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Cycle Time Reduction in Manufacturing Industry by Designing a Milling Fixture: A Case Study

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***Abstract*: In this ever expanding global market, industries are always keen to boost their profits, in manufacturing industry most cost effective way is reduction in machining cycle time. This is accomplished by examining current process for non-value added activities, designing suitable fixtures for improved machining process. Cycle time comprises of the following time element: operation, loading/unloading, set-up and idleness. In this work a case study of an oil and gas industry manufacturing company of US. It was observed that the client was facing frequent delays and occasional rejections in machining. This was leading to increased production cost and subsequent fall in profit and customer confidence. So there was a need to design the dedicated fixture so as to reduce the cycle time of milling and boring operations. Benefits of this new fixture are twofold. It reduced setup time because it eliminates re positioning of every job from scratch and marking and aligning every key point, the stability that fixture provided and lessen the cycle time that will afterwards enhance productivity in ways we did not predict.**

***Keywords*: Cycle time, Fixture, Productivity, Setup time.**

1. Introduction

The manufacturing cycle time of a job is the total time required to convert raw materials into finished products. Lean defines cycle time as the time it takes to do a process. It includes the time from when an operator starts a process until the work is ready to be passed on. This cycle time definition is rather simplistic, though, as there are several elements that can cloud the issue. Batching makes it difficult to determine the duration of the cycle, as well as waiting. On connected assembly lines, the end of a line change is often expected. Usually, this wait is not considered part of the cycle time, but the wait in the paper is generally included. Simple, cycle time is the minimum time that a stopwatch should run to produce a good amount of unity. It includes operating time, loading / unloading time, configuration time and rest time. Of these, only during operation time the addition takes place, and the loading / unloading, configuration and idling times appear under the label Downtime".

It can be achieved by reducing configured idle times of machines.

This work contributes to cycle time reduction of Milling and boring processes. The pump housing is major mart of the mud pumps for extracting shale gas from sea bed, the high temperature high pressure of the crude shale extracts takes its toll on the forged metal housing of the pump. The housing usually lasts for three to four months before needing a replacement. This is the reason customer is in ever need of these pump housings and the dynamics of this industry makes rejections a bigger deal than others [8]. Milling is a process performed with a machine in which the cutters rotate to remove the material from the work piece present in the direction of the angle with the tool axis.

With the help of the milling machines one can perform many operations and functions starting from small objects to large ones. Milling machining is one of the very common manufacturing processes used in machinery shops and industries to manufacture high precision products. In this work we are milling with a horizontal machine centre 'Fermat 3000' it has a rotating bed and a capacity of 6 Tons.

[1] Kaija, and Heino explained that the "main purpose of a fixture is to locate and in some cases hold a work-piece during either a machining operation or some other industrial processes." He also pointed out that what makes fixtures unique is that they are all manufactured to fit a particular shape or part.

The fixture is designed to position, hold and support equipment used in the manufacturing industry. Fixtures are used to keep work well positioned and maintained. It maintains a spatial association between fixed components and the machine tool on which the part is processed. In this work we attempt to design and model a dedicated fixture for milling and boring operations for mud pump housings.

The clamping device should be very simple and easy to operate. Apart from holding the work piece securely in place, the strength of the clamping device is that it holds the force of the cutting tool during operation. The need to clamp the work piece to the fixture is to apply pressure and press it against the positioning component, thereby locking it in the proper position for the cutting tool.

Design of the fixture is based on 3-2-1 principle and modelled using Autodesk Powershape modeling software. Once the broad area of study was chosen, a survey of related work done in the literature was studied.

2. Problem Definition

Achieving higher productivity and precision requires a reduction in downtime of job in manufacturing. One of the options to accomplish this is by the use of correct fixture that helps in minimizing setup time during manufacturing. because There is around 550 to 600 kg of material removal in milling and boring operations on all six faces, hence it was bound to have some issues calling for frequent reworks, some of the commonly faced issues were,

- Taper machining on J face
- Bore oversize
- Width undersize
- Coordinate out

They were a major concern for manufacturer. Demand for both variants of pump housing blocks remained unmet It was observed at the manufacturing site that there was a usual delay of four to five days in dispatch regularly as there were no dedicated fixtures for the intense boring and milling. Thus a major requirement from this project is to achieve precision and repeatability.

It is to be noted that while the fixture is being designed for both variants, the cycle time reduction is being done with concern to three pistons variant.

