Design, Modelling and Manufacturing of Fixture for Machining Adaptor of Gas Equipment with an Approach to Improve Productivity

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Abstract : Various areas related to design of fixture are very well described by renowned authors, but there is an urgent need to couple and apply all these research works to an industrial application. This paper satisfies this urgency by designing a fixture for a real industrial component - adaptor of gas equipment with an aim to reduce cycle time and increase productivity using time study and work study principles of Industrial Engineering. A fixture is designed to perform slotting operation. The salient fatures of the present volume of this research is that a slot on both walls of the component can be produced in a single set up using a designed fixture by providing a special ratchet screw attachment, which can turn a part after performing an operation on one side of wall. As fixture is not only designed but manufactured also, it sets the classical example of design for manufacturing.

Index Terms **- Fixture, Design for Manufacturing, Slotting, Productivity.**

1. INTRODUCTION

A machining fixture is an essential aspect of the manufacturing process to achieve correct relationships and alignment, intermediate with the tool and work piece throughout the machining operation. The aim of using fixture is to obtain high degree of accuracy and interchangeability at a competitive cost and increase industrial efficiency. One of the methods to reduce manufacturing cost of the job is to reduce machining cycle time by reducing non-productive time like loading and unloading work piece on the machine. Complex work piece can be located through fixture to make quick production and it is disassembled when production process is completed. Accuracy of any product is based on various machining parameters, skilled operators, machine alignment, clamping of tool and work piece. Clamping arrangement of tool is done on machine table only and provided by machine tool manufacturer company whereas clamping arrangement of workpiece is done with the help of other fixed body i.e. jig or fixture.

There is a clear demand for designing & manufacturing fixture for real industrial component and more research in computerized fixture design in such fields. The present research work satisfies this demand by deploying the fixture design task into an overall manufacturing process to obtain best fixture design solution for real industrial component. The component is adaptor of gas equipment. A fixture is designed to perform slotting operation. The salient features of the present volume of this research is that a slot on both walls of the component can be produced in a single set up by providing a special ratchet screw attachment, which can turn a part after performing an operation on one side of wall. As fixture is not only designed but manufactured also, it sets the classical example of design for manufacturing. The important details of the part and fixture are included in each fixture design section for clarifying doubts in addition to component drawing & fixture drawing. The research work includes the 3D of fixture using Creo 2.0.

The paper is organized as follows. Section 2 presents the conclusion obtained from literature review. Section 3 is the highlights of the research work and presents design & development of fixture for machining adaptor of gas equipment. Finally, conclusions are reported Section 4.

2. LITERATURE REVIEW

The fixture designing and manufacturing is considered as a complex process that demands the knowledge of different areas, such as geometry, tolerances, dimensions, procedures and manufacturing processes. While designing this work, a good number of literature and titles written on the subject by renowned authors are referred. All findings and conclusions obtained from the literature review and the interaction with fixture designers are used as a guide to develop the present research work. The following section gives a survey on the state of the art of this research.

Hargrove, S. K. and Kusiak, A. (1994) recognized functional requirements of fixture as centering, locating, orientating, clamping, and supporting. In terms of constraints, there are many factors to be considered, mainly dealing with: shape and dimensions of the part to be machined, tolerances, sequence of operations, machining strategies, cutting forces, number of set-ups, set-up times, volume of material to be removed, batch size, production rate, machine morphology, machine capacity, cost, etc. At the end, the solution can be characterized by its: simplicity, rigidity, accuracy, reliability, and economy.

As illustrated by Ibrahim M. Deiab and Mohamed A. Elbestawi (2005), workpiece location in a fixture is significantly influenced by localized elastic deformation of the workpiece at the fixturing points. These deformations are caused by the clamping force(s) applied to the workpiece. For a relatively rigid workpiece, the localized elastic deformations cause it to undergo rigid body translations and rotations which alter its location with respect to the cutting tool. It is therefore important to minimize such effects through optimal design of the fixture layout.

Four general requirements of a fixture are :
(i) Accurate location of the workpiece,
(ii) Total restraint of the workpiece during machining,
(iii) Limited deformation of the workpiece, machining interference.
(iv) No machining interference.

Dynamic machining conditions occur when a workpart is subject to machining forces that move through the work part or along its surface as stated by Meyer, R. T. and Liou F. W. (1997). A viable fixture designed for a workpart experiencing dynamic machining must ensure: the workpart is restrained for all time, the clamping forces are not too large or small, deterministic positioning, accessibility, stability of the workpart in the fixture while under no external forces, and a positive clamping sequence.

