IMPROVING FORGE CHANGEOVER PERFORMANCE AT AN AUTOMOTIVE COMPONENT SUPPLIER

J. Durbach\textsuperscript{1*}, D. Hartmann\textsuperscript{2} and T. Hattingh\textsuperscript{3}
\textsuperscript{1-3}School of Mechanical, Industrial and Aeronautical Engineering
University of the Witwatersrand, Johannesburg, South Africa
\textsuperscript{1}durbachj@gmail.com
\textsuperscript{2}dieter.hartmann@wits.ac.za
\textsuperscript{3}teresa.hattingh@wits.ac.za

ABSTRACT

A manufacturer of aluminium parts for the automotive industry is currently constrained by its forging process. Tool changes are required on the forge to produce different part types. This paper describes a project that was undertaken to reduce changeover time and improve the quality of tool changeovers. A study of current practices revealed high variability in the changeover times and showed that changeover performance could be improved by reducing the effort required to perform changeover tasks, reducing the need for making setting adjustments, removing opportunities for making errors and standardising the procedure. The design solution includes changes to tools and equipment, improvements to tool handling and fastening methods and the use of a changeover trolley. A new, standardised process is provided, focusing on task quality and not time. Changes to the organisation’s strategy, culture and performance measures are also required for improvements to be sustainable. The resulting improvements will allow more tool changes to be performed, reducing batch sizes and the amount of work in progress required in the plant, ultimately enabling the company to plan production closer to customer demand.

\textsuperscript{*} Corresponding Author
1 INTRODUCTION

1.1 Background

An automotive component supplier produces five unique suspension struts on a 1600 ton forging press. Changing between parts is a lengthy process ranging from 3 to 5 hours. Forge changeovers produce significant part defects at the start of a run whilst setting adjustments are made. This has resulted in the company adopting a policy of long batch runs to reduce the production downtime and defects caused by forge changeovers. Consequently the company is required to keep a large amount of work in progress inventory to feed subsequent processes and finished goods inventory to meet customer demand.

Figure 1 shows the company’s inventory levels of finished goods and work in progress over the last year.

![Figure 1: Company inventory of finished goods and work in progress](image)

The inventory levels are high and variable as a result of the company's forge, which is characterised by long changeovers, frequent stoppages and occasional occurrences of severe breakdowns.

Lean theory suggests that by reducing the changeover times of key equipment within a process, smaller batch runs can be used which can in turn lead to less reliance on high inventory levels [1]. This philosophy inspired this study which aimed to reduce the need for inventory by reducing changeover times on the company’s forge.

1.2 Forge Process Overview

Struts are formed from pre-heated aluminium bar, then forged in four stages before proceeding to a heat treatment and a calibration process. Parts are then shot blasted, inspected and transferred to a work in progress storage area, for parts that require further machining, or to finished goods storage.

Currently, five different strut types are produced at the forge. Changing between types requires a change of the bending, pre-form, final form and de-flash dies as well as the gripper and tongs on the transfer arms.

The forging process is shown in Figure 2 followed by a brief description of the different elements within the process.
Figure 2: Forging process

- **Tool** - The forge has a top and bottom tool, the tool is made up of a large steel jig to which the forming dies are attached.

- **Dies** - The top and bottom tools each have four dies, namely bending, preform, final form and de-flash. The first three consecutively convert the aluminium bar into the final shape and the de-flash separates the final part from the flash that has formed around it during the forging process.

- **Gripper** - A gripper picks the bars up from the conveyor and places it into the V-station at the entrance to the forge.

- **Transfer arms** - The transfer arms move in conjunction with the forging motion and are used to pick up and place aluminium as it moves from bending to de-flash.

- **Tongs** - Tongs are connected to the transfer arms and hold the part as it moves from one die to the next. Tongs are bolted to a tong barrel which is in turn bolted onto the transfer arm. Tongs are adjusted to ensure the correct placement of a part. Incorrectly set tongs will result in incorrect forming and subsequently a part will be scrapped. A V-station transfer is used to transfer the bar between V-stations and pre-form.