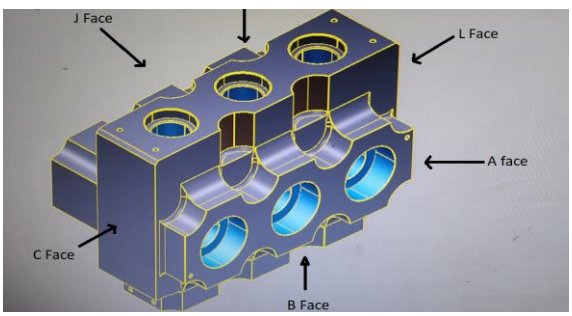

Fig. 1. 3D model of the job with marked faces

3. Methodology

The first thing we did was to assemble a CFT (cross functional team) meeting, in this meeting engineers from all concerned departments were present and agenda of the meeting was to list out the problems and brainstorm ideas to solve the issues.it was decided to design a dedicated fixture to tackle the issues. The design of Jigs and fixtures depends on many factors that are analyzed to achieve optimal performance. After noticing the problem and determining the project goals,

[3] To improve the cycle time, there are two possible options:

1. Reducing the number of tasks in progress and
2. Improve the pace of task completion

The chances of reducing the number of tasks were low or none.

So we had to immediately look for ways to improve the speed of tasks, and one of the clear ways to achieve this was the use of a milling fixture.

Typically, the design of the fixture includes the identification of clamps, locators and reference points and the selection of appropriate elements of the device for their respective functions. The process definition and setup planning determines the number of setups required to complete all production processes, the task for each setup, for example, the current production process and the workpiece, the orientation and position of the workpiece in each installation. Setup is a combination of processes that can be performed on a workpiece with a single machine without the need to manually change the position and orientation of the workpiece.

During the planning of fasteners, surfaces are identified that the locators and clamps should act on, as well as the actual positions of the placement and clamp points on the workpiece; the position of the installation points must be such that the workpiece is adequately limited during production. Suitable units (i.e. mounting and clamping units) are selected.

During the verification stage, the design is tested to ensure that all manufacturing requirements of the workpiece can be satisfied. By analyzing its geometric constraining ability,

Achieved tolerance, the deformation and stability of fixture workpiece system, and fixture accessibility, etc., The design also has to be verified to ensure that it doesn't fouls with rotating tool and considering rotation of machining bed .it should also be verified to meet other design considerations that may include fixture cost, fixture weight, assembly time, and loading/unloading time of both the workpiece and fixture units the subsequent step was to record current cycle time and examine the current procedure for non-value added activities.

A. Time keeping

Since the manufacturing process is done in three shifts, in order to track the process occurring, we divided ourselves in three for the three shifts. As per the standard process time sheet, the observations were recorded with stop watch according to start and end time, delay reason, number of workers and lay time for each process. The data noted down is then transferred to computer using excel sheets, using this sheet it was easy to calculate total Working time, setup time, total delay time, total man hour and unaccounted time. In total, seven jobs were observed before using the fixture that was meanwhile in design stages.

Observations were made while data collection as well as during analysis of the process,

- It is seen that there is a delay in between setup changes due to realignment and coordinate marking of job as well as cleaning of machine bed.
- It was observed that time taken for setting up the job was near to random, there was no clear pattern or too many factors directly affecting the same, it was seen that different operators took different time which was again dependent

on whether the supervisor was present or not. The main reason for this problem was a clear lack of a benchmark in setup time.

- It is seen that there is delay due to operators rechecking with supervisor before every operation.
- Tapping operation takes more time than the standard time without any considerable reason.
- Some amount of time is wasted while regularly checking for cutter inserts' damage.
- we noted that the HMC was running on 40 to 60% speed of the original as directed by the program.it was because machine would stat vibrating on higher speeds
- It is seen that manpower during night shift is comparatively less than other shifts. Setup and cleaning work take longer than usual.

Table 1
Old process flow on HMC

Process no.	Process detail	Resting face	Working face	Setup no.
10	Face identification	---------	-----------	0
20	Machining	A	K , B	1
30	Inspection	A	K , B	1
40	Machining	A	J	1
50	Inspection	A	J	1
60	Machining	J	K, C, L, B	2
70	Inspection	J	K, C, L, B	2
80	Machining	J	B	2
90	Inspection	J	B	2
100	Machining	J	K	2
110	Inspection	J	K	2
120	Machining	K	A	3
130	Inspection	K	A	3
140	Machining	K	J	3
150	Inspection	K	J	3
160	Machining	K	C	3
170	Inspection	K	C	3
180	Machining	K	L	3
190	Inspection	K	L	3

B. Designing of fixture

We started the design process with reference to large literature and understood the main principles. Fixtures are designed according to the 3-2-1 principle.

