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Design and Modeling of Fixture for Cylinder Liner Honing Operation

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Abstract - Model of new fixture design is presented for cylinder liners honing operation to improve productivity and reduce the rejection rate on honing machine. In mass production of cylinder liners, the industrial honing involves abrasive finishing process, during that liners need to be fixed on honing machine, For that a new model of fixture setup relative to honing operation of cylinder liner is proposed, planned and modeled such that the liners can be held in form closure and totally immobilized.

This paper uses newer and innovative design of present day manufacturing industries for locating, positioning, clamping, for uniforce clamping hydraulic clampings are used. Fixture design is one of the important factor that play a role in providing manufacturing processes with more productivity and have brought many benefits like reduced rejection.

Fixtures are used in many manufacturing processes to locate, hold and support the work securely. While designing this paper, a good number of literature written on the subject by renowned authors are referred. The paper includes finished parts model and 3D assembled view of fixture using Pro/Engineer Wildfire.

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Sandeep Soni [α] & Ravindra Mane [σ]

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I. Introduction

The need for improved productivity and reduced time to market has been increased significantly in manufacturing processes in recent decades. Fixtures have a direct impact upon product manufacturing quality, productivity and cost hence there are many factors playing roles in manufacturing processes in order to improve productivity and reduce production time. Fixtures are one of the important tools that are widely used to achieve this goal.

Fixtures are mechanism used to rapidly, accurately, and securely position workpiece during machining such that all machined parts fall within the design specifications. This accuracy facilitates the inter-changeability of parts.

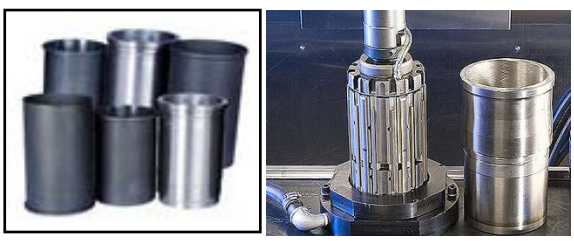
Several designs and design methodologies associated with fixture design and their practical implementation, which have been addressed by many authors [1], [2], 3], [6], [9]. The most important work on design of fixture is discussed as, the fixture designing and manufacturing is considered as complex process that demands the knowledge of different areas, such as geometry, tolerances, dimensions, procedures and manufacturing processes [1],[3]. Generally, the costs associated with fixture design and manufacture can account for 10%–20% of the total cost of a manufacturing system. Approximately 35% to 40% of rejected parts are due to dimensioning errors [6].

Therefore, with the increasingly intense global competition which pushes every manufacturer in industry to make the best effort to sharpen its competitiveness by enhancing the product's quality, reducing the production costs and reducing the lead time to bring new products to the market, there is an strong desire for the upgrading of fixture designs with the hope of making sound fixture design more efficiently and at a lower cost.

While designing this work, a good number of literatures written on the subject by renowned authors are referred. All findings and conclusions obtained from the literature review regarding the fixture design are used as guide to design the present work.

II. Problem Statement

Honing is a machining process for finishing internal cylindrical surfaces. In order to reduce engine oil consumption a high percentage contact area of cylinder liner is required and minimal dislocations in the boundary layer and the creation of a uniform and consistent surface over the whole cylinder bore. For guaranteed producibility with efficient productivity in mass production of cylinder liners, the industrial honing involves an interrupted multistage abrasive finishing process (fig. 1), for this cylinder liner must be fixed on fixture during honing operation [5].



(a) (b)

Figure 1 (a) : Photograph of cylinder liner, (b) photograph of honing tool with cylinder liner

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The main problem in such operation is low productivity with high rejection. It is cumbersome process for the workers. The main task for it is to make the loading and unloading process simple, the time required should be minimized and operation should be easier one. By observing industrial problems and studying previous process of fixing cylinder liner on honing machining, there is need of designing new fixture to increase the productivity and reduce the rejection rate with the loading and unloading process simple.

For this fixture and innovative design are considered. Various areas related to design of fixture are already been very well described by various renowned authors, this paper integrates all these research works and theoretical knowledge of fixture design to design this new fixture for component like cylinder liner.