- **Lubrication** - Lubrication nozzles spray an oil ‘mist’ on the top and bottom die before each press. Oil is used to prevent the part from sticking to the dies. Too much oil will however result in unwanted marks on the part, while too little may result in parts sticking to the dies. Both cases result in scrapped parts.

The forge is operated by a forge operator and a forge assistant. Together they are responsible for constantly monitoring the forge, loading bars into the heating furnace, making adjustments, and ensuring parts produced are not defective. The forge is a demanding piece of equipment and requires constant attention and adjustments.

It takes approximately 11 seconds for the part to move from the gripper to the exit of the forge with the forge having a design cycle time of 3.24 seconds per part. This cycle time translates to a potential of 1 110 parts per hour, if the forge runs seamlessly without stopping. The current production target is 1 000 parts per hour and 21 000 parts are planned for the forge per day. Three hours a day are set aside for breakdowns, stoppages and other problems with the forge system. The historic, average daily production is however only 19 500 parts per day. The variability of this average is an important consideration as the forge does not produce 19 500 parts per day, every day. Instead it has good days, where it produces up to 26 000 parts, and bad days when no parts are produced.
1.3 **Objective**

The project objective is to improve the changeover performance of the 1600 ton forge. This will enable the company to improve their planning, run smaller batches, increase their flexibility and responsiveness to customer demand, shorten their lead time and ultimately reduce inventory in the plant. Improved changeover performance includes:

1. Reducing changeover time
2. Reducing run-up time to full production after changeover
3. Reducing stoppages for setting adjustments and breakdowns during production

1.4 **Method**

The improvement of changeover performance was based on an integrated approach where improvements were required from a design and an organisational point of view. This is based on McIntosh, Culley and Owen’s matrix methodology for improving changeover performance [2]. Their design improvement approach focuses on making improvements to machinery and methods of performing a tool change. Improvement focuses on system influences, such as; training, scheduling and operating procedures. The matrix methodology suggests investigating opportunities for improvement within four broad categories:

1. On-line activity
2. Adjustment
3. Variety or Variability
4. Effort.

This approach was supplemented with methods of improvement from Shingo’s work on single minute exchange of dies (SMED) [3].

2 **INVESTIGATION**

In order to understand the current state of the forging process, detailed analyses of the company’s historical data and observations of processes, operations and equipment were performed.

2.1 **Analysis of Historical Performance**

Company data was analysed to determine reasons for forge downtime as any increase in forge uptime would allow for more frequent changeovers. The cumulated forge downtime is presented in Figure 3 for a period of 1 year, showing breakdown categories.
The tool change and setup is the most significant reason for forge downtime amounting to a cumulative downtime of 74 hours, an average tool change time of 1 hour and 48 minutes. Tong and lubrication settings were also a major reason for downtime cumulatively 54 and 36 hours respectively. The company’s data system does not record reasons for stoppages that are less than 5 minutes meaning that often setting adjustments go unrecorded. It was also observed that the majority of setting adjustments take place in the period following the tool change in order to get the forge running properly. Using a Pareto analysis it can be concluded that setting adjustments together with the tool change and set-up have the most potential for improvement.

To determine the total changeover time, (the time from the end of production until normal production commences on a new part) data was extracted manually using a sample of 14 changeovers. Figure 3 shows the total changeover time from stopping the forge until the start time of normal production (normal production was defined as the forge running at, at least 90% of capacity for at least 30 minutes). The figure also shows the proportion of time which is spent on tool change and set-up time, and that which is spent on adjustments.
Figure 4 shows that while average tool change and set-up is 1 hour and 46 minutes, it takes longer when the total adjustment time is considered as part of the changeover. The sample average for total changeover time is 4 hours and 20 minutes. This is, however, skewed by the lengthy times in March and September caused by breakdowns during the changeover. With the outliers removed the changeover average is 3 hours and 18 minutes with a standard deviation of 43 minutes. This represents an average adjustment time of 1 hour and 35 minutes. Almost the same amount of time is required to change the tool as is required to make the necessary adjustments for normal production to continue after the machine has been started.