[5] The 3-2-1 principle explains the degree of freedom of design. All free bodies have a total of 12 degrees of freedom. 6 translation degrees of freedom, namely; +X, -X, +Y, -Y, +Z, -Z and 6 degrees of freedom of rotation, i.e.; Clockwise and counterclockwise in X, Y and Z directions. In order to position the workpiece in the fixture, all 12 degrees of freedom except three transitional degrees of freedom (-X, -Y and -Z) must be fixed. Therefore, the nine degrees of freedom of the workpiece must be fixed.

1) Core idea

after examining the ongoing process there were few points that [7] governed the idea of designing this fixture.

- There are three setups during entire machining process, where first two major setups are for boring operations. These three setups are necessary so as to work six faces as we are working with a HMC.
- The fixture had to two support both variants of housings i.e. three piston and five piston. Luckily the bore sizes of both are same so, the only issue was to use different locations for both the jobs.

It was decided to locate three piston job by bores' 1 and 3
And five piston job by bores' 1 and 5.

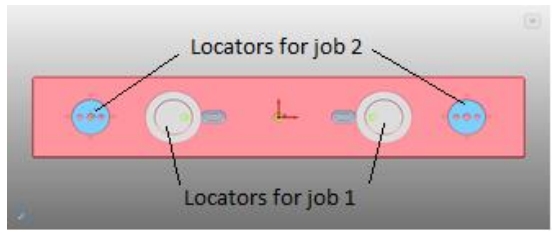

Fig. 2. Locators pins for both jobs


Fig. 3. Three piston variant (job1)


Fig. 4. Five piston variant (job 2)

[11] Following procedure was followed in designing the fixture:

- Fixture Planning: it included study of various literature and consulting experts in this field. Proper plan for fixture design was made; responsibilities were assigned in between the team.
- Fixture Layout: In this phase the dimensions of job were noted and also dimensions of working bed of the HMC. The characteristics of fixture were decided. Such as type of clamp to use, tooling, material etc.
- Fixture body design: In this step detail drawings of fixture were considered on paper. Solid models were created in Autodesk powershape .in this phase the solid model was

also tested in the software.

- Fixture fabrication: Here a block of EN24 Steel grade was taken to turn it into the model that was finalized in earlier stage. Autodesk PowerMill software was used.
- Evaluation, approval and Testing: Lastly, the design was evaluated, tested and later approved by the Engineering team of manufacturing facility.
- Production: after successful testing two more fixtures were produced.

4. Results and Discussion

A. Fixture details

After noting down the dimensions of both the jobs and the machine bed the design of the fixture was ready based on 3-2-1 principle it was generated using Autodesk powershape modeling software. A brief explanation of designed fixture, element wise, is discussed below,

- The first setup is located by pin of diameter 105mm that is on A face. The bore on J and K face now machined to 160 mm, the next setup is located on J face.
- During the setup change next pin of 160 mm is added so as to locate the bores on J face.
- For third setup there is no need for pin change as K face is already at 160 mm.

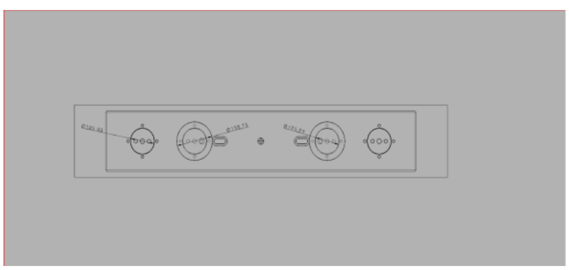

Fig. 5. Drawing of top view showing dimensions of locator pins

- For the fixture to attain repeatability it was important for fixture to clamp into the machine bed perfectly, so the bottom of the fixture is designed keeping the dimensions of grooves in machine bed.

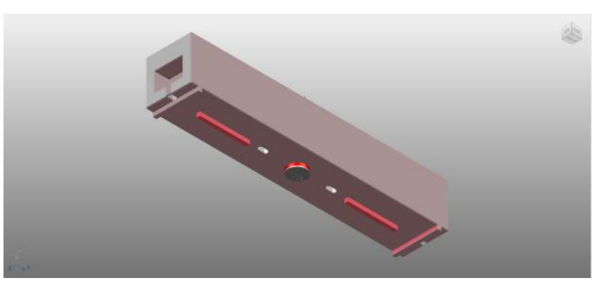

Fig. 6. Bottom view showing guide slots

- The side view will show the space for clamping the fixture into the machine bed from both sides

