SETUP TIME REDUCTION FOR CNC HOBBING MACHINE IMPLEMENTING SMED AND DESIGN OF “SPLIT FIXTURE”

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Abstract- Setup reduction is a process through which the total time required to changeover or set-up equipment or a work center is dramatically reduced through a systematic, problem-solving, waste-eliminating approach. It is an important tool in lean production to realize quick setup change and meet the demands of individualized customers. The setup time reduction for CNC hobbing machine has been done by implementing SMED (Single Minute Exchange of Die) technique, optimal crane operation and by incorporating the design of “Split fixture”. The execution of this project has successfully managed to reduce 02:28:30 of setup time per day of the CNC hobbing machine and further has the reduction potential of reducing 00:55:15 of the setup time per day by incorporating the “Split fixture”.

Keywords- Setup, Setup time reduction, SMED, Split fixture, Optimization.

I. INTRODUCTION

A. Setup reduction
Setup is a set of activities to prepare for the next part to be produced. Setup time is total elapsed time from completion of the last good part from the previous setup to the first good part from the new setup. Setup reduction is a kind of theory and method to shorten the setup time furthest.

B. SMED (single minute exchange of die)
The primary method chosen for setup time reduction of a CNC hobbing machine for this project is SMED (Single Minute Exchange Of Dies). SMED, also known as Quick Changeover of Tools, was developed by Shingo (1985), who characterized it as a scientific approach for the reduction of setup times, and which can be applied in any industrial unit and for any machine. SMED is defined as the minimum amount of time necessary to change the type of production activity taking into consideration the moment in which the last piece of a previous lot was produced or the first piece produced by the subsequent lot. The objective of SMED is to try to separate internal operations– namely the Die exchange or the fitting of the equipment, which have to be performed with the machine in switched off mode – from external operations – namely those performed with the machine in normal operation mode, as is the case of the preparation of tools.

C. “Split fixture”
From the SMED study of the CNC hobbing machine it was evident that there was much more scope of further reduction in setup process time as it was seen a considerable amount of setup time was contributed by the transportation of various elements (clamping stud, fixture, clamping plate, job) of different configurations at the shop floor. If only it was possible to create a fixture which could have a design capable of withstanding load between 1- 2.5 tons, provide stability under operating conditions also if it could have the ability to adjust its outer diameter in order to rest jobs of various diameters ranging from 350mm – 750mm, it would be possible to eliminate a considerable amount of setup time as the fixture would act as a universal fixture to rest various jobs. Hence, designing of a prototype “Split Fixture” was taken into consideration.

II. LITERATURE SURVEY
SMED study was to be conducted on the CNC hobbing machine in order to reduce the setup time. The CNC hobbing machine took one hour twenty two minutes (average) for its setup. This great setup time was a major barrier for the production capacity. In order to boost the rate of production of helical gears and pinions, it became necessary to study and conduct SMED on the machine and reduce its setup time. As a result, the machine showed further potential of increase in production, also reduction of operating cost.

A. Working of the present system
The shop floor provided to the hobbing section consists of five hobbing machines in which four are semi-automatic, they take up more time to operate and their job completion and product delivery is of greater duration.

The shop floor consists of only 1 CNC hobbing machine worth Rs8 crores. The advantage of having this machine is that it can load heavier (1-2 tons) and wider jobs. It provides faster delivery, gears being produced within 2 hours 30 minutes to 3 hours depending on the job profile. The average number of
jobs dispatched daily is six. The production unit is operating for 20 hours and 30 minutes 6 days a week. This daily production span is divided for 3 operators each one occupying a different shift out of 3 shifts daily.

B. List of Operations on CNC hobbing M/c

The observation of various internal activities on the CNC hobbing machine made it possible to identify and classify the various activities taking place. The list consisted of internal activities taking place with their respective average time or duration listed after a series of time recordings of the respective task to get the base time (average time). From the list of 34 recorded tasks, the total setup time (average) came to be 01:21:17.