2.2 Performing a Tool Change

In order to understand the tool change procedure tasks were separated into four categories:

1. Changing and adjusting the tongs and transfer arms.
2. Removing and installing the bolts
3. Handling the tool
4. Installing and adjusting the lubrication system

Time studies were completed on the total changeover and tasks on the critical path in each of the four categories are compared in Table 1.

Table 1: Categorised task time analysis

<table>
<thead>
<tr>
<th>Time(min)</th>
<th>Tong and transfer</th>
<th>Bolts</th>
<th>Tool handling</th>
<th>Lubrication</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00</td>
<td>Record tong settings</td>
<td>Remove de-flash</td>
<td>Grab top tool &amp; remove</td>
<td>Disconnect lubrication</td>
</tr>
<tr>
<td>0:02</td>
<td></td>
<td>Loosen top bolts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:04</td>
<td>Remove tongs</td>
<td>Remove top bolts</td>
<td>Transfer to tool room and return to forge</td>
<td>Insert bottom Lubrication</td>
</tr>
<tr>
<td>0:06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:08</td>
<td>Set tongs</td>
<td>Loosen bottom bolts</td>
<td>Remove bottom</td>
<td>Insert Lubrication</td>
</tr>
<tr>
<td>0:10</td>
<td></td>
<td>Transfer to tool room</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:12</td>
<td>Remove bottom bolts</td>
<td>Remove new top then bottom from oven</td>
<td>Connect Lubrication</td>
<td></td>
</tr>
<tr>
<td>0:14</td>
<td>Fit new tongs</td>
<td>Raise press</td>
<td>Transfer &amp; place in forge</td>
<td></td>
</tr>
<tr>
<td>0:16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:18</td>
<td>Set transfer</td>
<td>Insert bottom bolts and tighten</td>
<td>To tool room, collect &amp; transfer top to forge</td>
<td></td>
</tr>
<tr>
<td>0:20</td>
<td></td>
<td>Install top bolts and tighten</td>
<td></td>
<td>Place in forge</td>
</tr>
<tr>
<td>0:24</td>
<td>Disconnect transfer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:26</td>
<td>Changeover V-transfer</td>
<td>Install de-flash</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:32</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:34</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:36</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:38</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thus, to shorten the total time of the tool changeovers the tasks in each of these categories must be reduced, moved to external activities or eliminated entirely. Detailed observations are made for each of the changeover categories.

2.2.1 Tongs and Transfer

At the start of the tool change, the current settings on the tongs are recorded using digital vernier callipers. These will be used to check the setting specification for the next time a particular part is run. Once recorded, tong settings can then be changed for the new part. This is done by adjusting 2 bolts to lengthen or shorten the tongs.
Once settings are recorded and re-set, the tongs are removed. A pneumatic tool is available but is not always used, the correct attachment was missing and a pneumatic pipe was broken. New tongs for the new part are then installed at the end of the tool change.

### 2.2.2 Bolts

The top and bottom tools are each fastened to the press by four bolt pins. The nuts on the bolts are loosened and tightened using a ring spanner and a steel pipe to provide leverage. This is a difficult task as the nuts require substantial effort to loosen and tighten, the floor is slippery due to oil and grease spillage and the bolts are hot. The bolts and nuts are also caked with oil and grease during a run, making them harder to turn. The required torque on the nut is 2500 N.m but no torque wrench is used and operators just make the nut as tight as they can. Sometimes two people pull on the pipe to ensure the nut is ‘tight’.

Once the nuts have been loosened, the bolt pins are removed by sliding them from the tool using a bolt puller. During operation, the slot which the bottom bolts are seated in, becomes filled with oil and grease. This makes it harder for the bolts to be removed. A copper hammer is sometimes used on the bolt puller when the bolt is stuck. A rag is also used to cover the bolt to prevent hot grease from spraying and burning operators.