III. Design of Fixture - Methodology

A fixture is a production tool that locates, holds, and supports the work securely so the required machining operations can be performed. A fixture should be securely fastened to the table of machine upon which the work is done. Fixtures are essential elements of production processes as they are required in most of the automated manufacturing, inspection, and assembly operations [16].

In mass production fixture have five key aspects [12]:

- Reduce the cost of production.
- Maintain consistent quality.
- Speed up production.
- Prevent or reduce improper techniques.
- Improve the overall safety to the part, operator, and machine.

Fixture planning is conceptualize by a basic fixture configuration through analyzing all the available information regarding the specifications of the workpiece such as its shape, dimensions and tolerances, material and geometry of the work-piece, operations required, processing equipment for the operations, and the operator [7]. Other factors also influence the machining outcome including machining operations sequence, cost considerations, direction and strength of machining forces, capabilities and orientation of the machine tools.

Typically the design process by which such fixtures are created has major four phases (fig. 2) such as fixture planning, fixture layout, fixture element design, fixture body design [8]:

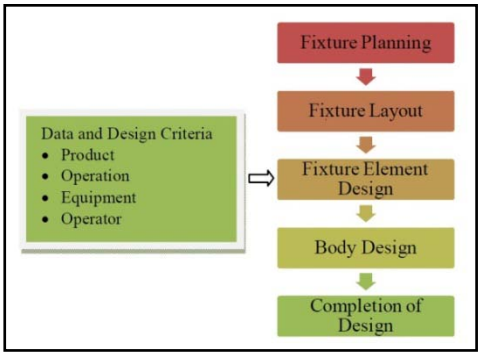


Figure 2 : Phases of fixture design

The following inputs are included in the fixture plan:

- Fixture type and complexity.
- Number of work-pieces per fixture.
- Orientation of work-piece within fixture.
- Locating datum faces.
- Clamping surfaces.
- Support surfaces.

Generation of fixture layout is to represent the fixture concepts in a physical form. The following outputs are included in the fixture layout:

- Types and Position of locators.
- Types and Position of clamps.
- Types and Positions of supports.
- Clamping forces and sequence.

Fixture element design is either to detail the design drawings committed on paper or to create the solid models in a CAD system of the practical embodiment of the conceptual locators, clamps and supports. It is possible to use standard designs or proprietary components. Fixture body design is to produce a rigid structure carrying all the individual fixture elements in their proper places.

IV. Work Holding Principles

a) Locating Principles

A locator is usually a fixed component of a fixture. It is used to establish and maintain the position of a part in the fixture by constraining the movement of the part. For work-pieces of greater variability in shapes and surface conditions, a locator can also be adjustable.

An unrestricted object is free to move in any twelve possible directions. Fig. 3 shows an object with three axis and planes, along which movement may occur [16]. An object is free to revolve around or move parallel to any axis in either direction. To illustrate this planes have been marked X-X, Y-Y, Z-Z, The directions of movement are numbered from one to twelve.

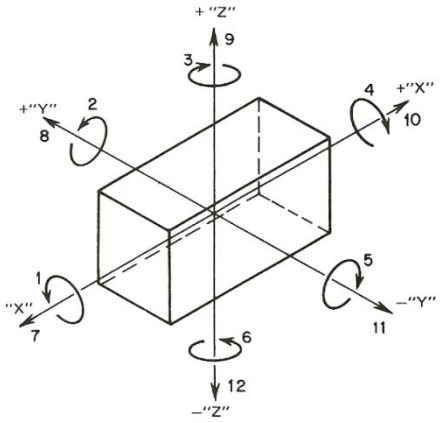


Figure 3 : Degrees of freedom (DOF) and planes of movement

To restrict the movement, accurately locate a part in fixture. This is done with locaters and clamps.

b) Characteristics of good location

– Minimum locating points should be used.
– Locating points should be placed as far as apart as possible.
– Locating should be small and size.