C. Significance of “Split fixture”

From the SMED study conducted on the CNC hobbing machine, it was observed that only some portion of the setup time could be reduced by separating and converting the internal operations to external operations. It did not provide the results expected, hence there was a need to look for other options in order to reduce the setup time on the CNC hobbing machine. One of the further methods which was adopted was to produce a standby stage which could rest at least 5 elements, three new (clamping stud, fixture, job) and 2 old (fixture and clamping stud) so as to be able to produce quick changeover. But, this method had its limitations as the shop floor consisted of limited space, also it was not possible to move or to accommodate the heavy hobbing machines elsewhere. Therefore, a new concept was visualized. If only it was possible to create a fixture which could have a design capable of withstanding load between 1-2.5 tons (weight of various jobs), provide stability under operating conditions also if it could have the ability to adjust its outer diameter in order to rest jobs of various diameters ranging from 350mm – 750mm, it would be possible to eliminate a considerable amount of setup time as the fixture would act as a universal fixture to rest various jobs. Hence, designing of a prototype “Split Fixture” was taken into consideration.

D. “Split fixture” setup time reduction potential

A list of operations were highlighted from the SMED study list which showed the advantages of having the “split fixture” and the potential of further contributing to setup time reduction.

Table 1: “Split fixture” setup reduction potential

<table>
<thead>
<tr>
<th>TASKS</th>
<th>TIME (AVG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction of old fixture</td>
<td>00:04.40</td>
</tr>
<tr>
<td>Transport old fixture to fixture stand</td>
<td>00:01.40</td>
</tr>
<tr>
<td>Bring back crate for extraction of clamping stud</td>
<td>00:01.30</td>
</tr>
<tr>
<td>Extraction of old clamping stud</td>
<td>00:02.35</td>
</tr>
<tr>
<td>Transport old clamping stud to fixture stand</td>
<td>00:01.23</td>
</tr>
<tr>
<td>Transport new clamping stud to machine</td>
<td>00:01.41</td>
</tr>
<tr>
<td>Ream and fixtures clamping stud new worktable</td>
<td>00:02.40</td>
</tr>
<tr>
<td>Bring back crate towards fixture stand</td>
<td>00:01.0</td>
</tr>
<tr>
<td>Transport new fixture to machine</td>
<td>00:02.00</td>
</tr>
<tr>
<td>Ream new fixture over worktable</td>
<td>00:01.00</td>
</tr>
<tr>
<td>Fixture of new fixture</td>
<td>00:01.30</td>
</tr>
<tr>
<td>Fixture of new job</td>
<td>00:02.30</td>
</tr>
<tr>
<td>TOTAL</td>
<td>00:16:25</td>
</tr>
</tbody>
</table>

The 18 minutes 25 seconds is the further setup time reduction potential with “split fixture”.

III. METHODOLOGY

A. Separating internal from external operations

In this phase the setup operations were analyzed in order not only to separate internal from external operations, but also to identify external operations that were taking place together with internal operations. Separating internal from external setup operations involves distinguishing all the activities of the setup operation and to divide the setup in stages. Thus, the setup was divided into the following four stages:

1. Operations to be accomplished one hour before the machine stops;
2. Operations to be carried out immediately before the machine stops;
3. Operations to be carried out during the setup operation;
4. Operations to be accomplished after the machine is back to normal production.

The stage 3 is classified under internal operations. The rest of the stages were identified and classified under external operations, hence reduced. Table 2 shows the setup time reduction per classification.

Table 2: Internal operations converted to external

<table>
<thead>
<tr>
<th>TASKS</th>
<th>TIME (AVG)</th>
<th>TIME (AVG)</th>
<th>TIME (AVG)</th>
<th>TIME (AVG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produce new job before machine stops</td>
<td>00:00:40</td>
<td>00:00:50</td>
<td>00:16:00</td>
<td></td>
</tr>
<tr>
<td>Produce crane in front of machine for extraction</td>
<td>00:00:40</td>
<td>00:00:50</td>
<td>00:16:00</td>
<td></td>
</tr>
<tr>
<td>Arrangement of clamping studs</td>
<td>00:02:00</td>
<td>00:02:00</td>
<td>00:02:00</td>
<td></td>
</tr>
<tr>
<td>Fixtures of new jobs</td>
<td>00:04:30</td>
<td>00:00:30</td>
<td>00:02:00</td>
<td></td>
</tr>
<tr>
<td>Fixtures of new fixture</td>
<td>00:02:30</td>
<td>00:02:30</td>
<td>00:02:30</td>
<td></td>
</tr>
<tr>
<td>Fixtures of new job</td>
<td>00:02:30</td>
<td>00:02:30</td>
<td>00:02:30</td>
<td></td>
</tr>
</tbody>
</table>