The top 4 bolts each have 2 nuts, the purpose of the second nut is meant to create a locking effect to prevent loosening from vibrations and ensures that there is a back-up if the first nut fails. It is doubtful whether a locking effect is achieved without the correct torqueing of bolts. There are a total of 12 nuts which have to be loosened and tightened during a tool change, and 8 bolts which have to be removed and replaced. The lack of space between the tools and the high torque required makes it difficult to use standard power tools to assist in the loosening of the bolts.

### 2.2.3 Lubrication

The lubrication hoses need to be disconnected before the tool is removed and reconnected after the new tool has been placed, for both the top and bottom tools. Lubrication hoses are covered in oil and while each pipe has a quick release system there are a total of 40 hoses to disconnect and reconnect. It is also unclear which pipes must go where. The lubrication hoses can be seen in Figure 5.

![Cleaned and connected lubrication hoses](image)

**Figure 5: Cleaned and connected lubrication hoses**

### 2.2.4 Contributing Factors and Areas of Concern

Several other issues were noted that affect the people and processes of a tool change and pose opportunities for improvement.
• Working conditions - Operators have to wear cumbersome gloves to protect themselves from the hot forge, there is a limited space available to move forge and everything is covered in grease and oil. The required tasks are physically tiring.

• Inability to communicate - The environment is too noisy for operators to be able to speak to one another unless they are standing together. Operators communicate by shouting ‘whoooh’ which has several meanings, including: ‘Close the forge gate for lockout’, ‘I need help’, ‘I need a tool/ to tell you something’, or ‘be careful’.

• Tools - Manual tools are used throughout, all of which are different sizes. Tools were missing from some toolboxes, ratchet wrenches did not always work smoothly and bolt pullers were often bent meaning operators had to share the one working tool. The pneumatic Allan key, the only power tool used, was initially broken but once fixed was still not used out of habit.

• Motivation - As changeovers are such hard work they are dreaded by all operators.

• Following correct procedure - The required procedure is not followed during a changeover. A standard procedure does exist, all the operators were aware of a formal procedure but none knew the procedure or thought that it was important. It is thus not possible to optimise operator work process until all teams are performing the same tasks using the same sequence and technique.

• Previous improvement initiatives - Many good ideas have been implemented to improve changeovers but implementation of ideas has not been sustained.

• Time - Changeovers are usually performed at the start of the morning (6am) or afternoon (2pm) shift, this was done so that a team would be responsible for the changeover and then running the forge for the rest of the shift. The main problem is that teams arrive at work, with the forge already stopped and immediately need to start the changeover, but have not had time to adequately prepare. Previous shifts also stop the forge early in anticipation for the tool change.

• Safety - Protective equipment such as gloves and face shields are often removed during the tool change as it is difficult to perform tasks with them on. The risk of burning is extremely high during a tool change, by accidentally touching the tool or press bed and from hot oil dripping or spraying from the forge. There is also a risk of slipping.

3 DESIGN IMPROVEMENTS

The investigation of current changeover practices showed that the tool change and setup time as well as adjustment time were contributing to the overall long changeover times. Improving setup time in isolation can often lead to increased adjustment times, if the overall quality of the changeover is not improved in conjunction with reducing the time [4]. Improvements to the changeover were therefore focused on improving the overall quality of the entire tool change process as well as reducing the time.

3.1.1 Tong Settings Gauge Blocks

Gauge blocks are suggested to replace the use of vernier callipers to set the tongs. Gauge blocks are permanent spacers between the tong adjuster and transfer arm, during a tool change the spacers are changed, changing the tong settings. Gauge blocks and their placement is shown in Figure 6.
3.1.2 V-station Transfer

Changing the V-station transfer is a challenge because the operator has to lean far into the forge to remove 8 bolts and then replace them. In order to make this easier for the operator and reduce the time it takes. Slots in the V-station transfer will be cut to allow the operator to complete only half a turn on each bolt and then slide the plate up and over the bolts without removing them. Slot dimensions are shown in Figure 7.

3.1.3 Hydraulic Torque Wrenches

The lack of work space around the forge and the high torque requirements makes it difficult to specify a power tool that will be suitable for this application. Of all the tools investigated, a limited clearance hexagonal torque wrench is the most suitable. This tool will decrease bolting time, ensure bolts are torqued to the correct specification and reduce the workload on operators.