According to Menassa, R., and Devries, W. (1991), the types of fixture applications considered are for prismatic workpieces that use the 3-2-1 locating principle as the general structure of the fixture. The design synthesis problem uses six rules based on machining practice to select the secondary and tertiary locating datum for a workpiece stored in a boundary representation solid modeler. Once these edges are selected, kinematic rules are used to determine the position of the locating points so as to allow accessibility when loading and unloading a workpiece. Examples are given to illustrate this method, as well as the positioning of support points on the primary datum plane.

The positioning and orientation error results in the in accuracy of the work piece. The ability to accurately locate a work piece in a machining fixture is strongly influenced by displacements of the rigid body work piece caused by elastic deformation of loaded fixture–work piece contacts. Since the locator error is an important factor contributing to the overall machining error minimization of the contribution of locator error reduces the machining error. Deterministic location is ensured throughout the optimization process and minimal machining error is arrived at complying with the machining tolerance specification. This also provides the user with flexibility in choosing the layout according to the requirements illustrated by Bo Li, Shrikes N. Melrose (1999). By improving the fixture layout, considerably increase in the production rate and reduction in time is reported by Rétfalvi Attila, Michael Stampfer, SzeghImre (2013).

As stated by Iain Boyle, Yimingrong, David C. Brown (2011), fixtures are used to rapidly, accurately, and securely position workpieces during machining such that all machined parts fall within the design specifications for that part. This accuracy facilitates the inter-changeability of parts that is prevalent in much of modern manufacturing where many different products feature common parts.

Now follows the highlight of this research work – design & development of fixture for a real industrial component.

3. DESIGN AND DEVELOPMENT OF FIXTURE

In this section, an empirical study is presented to illustrate the application of the proposed trapezoidal fuzzy AHP method for identifying and ranking the enablers of KM adoption in SC.

3.1 PROBLEM STATEMENT

Design, modelling and manufacturing of fixture for machining adaptor of gas equipment on milling machine. The operations to be performed are forging, cutting, facing, turning, drilling, threading and slotting. The fixture is designed to perform slotting operation on both walls of the component in a single set up. The fixture should reduce product cycle time and increase productivity.

3.2 COMPONENT DETAILS

The component is made up of brass material, having weight 65 g. It is used as a joint or coupler for pipes through which gas fluid flows. The component in the raw material form is a hollow circular rod having 26 mm outside diameter, 10 mm inside diameter and 44 mm length. It is cut, then forged and machining with 2 mm allowance on conventional troop. Figure 1 shows 3D views and photographs of finished component.

Figure 1. 3D views and photographs of finished component

3.3 MANUFACTURING STEPS OF ADAPTOR

Cutting operation is performed on extrude rod, followed by forging process on brass rod.

The rod is being examined by inspection department.

Facing, straight turning, step turning, drilling, reaming, threading and slotting are performed. First of all facing operation is carried out, then straight turning using form tool and at last step turning operation. Hole is being drilled on the rod following by reaming operation. 14TPI thread is made on the rod by using single point cutting tool.

At last two slots are made with the help of designed fixture. The operation is carried on the universal milling machine. Slots are made by milling cutter. Fixture is mounted on the base plate of the machine. Rod is placed on the fixture and it is tightened through threaded screw. Then one slot is made by milling cutter. Now the workpiece is rotated through 180 degree and again same procedure is been carried out.

3.4 MANUFACTURING STEPS OF FIXTURE

Fixture is made from rectangular rod of 48 x 78 x 4.2 mm. Various operations required are turning, facing, milling, drilling and slotting. After turning operation, facing operation is performed using single point cutting tool. Drilling operation is performed to create holes on fixture. Hole is required to insert the threaded screw, which can be used to hold the workpiece. Slot is made using milling cutter on the universal milling machine. At last zinc coating is done on the fixture to prevent corrosion. Grinding operation is performed after final inspection by quality control department. Figure 2 shows 2D drawing and 3D views of fixture and fixture components.

3.5 FIXTURING SEQUENCE

Fixture is located on the base plate of the machine. Base plate is made up of CI material by casting process. Operation is performed on the Universal Milling Machine having horizontal bed. T-slot is placed on bed of the machine above which base plate is mounted. Base plate is fixed on the horizontal bed with the help of 4 hexagonal screw having B.S.W. thread. Fixture is placed in the hole of 23 mm diameter in centre of the base plate, so external support is not required.