B. Optimal crane operation

The shop floor consists of a single crane. It is used for the transportation of jobs, fixtures and clamping studs towards the hobbing machines and it occupies a considerable amount of the setup time. The fixtures and clamping studs are located to the left side of the CNC machine at about 30 yards away and the jobs are located to the right side of the CNC machine at about 17 yards. Various activities were highlighted from the SMED study related to the transportation of these elements. There existed a greater scope for reducing setup time. The method which was adopted to do this was to produce a standby stage for the job, fixture and clamping stud right in front of the CNC machine for reducing the distance the crane had to cover thereby
A. Design Attributes

The design of the “Split fixture” was inspired from the three main fixture designs on the basis of their functionality which were widely used and exchanged for different jobs sizes. Their specific attributes and dimensions were noticed and all combined into a single significant prototype fixture. These are the following fixtures:

- **Fixture A (OD-350mm, Height-390mm, Resting face-70mm)**
- **Fixture B (OD-400mm, Height-350mm, Resting face-75mm)**
- **Fixture C (OD-550mm, Height-450mm, Resting face-75mm)**

B. Manufacturing and dimensional considerations

Internal parts: To develop a prototype fixture which could accommodate jobs of various sizes (diameter, width and weight), following were taken into consideration.

1. Height of fixture-Considering minimum stroke of hob slide also incorporating job blanks with greater width, there was a need for a fixture with less height from the surface. Height of fixture A (390mm) was considered.
2. Initial Diameter of fixture -Since fixture A became immediately considered for its respective jobs, its outer diameter (350mm) became the initial OD of the prototype fixture.
3. Final diameter of fixture - Since fixture C has a larger diameter (550mm), the prototype must be a fixture split into two pieces connected via ball screw threading in order to alternate the diameter variation accommodating different diameter of different jobs.
4. Length of job resting section - From fixture B and C, resting section length to be considered 75mm (maximum).
5. Axial stroke - Axial stroke of the job should not touch the fixture and the hob housing. Hence, prototype to be of tapered design (2-3 degrees min).
6. Wheel location - The wheel to be located at 190 mm from the base such that the hob cutter does not touch the wheel.
7. Weight consideration - Load carrying capacity of the fixture to be considered (2 tons).
8. Easy alteration of OD - The fixture to be allowed to change its OD with ease by the operator with the aid of the wheel. Hence, fixture to be kept under light weight consideration by incorporating front and back hollow sections (60 degree each) to reduce weight and incorporating ribbing for strength and stability.
9. Collar height - In order to accommodate both larger and smaller sized chucks for pinion production, the collar height to be of 60mm above and 40 mm below the job resting section respectively. This is due to the clearance consideration of the collar to the jaws of the smallest chuck.
10. Collar clearance - Both the collar parts to have minimum clearance of 120 mm such that the collars do not touch the clamping stud.
11. Threading for OD alteration - Ball screw thread to be incorporated for ease of alteration in OD of fixture.
12. Width of the fixture structure plate - Although 20 mm is the width of the structure plate of the above three fixtures, the structure plate of the prototype to be produced of 40 mm to improve strength and stability since it consist of two hollow sections front and back (60 degree each).
13. Base of fixture- The base to be designed for 30 mm height and 70 mm length. Also, the base to be extended in order to provide stability to the fixture posture and also to avoid the pressure being developed on the ball screw thread by the two fixture pieces.
14. Extended slots - The slots of the fixture should have an elongated designed to clamp fixture to the worktable with the aid of nuts and bolts such that the nuts and bolts can be firmly fixed to the work table (as the OD of the fixture increases, the small slots of the fixture do not come in contact with the slots of the worktable). Eg – front right slot size- 30 degree below the right of the base to 60 degrees.

**Table 3: Element transport time reduction**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport of job to oil retainer</td>
<td>00:00:15</td>
<td>00:01:30</td>
</tr>
<tr>
<td>Transport of fixture to fixture stand</td>
<td>00:00:20</td>
<td>00:00:25</td>
</tr>
<tr>
<td>Bring blank over fixture and clamping stud</td>
<td>00:02:10</td>
<td>00:00:10</td>
</tr>
<tr>
<td>Transport blank to fixture stand</td>
<td>00:00:25</td>
<td>00:00:25</td>
</tr>
<tr>
<td>Transport new clamping stud to machine</td>
<td>00:05:45</td>
<td>00:00:25</td>
</tr>
<tr>
<td>Bring blank back towards fixture stand</td>
<td>00:01:25</td>
<td>00:00:15</td>
</tr>
<tr>
<td>Transport new Fixture to machine</td>
<td>00:00:50</td>
<td>00:00:05</td>
</tr>
<tr>
<td>Bring blank towards new job</td>
<td>00:00:30</td>
<td>00:00:30</td>
</tr>
<tr>
<td>Transport new job towards machine</td>
<td>00:00:05</td>
<td>00:00:05</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>00:13:15</strong></td>
<td><strong>00:01:45</strong></td>
</tr>
</tbody>
</table>

