

Principles for Effective Design of Fixtures

Aditya Gandhi¹, Aradhya Gupte², Shourya Gorivale³, Mihir Khedkar⁴ and Prof. Mrs. S. A. Dhavale⁵

¹Department of Mechanical Engineering, Savitribai Phule Pune University, Pune, India

²Department of Mechanical Engineering, Savitribai Phule Pune University, Pune, India

³Department of Mechanical Engineering, Savitribai Phule Pune University, Pune, India

⁴Department of Mechanical Engineering, Savitribai Phule Pune University, Pune, India

⁵Department of Mechanical Engineering, Savitribai Phule Pune University, Pune, India

Abstract - In machining fixtures, minimizing workpiece deformation due to clamping and cutting forces is essential to maintain the machining accuracy. The various methodology used for clamping operation used in the application for designing fixtures for Shear Rams are reviewed in this paper.

Fixture is required in various industries according to their application. This can be achieved by selecting the optimal location of fixturing elements such as locators and clamps. The fixture set up for component is done manually. For that more cycle time required for loading and unloading the material. So, there is need to develop system which can help in improving productivity and time. Fixtures reduce operation time and increases productivity and high quality of operation is possible.

Keywords: Design of Fixtures, Jigs, Clamping, Productivity, Shear Rams

1. Introduction

Increasing the productivity and accuracy are the two basic aims of mass production. As we know the solution to this is by reducing the set-up cost of the machine and also reducing the manual fatigue. In this case the device that caters our needs is the use of fixtures.

The fixture is a special tool for holding a work piece in proper position during manufacturing operation. For supporting and clamping the work piece, device is provided. Frequent checking, positioning, individual marking and non-uniform quality in manufacturing process is eliminated by fixture. This increase productivity and reduce operation time. Fixture is widely used in the industry practical production because of feature and advantages.

To locate and immobilize workpieces for machining, inspection, assembly and other operations fixtures are used. A fixture consists of a set of locators and clamps. Locators are used to determine the position and orientation of a workpiece, whereas clamps exert clamping forces so that the workpiece is pressed firmly against locators. Clamping has to be appropriately planned at the stage of machining fixture design. The design of a fixture is a highly complex and an intuitive process, which require knowledge. Fixture design plays an important role at the setup planning phase. Proper fixture design is crucial for developing product quality in different terms of accuracy, surface finish and precision of the machined parts in existing design the fixture set up is done manually, so the aim of this project is to replace the manual induction hardening process, with automated induction hardening process with fixtures.

There are numerous advantages of jigs and fixtures

- Production increase and cost reduction.
- Low variability in dimension, thereby leading to consistent quality of manufactured products.
- Reduces the need for inspection.
- Reduces accident, as safety is improved.
- Semi-skilled machine operators can easily use them thereby saving the cost of manpower.
- The machine tool can be automated to an appreciable extent and complex components can be machined.
- Easy assembly operations save labor, and also lead to reduction of defective products.
- Eliminates the need for measuring, marking out, punching, positioning, alignments, and setting up for each work-piece thereby reducing the cycle and set up time.
- Increases technological capacities of machine tools.
- The application of more than one tool simultaneously on a work-piece can be achieved.

2. Steps of Fixture Design

Successful fixture designs begin with a logical and systematic plan. With a complete analysis of the fixture's functional requirements, very few design problems occur. When they do, chances are some design requirements were forgotten or underestimated. The workpiece, processing, tooling and available machine tools may affect the extent of planning needed. Preliminary analysis may take from a few hours up to several days for more complicated fixture designs. Fixture design is a five-step problem-solving process. The initial framework of the steps are similar to the PDCA steps. The following is a detailed analysis of each step.