Machine is operated now to check for the vibration of base plate and fixture as a measure of safety and for checking proper location on the bed as overall accuracy depends on consistent location. Fixture is located with reference of milling cutter central line.

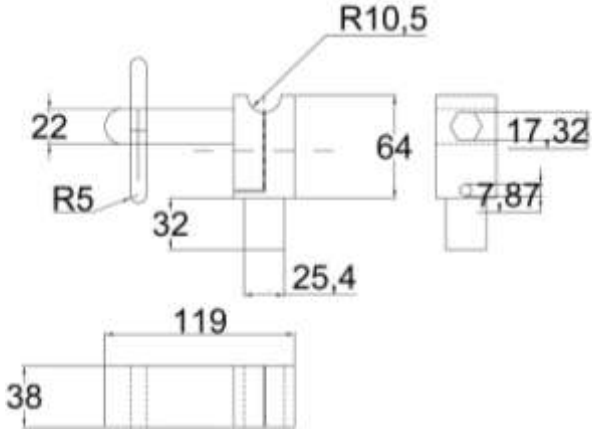
Clamping is to securely hold the position of workpiece while machining. The component is located on the fixture once fixture is set properly on the base plate. Precaution is required to match the center of the tool and workpiece before mounting the job. Fixture jaws hold the component with the help of screw and key. Key and screw attachment reduces non-productive time by decreasing loading and unloading time of the component.

4. TIME STUDY

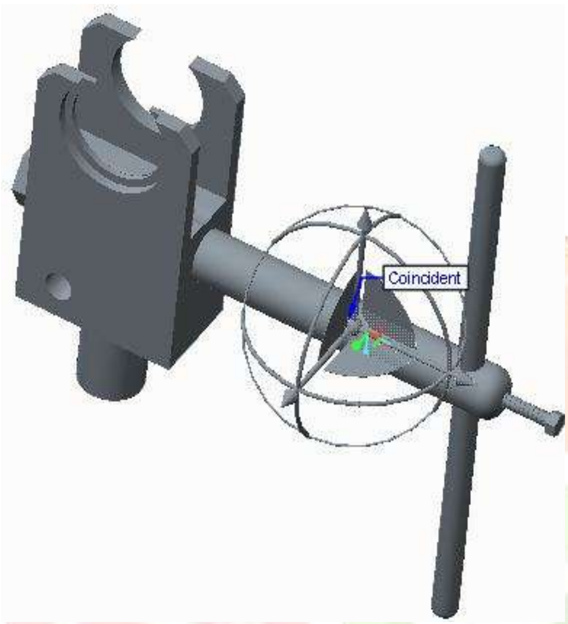
The foremost purpose of using a fixture is to improve productivity by decreasing cycle time to promote mass production and significant reduction in product cots. For the purpose of time study, observations of cycle time are recorded while performing the operation without / with the use of fixture. Table 1 shows the observations of cycle time using a fixture for 10 cycles. The average cycle time using a fixture is 20.7 sec per piece, which is 50 sec per piece on an average without using a fixture. Here the research work is proved, cycle time is reduced to less than half, resulting into significant improvement in productivity.

Table 1 Time study observations

Sr. No.	Cycle time (sec)	Sr. No.	Cycle time (sec)
1	20.7	6	18.7
2	19.5	7	21.5
3	17.4	8	22.1
4	19.3	9	19.8
5	21.3	10	20.4



(a) 2D drawing of fixture



(b) 3D view of fixture assembly

(c) Screw and key attachement

Figure 2 2D drawing and 3D view of fixture

5. CONCLUSION

An integrated approach of design for manufacturing with principle of Industrial Engineering has been adopted in this work. This approach is of crucial importance in real manufacturing environment. By using the designed fixture, operation time of jo b is minimized and productivity is increased. Traditionally, two fixtures were used to perform slotting operation on two walls of the component. Now two slotting opration can be performed in a single set up using a designed fixture, which results into improvement in accuracy, reduction in set up time, reduction in quality control cost and manufacturing cost with better quality output. Cycle time is reduced to 20.7 sec in comparison to 50 sec without using a fixture. These all results conclude that fixture is an excellent answer for questions related to mass production and productivity improvement in modern manufacturing industries.

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