3.1.4 Bolt Covers

Bottom bolts are difficult to remove as grease gets stuck in the slots. A bolt cover was designed to protect bolts and slots from grease during operation. A sample bolt cover, Figure 8, was manufactured and implemented to test the design. The bolt cover successfully kept the bolt and the bolt slot clean, significantly reducing time and effort to remove the tested bolt.
3.1.5 Clean Bolts

During a run, bolts and nuts get covered in grease. Grease also fills the threads making it difficult to turn the nut on the bolt by hand. It was also noted that damaged bolts go unnoticed as cracks are covered by grease. Moreover bolts have lost temperature by the time they are re-fitted to the tool resulting in incorrect torqueing.

In future, a clean set of bolts must be placed in the oven with the tool and brought to the forge resting on top of the top tool in two containers, one for the front and one for the back of the forge. Each container should have the bolts with the nuts in the correct position so that they can be immediately inserted into the bolt slot.

The top bolts should be tightened before the bottom bolts to reduce the risk of mismatch problems.

Bolts and nuts removed from the tool must be sent to the tool room for cleaning, inspection and preparation for the next tool change.

3.1.6 Lock Nuts

The locknuts on the top tool are safety redundancies against nut failure and vibration loosening. It is however possible to ensure safety without having the second nut. The risk of vibration loosening is eliminated by correctly torquing nuts, to the specified 2500 N.m which will be possible with a hydraulic torque wrench. The risk of nut failure can be reduced by using longer nuts on the top of the tool. Currently a standard M30 nut is used. This must be replaced by a longer nut with more thread to prevent thread failure and more material to reduce the risk of cracking. Finally by using clean bolts and nuts when the tool is replaced nuts can be thoroughly inspected after every run and damaged nuts or bolts can be detected and replaced before failure.

3.1.7 Lubrication Hose Multi-coupling System

To remove the need to disconnect and reconnect 40 lubrication hoses during a tool change a commercially available multi-coupling systems needs to be adapted and installed. A multi-coupling system will reduce the 40 connection points to only two, one for the top and one for the bottom of the forge.
3.1.8 Oven Shelf for Top Tool

The tools are currently placed on top of one another in the oven, the bottom tool is however required first meaning the top tool has to be removed from the oven, placed on steel blocks so the fork lift can move the bottom tool. A second shelf was designed for the oven so the tools can be pre-heated separately. Besides the savings from reducing tool handling time, the second shelf has the added benefit of keeping the top tool hot while the bottom tool is being transported and installed.

3.2 Process Improvements

3.2.1 New Procedure

Before improvements can be made in the tool changeover process time, the procedure first needs to be standardised between all teams and operators. A new process will also ensure that bad habits and personal preferences and methods are eliminated. It is essential that all teams follow the exact same procedure even if it initially seems slower.

The new procedure is broken down into three sections that are not interdependent. If an operator finishes a task they may move onto the next task provided it is in the same section of the process, if an operator finishes a section before other operators they must wait for everyone to catch up before continuing. The completion of a section is important as historically one operator would stop doing an ‘unimportant tasks’ halfway through so the ‘important tasks’ can continue, only to delay the changeover at a later stage. The time it takes to complete sections is secondary to quality. Operators must complete tasks in order, slowly and correctly rather than keeping within the time frame.

Team leaders should note the start and end times of completing each section but should not focus on keeping to any time target until all teams are achieving similar times and issues and imbalances within the procedure are resolved. Once production samples have been made and the settings checked all operators must meet again at the front of the forge and the tool change declared over. The forge can then be started in its automatic cycle. Any adjustments made after this point are a reflection of the changeover quality.

3.2.2 Changeover Trolleys

A changeover trolley was designed to hold all the tools and parts required to perform a changeover. The changeover trolley serves three main functions:

1. To reduce operator movement by providing all the necessary tools and equipment in the right place.
2. To improve tool change preparation, by ensuring the trolley is prepared
3. To assist the operator in following procedure, by using the items on the trolley from left to right.