Fig.1 Principles of PDCA

- a. **Plan:** To initiate the fixture design process, clearly state the problem to be solved or needs to be met. State these requirements as broadly as possible, but specifically enough to define the scope of the design project.
- b. **Gather Information:** Collect all relevant data and assemble it for evaluation. The main sources of information are the part print, process sheets, and machine specifications. Make sure that part documents and records are current. For example, verify that the shop print is the current revision, and the processing information is up-to-date. Check with the design department for pending part revisions. An important part of the evaluation process is note taking. Complete, accurate notes allow designers to record important information. With these notes, they should be able to fill in all items on the "Checklist for Design Considerations." All ideas, thoughts, observations, and any other data about the part or fixture are then available for later reference. It is always better to have too many ideas about a particular design than too few. Four categories of design considerations need to be taken into account at this time: workpiece specifications, operation variables, availability of equipment, and personnel.
- c. **Develop several options and choose the best one:** This phase of the fixture-design process requires the most creativity. A typical workpiece can be located and clamped several different ways. The natural tendency is to think of one solution, then develop and refine it while blocking out other, perhaps better solutions. A designer should brainstorm for several good tooling alternatives, not just choose one path right away. During this phase, the designer's goal should be adding options, not discarding them. In the interest of economy, alternative designs should be developed only far enough to make sure they are feasible and to do a cost estimate. The exact procedure used to construct the preliminary design sketch is not as important as the items sketched. Generally, the preliminary sketch should start with the part to be fixtured. The required locating and supporting elements, including a base, should be the next items added. Then sketch the clamping devices. Finally, add the machine tool and cutting tools. Sketching these items together helps identify any problem areas in the design of the complete fixture.
- d. **Implement the design:** The final phase of the fixture-design process consists of turning the chosen design approach into reality. Final details are decided, final drawings are made, and the tooling is built and tested. The following guidelines should be considered during the final-design process to make the fixture less costly while improving its efficiency. These rules are a mix of practical considerations, sound design practices, and common sense
 - a. Use standard components
 - b. Use predefined materials
 - c. Keep tolerances as liberal as possible

3. Selection of Materials

There are a wide range of materials from where jigs and fixtures could be made, to resist tear and wear, the materials are often tempered and hardened. Also, phosphor bronze and other non-ferrous metals, as well as composites, and nylons for wear reduction of the mating parts, and damage prevention to the manufacturing part is also used. Some of the materials are discussed below:

- **Phosphor Bronze:** phosphor bronze is used in the production of jigs and fixtures for processes that involve making of interchangeable nuts in clamping systems like vices, and also in operated feedings that require screws. As the manufacturing of screws is very expensive and also wastes a lot of time, the reduction of their tear and wear is often achieved by using replaceable bronze mating nuts made with phosphor bronze.
- **Die Steels:** the three variants of die steel - high chromium (12 %), high carbon (1.5 to 2.3%), and cold working steels are applied in the production of jigs and fixtures for the making of thread forming rolls, as well as cutting of press tools. When alloyed with vanadium and molybdenum for it to retain toughness at very high temperature, die steels are applied in the fabrication of jigs and fixtures that are used in high temperature work processes which include extrusion, forging, and casting processes.
- **High Speed Steels:** high speed steels which contain more quantity of tungsten and less quantity of chromium and vanadium has high toughness, hardenability, hardness retention at high temperature, and good wear, tear and impact resistance. When tempered, they are applied in the production of jigs and fixtures for reaming, drilling, boring, and cutting operations.
- **Mild steels:** mild steel which contain about 0.29% of carbon are very cheap and because of their easy availability are often the choicest material for the making of jigs of fixtures.

- Other materials for the making of jigs and fixtures include: Nylon and fiber, steel castings, stainless steel, cast iron, high tensile steels, case hardening steels, and spring steels

4. Design Considerations

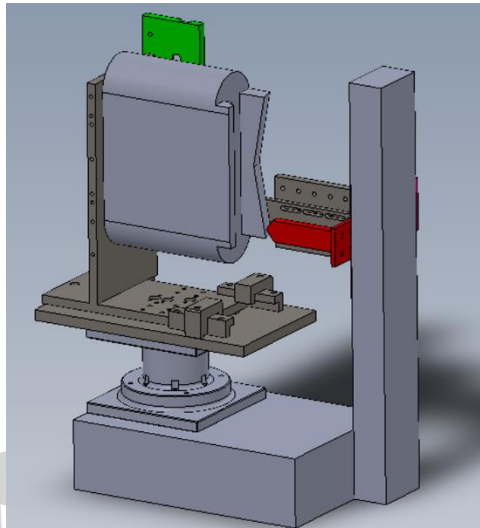


Fig 2 Isometric View of a Fixture

The above figure depicts a final assembly of a fixture. This particular fixture was designed to improve the process of induction hardening of shear rams. The dark grey shaded components are the part of the fixture. The points that are taken into consideration for designing a product are as following:

- Jig must be so strong that the deflection in the jig should be as less as possible. The deflection that is mentioned includes the forces of cutting, clamping of workpiece to the machine table. The frame of the fixture should have sufficient mass to prevent vibrations during the machining of the job.
- Another important design consideration is the clamping which should be fast enough and require less amount of effort.
- Arrangement of clamps should be such that they are easily available. They should also have the arrangement for easy removal as well.