**IV. DESIGN**

From fixture B and C, the prototype must be a fixture split into two pieces connected via ball screw threading in order to alternate the diameter variation accommodating different diameter of different jobs.
15. Production material - The prototype to be produced of the same material as that of fixture C. Mild steel 25 HRC.

16. Production method - The prototype to be produced by fabrication method in which different elements are to be welded together. Also incorporating ribbing for strength and stability.

External parts
1. Sliding T bars - Two T bars are to be separately produced which will slide with ease along the worktable slots manually. They are designed according to the slots of the worktable by providing to clearance of 1mm along its edges. The dimensions of the sliding T bars are shown in Figure 1.

2. T bar coupler - Two T bar couplers are to be separately produced so that they can couple with the sliding T bars in between the slots with ease. The dimensions of the couplers are shown in Figure 2.

Fixture parts - The Figure 3 below indicates the various fixture elements. Also different viewing angles are shown.

C. “Split fixture” features
1. Outer diameter increases or decreases as required by the job, accommodating all sizes of jobs.
2. Four circular extended slots provided for easy clamping of fixture to the worktable (as increasing the diameter of fixture would result in formation of an ellipse thereby fixture slots not in contact with the worktable slots for clamping)
3. Hand wheel provided for altering the diameter of the fixture.
4. Detachable slides provided at the bottom of the fixture with easy extraction to allow the fixture to move along the 180 degree axis which are coupled firmly with fixable and detachable T shaped elements.
5. Collars provided to accommodate and relax trueing of job and fixture.
6. Length of collar (6 mm above rest) allowing the fixing of different chucks used to produce pinions.
7. Easy extraction of clamping stud from the front empty section of the fixture when chuck is to be installed for switching production of gears to pinion.
V. RESULT ANALYSIS

A. Setup time reduction
1. Implementing SMED - Total forecasted time withdrawn from internal setup = 00:04:00 + 00:00:50 + 00:03:00 = 00:07:50 (per change over)

Currently the arrangement of the PNS and drawing sheets takes place 3 times a day (minimum) which creates idle time. Average number of jobs dispatched are 6 per day. Hence, Setup time reduction per day = (00:16:00 * 3) + (00:07:50 * 6) = 01:31:30

2. Implementing optimal crane operation
By optimizing the crane operations required to transport the elements with the concept of standby platform, 00:13:15 setup time was reduced to 00:03:45 setup time. Hence, further contribution to setup time reduction = 00:13:15 – 00:03:45 = 00:09:30 (per change over) Therefore, setup time reduction per day = 00:09:30 * 6 = 00:57:00

3. Incorporating prototype “Split fixture”
With the development of the prototype fixture there exists potential of further decrease in setup time by 00:18:25. Change over of fixture takes place 3 times a day (approximate) Therefore, predicted setup time reduction per day = 00:18:25 * 3 = 00:55:15

Fig. 9 and fig. 10 show the individual setup time reduction comparison of the three implemented methods and initial and final setup time reduction incorporating all the three methods respectively.

B. Economic consideration
Machine operating cost = Rs3500 per hour (inclusive of electricity input and labor cost)
Setup Time Reduction for CNC Hobbing Machine Implementing SMED and Design of “Split Fixture”

Total capital generated/saved per day = 3500 * (01:31:30 + 00:57:00) = 3500 * 02:28:30 = Rs 8662.50
Capital generated/saved monthly = Rs 8662.50 * 25 operating days = Rs 216562.50
Estimated annual capital generated= Rs 216562.50 * 11 months = Rs 2382187.50
Predicted capital generation/savings incorporating “Split fixture” per day = 3500 * 00:55:15 = Rs 3217

2. The work also focused on redesign of the prototype of Gear hobbing fixture used for manufacturing gears at Premium Transmission Limited. A lot of time was wasted in changing of the fixture, changing the clamping stud and Zero dialing it. All this time which was wasted is now saved with the newly designed fixture by reducing the no of settings. It can be concluded that the amount of saving to the company is considerable in terms of time and money.

REFERENCES