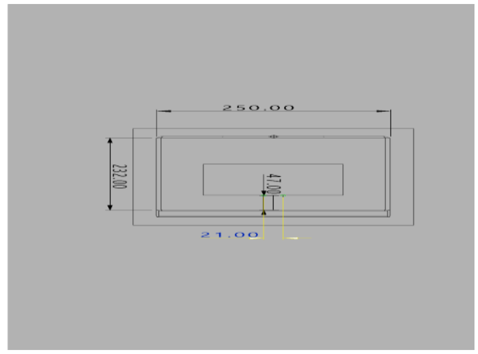

Fig. 7(a). Drawing of side view with dimensions

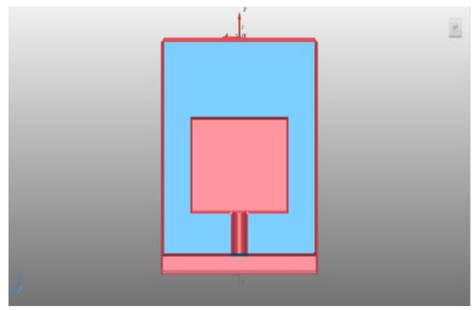

Fig. 7(b). 3D model showing side pocket for clamping

- As for the locating pins they were manufactured manually on lathe machine.

Fig. 8. Inner pin and outer pin

- The clamping were not an issue as the standard screw clamping did the job just fine. easy to clamp and unclamp and most importantly they were adjustable so they do not provide hindrance to machining tool

B. Improvement in Cycle time

Observations were made while data collection.

- [4] The fixture was setup by all the concerned operators of different shifts in presence of their supervisors and the avg. time was set as benchmark for setup time of the fixture on the machine bed and was posted on the manual as well.
- Since the job was resting on the fixture not the bed, the recurring need to clean the bed was eluded.
- The clamping and unclamping is quick and easy now that job is resting on the fixture we are able to rearrange some operations as well as shown in the new process flow table.

Table 2
New process flow on HMC

Process no.	Process detail	Resting face	Working face	Setup no.
10	Face identification	---------	-----------	0
20	Machining	A	K , B	1
30	Inspection	A	K , B	1
40	Machining	A	J	1
50	Inspection	A	J	1
60	Machining	J	K, C, L, B	2
70	Inspection	J	K, C, L, B	2
80	Machining	J	B	2
90	Inspection	J	B	2
100	Machining	J	K	2
110	Inspection	J	K	2
120	Machining	K	A	3
130	Inspection	K	A	3
140	Machining	K	J	3
150	Inspection	K	J	3

- As discussed above the clamping and unclamping of job did not interfere with alignment of job hence the last two operations 160 and 180 on C and L face respectively were merged with operation 60. This save on inspection time on separate operations
- With the fixture in use and better clamping forces the machine was now able to run at 80% speed which was a bonus as we did not expect the fixture to solve this issue.

Gap Analysis: [9] Gap analysis chart is analysis tool that helps visualize the difference among actual process time, actual cycle time, accounted and unaccounted delay time.

Actual process time (APT)

Actual cycle time (ACT)

Total non-value-added time (TNT) = ACT-APT

Data collected for gap analysis on avg. from seven jobs before and after the deployment of the milling fixture.

Table 3
Gap Analysis

Attribute	Before Time in seconds	After Time in seconds
Actual Cycle Time	65920	54447
Actual Process Time	66541	55027
Total non-value added time	621	580
Accounted non-value added time	512	494
Unaccounted-non value added time	109	86

Table 4
Comparison of cycle time with and without fixture

Cycle time Without fixture	Cycle time With fixture	Saving in Seconds (minutes)	Percentage saving
65920	54447	11473 (191mins)	**17.4**

This table shows that a saving of 17.4% was achieved for this project. Different techniques such as lean principles, value stream mapping etc. were found in literature being used to reduce cycle time in manufacturing industry. This case study adds to it by showing how cycle time could be reduced by the proper design of dedicated fixture for milling process.

Table 5
Details of rejected parts (Monthly)

Type of defect	Before fixture	After fixture
Taper machining on J Face	3	0
Bore Oversize	2	1
Width Undersize	2	0
Coordinate out	2	0
Total defects	9	1

5. Conclusion

In the manufacturing of three-cylinder mud pump housing it was observed that fixtures were not used for the milling and boring operations. This led to increased cycle time and reduced productivity. Hence it was decided to design a dedicated fixture so as to accelerate intense milling and boring operation. When this dedicated fixture was used it was possible to achieve substantial saving in set-up time because it eliminated marking for each job and positioning by trial and error method. As a result, the cycle time for front chassis was reduced by 17.4%. Benefits of this new fixture are twofold. Set-up time is one of the components of cycle time and saving in set-up time contributes to reduction in the cycle time. Second benefit is that the rework issues that were a major concern for manufacturer were also resolved without the need to hire higher skilled labor.

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