In general, three locating forms can be considered, namely plane, concentric, and radial. For plane locating form, locators are used to locate the workpiece on any surface such as flat, circular or irregular surfaces. For concentric locating form, pin-hole locators are used and for radial locating form, locators restrict the workpiece movement around the concentric locators [7]. The 3-2-1 principle is the most commonly method used. In this method, three perpendicular surfaces of the workpiece are used to define the locating position.

c) Clamping Principles

As the locating is important to restrict the movement of the workpiece, clamping is also important to resist the effects of cutting forces. The direction of clamps should be determined according to cutting force direction in order to perform machining operations securely. Clamping forces should be in the same direction of the machining forces which try to push the workpiece down onto the locators and supporters. The clamp should be large enough to hold the workpiece and small enough to stay away of the cutting tool path [7]. There are some other factors that should also be considered in use of clamps. These include machine tool vibration, loads and stresses, damage preventing of the workpiece, and improving loading/unloading speed.

A clamp is a force-actuating mechanism of a fixture. The forces exerted by the clamps hold a part securely in the fixture against all other external forces. In every machining operation, clamping of work-pieces is an essential requirement. A clamp can be defined as a device for providing an invariant location with respect to an external loading system. In other words, the process of clamping induces a locking effect which, through frictional or some other forms of mechanism, provides a stability of location which cannot be changed until and unless external loading is able to overcome the locking effect [11]. Hence, when a cutting force is producing a load or moment on the work-piece, it is necessary that a sufficient clamping force must be exerted to withstand such actions.

It is also essential that the idle time involving loading, locking, unlocking and unloading of work-pieces should be minimized as much as possible to reduce the overall set-up and non-machining time. Clamping elements may be either manually operated or actuated by pneumatic, hydraulic or a combination of other power facilities [14]. They are also classified according to the mechanism by which a mechanical advantage is attained.

V. Component Details

In industries there are different types of cylinder liners are manufactured according to application requirement.. For this fixture all input data explained in above design procedure is collected. MS material is selected for design and components are designed and modeled.

Top and base plate locate the cylinder liner, four guide pillars are used to guide the top plate for clamping and unclamping, guide bush of Gun Metal material is used to avoid the wear between guide pillar and top plate, oil ring is used at top plate to provide oil at inside surface of liner for cooling and to remove fine particles of machining, bottom plate and fixture riser ring are used as fixture body base. For clamping hydraulic cylinders are selected according to clamping force requirement,

$$\text{Clamping force} = P \times \frac{\pi}{4} d^2$$

Where, P = Hydraulic pressure N/mm^2.
d = Cylinder diameter in mm.

Cylinder riser ring is used to get the required stroke length of hydraulic cylinder.

Following figures shows the detailed 3D modeling of fixture components:

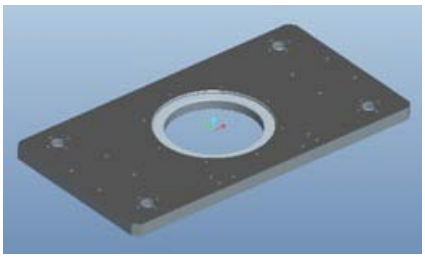


Figure 4 : 3D model of base plate

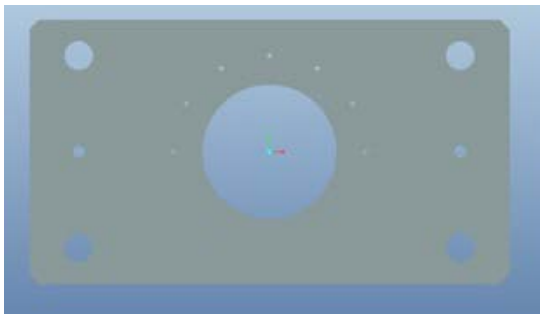


Figure 5 : 3D model of top plate

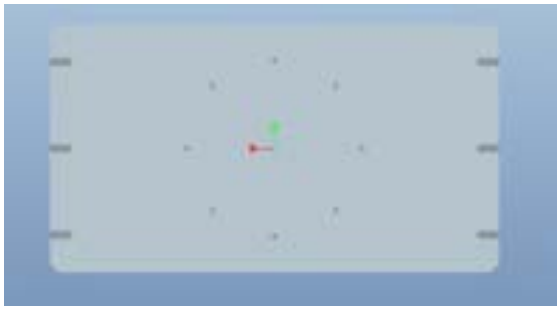


Figure 6 : 3D model of bottom plate

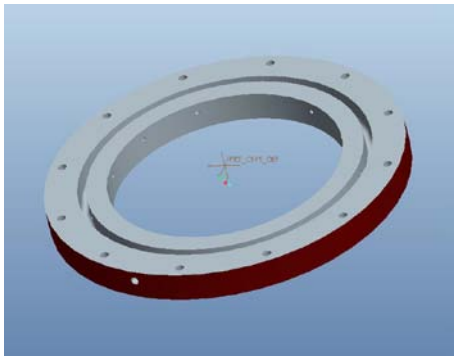


Figure 7 : 3D model of oil ring

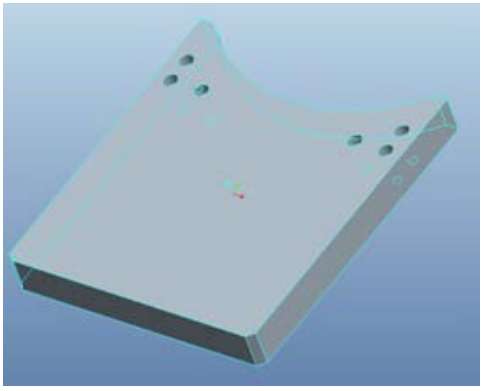


Figure 8 : 3D model of liner loading guide plate

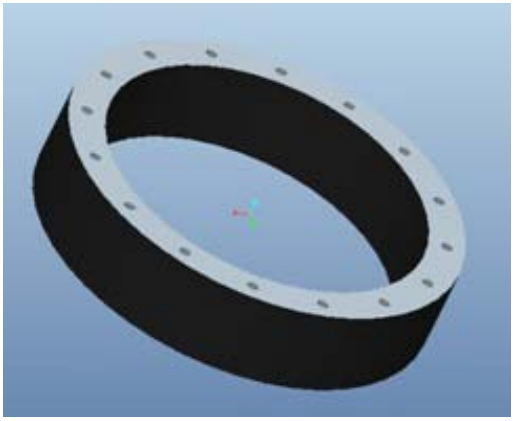


Figure 9 : 3D model of fixture riser ring

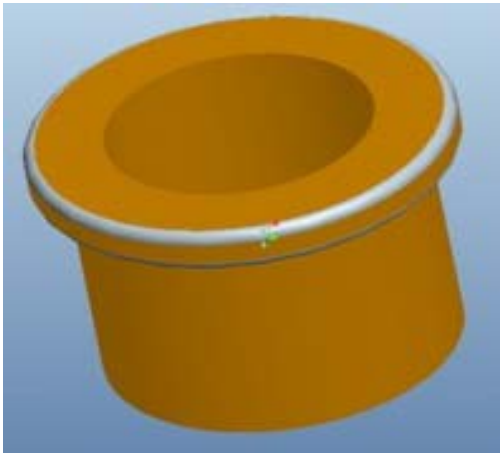


Figure 10 : 3D model of guide bush

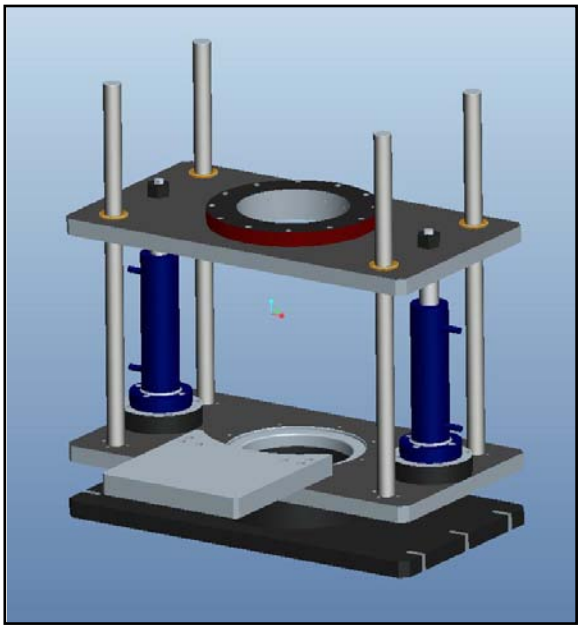


Figure 11 : 3D model of fixture assembly without liner

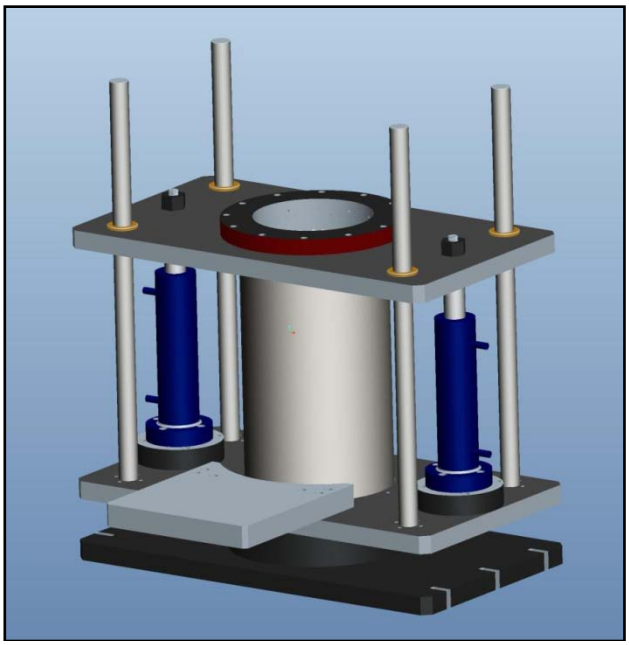


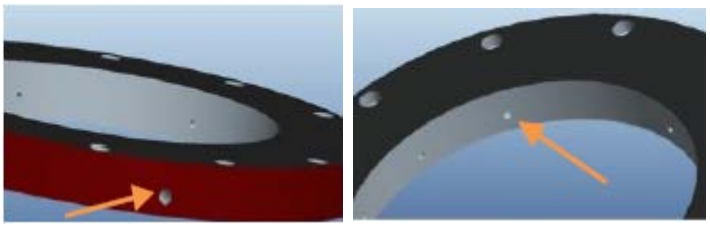
Figure 12 : 3D model of fixture assembly with liner

VI. Results and Discussion

The flexibility of fixture plays an important role in reducing machining costs and the times in manufacturing industries.

Fixture design explained in this paper can help to improve productivity and accuracy of machining significantly, lowering the time and skill level needed.

i. Due to new hydraulic automated fixture cylinder liners are exactly located, supported and clamped which reduces the machine settings time, hence productivity increased by 20% and also increase in accuracy and Process control.
ii. Rejection rate reduced to less than 2% in new set up in comparison to 10% in an old set up, because use of new hydraulic automated fixture gives uniform clamping and reduced vibrations.
iii. For this new hydraulic automated fixture oil ring (fig. 13) is provided to supply oil as coolant for cooling the honing area and to remove very small metal particles of machining, which is very advantageous, uniform and easy method as compared to old one.



(a) (b)

Figure 13 (a) : Oil ring showing oil inlet to oil ring, (b) Oil holes to supply oil to honing area of liner

VII. Conclusion

The machining fixture is a key contributor to the manufacturability of a component, and should be designed to optimize the performance of the overall machining process. However, at the present time, due to increase in competition in many industries, they are using automated fixture for their early product launch and to increase productivity and accuracy.

The present fixture model development described in this paper includes the unique aspect of designing a hydraulic fixture is novel in that it enables the user to take account of machining strategy and all key interactions between fixture, component and other system elements at an early stage. By designing above automated fixture for honing machine, cylinder liners are exactly located, supported and clamped which reduces the machine settings time, hence productivity increased by 20% and which also increase the accuracy, improved quality of machining and process control. With less than 2 % rejection rate and 20 % increase in productivity, cost to build and maintain honing fixture set up can be recovered in less than a one year.

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