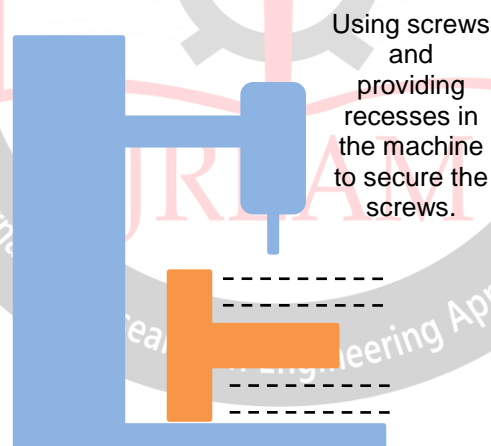


Fig 3 Clamping explanation on a fixture

- Is swinging of clamp system is provided for removal of workpiece the clamp should swing as far as possible for unclamping the device.
- There should also be provision for easy removal of chip. This will prevent the interference of the chip with the operation on the workpiece i.e. cutting operation.
- The clamps and support points which are to be adjusted in due course of time should be preferred of same size. It will be better if the clamps and adjustable support points can be operated from the front of the fixture.
- If the surface area of clamping is more it damages the workpiece. This can be avoided by making the surface area of clamping as small as possible.
- As it is difficult to get spare parts during the operation so it is designed in such a way that they can be easily replaced on failure.
- The study of the design should be done thoroughly before fabricating. It should always be ensured that the work is done in proper sequence. This will ensure zero loss of material. It should always be preferred that there is maximum operation in a single setting of the workpiece.

- j. The movement of the workpiece is restricted i.e. there is zero degree of freedom of the workpiece after clamping the workpiece. Sharp corners and redundant locators must be avoided. One should try to maintain at least one datum surface and have basic design modifications on a fixture.

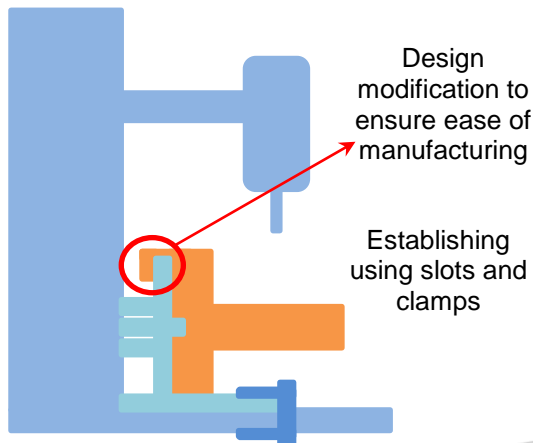


Fig 4Basic design modifications on a fixture

- k. The design must possess enough rigidity and robustness to prevent vibration else it may lead to undesired movement of the workpiece and tools.
- l. Minimum cost should be incurred during the fabrication of the project and the design should be as simple as possible.

5. Conclusions

The efficiency and reliability of the fixture design has enhanced by the system and the result of the fixture design has made more reasonable. To reduce cycle time required for loading and unloading of part, this approach is useful.

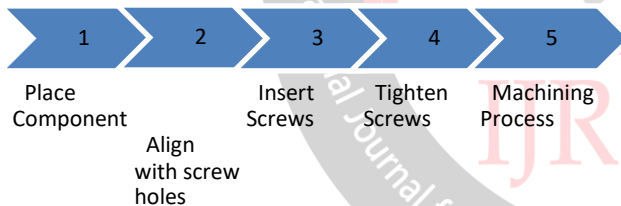


Fig 5: Procedure of loading jobs on jobs

If modern CAE, CAD are used in designing the systems then significant improvement can be assured. To fulfil the multi-functional and high performance fixturing requirements optimum design approach can be used to provide comprehensive analyses and determine an overall optimal design. Fixture layout and dynamic clamping forces optimization method based on optimal fixture layout could minimize the deformation and uniform the deformation most effectively.

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