkey.

[8] Jo Lee, L.S. Haynes, "*Finite-Element Analysis of Flexible Fixturing System*", Gaithersburg, Vol. 109, Journal of Engineering for Industry, May 1987.

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