Three changeover trolleys are required; one for the front, one for the back and one for the left of forge, for the three operators who perform a tool change. Each trolley should have its own unique layout based on the tasks each operator needs to perform. The required layout for the forge operator’s trolley at the front of the forge is shown in Figure 9.
3.3 Strategic Changes

3.3.1 Scheduling Changeovers

Changeovers are scheduled for the beginning of the morning or afternoon shifts (6:00 or 14:00), in future, this should be moved to one hour into a shift (7:00 or 15:00). This is important as its means operators do not arrive at work and immediately have to start with the tool change usually meaning they are unprepared and not in the correct mind-set. It will also make the entire changeover, a single team’s responsibility including changing bars at the loading bay as well as the production samples at the end of the previous run. The shift before a changeover also often stop the forge before the end of their shift in anticipation for a changeover resulting in a longer amount of forge downtime which is not included in the changeover time.

More changeovers should also be scheduled per month. Doing more changeovers before changeover time is reduced may create an initial decrease in plant performance but it will raise the importance of improving changeover performance and make it a priority in the organisation. Performing more changeovers will also change employee perception that changeovers are unimportant and only performed occasionally to something that is part of everyday work. While this will initially be difficult to accept, eventually changeovers will just be the norm and will not be dreaded by operators, team leaders and management.

3.3.2 One Attempt Adjustments

Currently when the forge goes down or there is a defect due to an incorrect setting there is an informal company protocol that the forge operator has 15 minutes to solve the problem. If he does not resolve the problem in 15 minutes the team leader must be involved. Together the operator and team leader have a further 15 minutes to resolve the issue. If after half an hour the problem persists a forge specialist must be contacted and involved in resolving the situation. It is suggested that a new protocol is introduced.

When the forge is stopped or goes down due to a defect on the part, a forge failure or a problem with settings the forge operator has one attempt to resolve the problem. One attempt means that once the forge is stopped the operator can make the changes or adjustments they think necessary but once they set the forge to run again the one attempt is over.

If after one attempt the problem persists the team leader must be involved and the operator and team leader, working together, have one attempt to resolve the problem. If after a
total of two attempts the problem is unresolved the forge specialist must be involved. When the forge specialist is involved he must work with operators and the team leader until the problem is resolved.

This protocol is designed to encourage the operators to follow a troubleshooting process before making an adjustment based on a guess. Currently operators know that time is essential and thus make quick adjustments to get the forge running again. This results in many minor stoppages where one longer stop would be far faster overall.

Operators and team leaders must be trained in troubleshooting, such as inspecting everything first for cracks, loose bolts, broken equipment or any abnormality before making any changes. A white board should be placed next to the forge to facilitate trouble shooting. Team leaders and operators should be encouraged to record problems and the steps they followed to resolve it. This can allow lessons and knowledge to be shared between teams.

3.3.3 Performance Measuring

The current changeover performance measures do not give changeovers enough importance and do not adequately represent whether a changeover was good or bad. Three performance measures should be recorded and charted after every tool change. Forge performance charts should be reported on in the production meeting by the team leader the day following the changeover.

1. Tool change and set-up time - which is recorded automatically on an Overall Equipment Effectiveness (OEE) system. This measure is currently recorded and is the time it takes to replace the actual tools. The target for changing the tool should be to reduce the time from 90 minutes to 60 minutes in 6 months.

2. Scrap produced during a changeover - which is already measured and should be continued to ensure the defect rate continues to remain low.

3. The time between full production - This new measure will need to be calculated manually by team leaders. The time between full production is measured from the time the forge is stopped at the end of a part run until the time when a production run of more than 500 parts are produced at a production speed of at least 900 parts per hour. This means that the machine has to run for at least half an hour non-stop before the changeover can be considered complete. Figure 10 shows how to calculate the time between full production. The target for the time between full production should be to reduce the time from 200 minutes (3 hours and 20 minutes) to 120 minutes in 6 months.
4 BENEFIT ANALYSIS

This section summarises the expected benefits associated with the presented design solutions.

4.1 Time Savings

4.1.1 Changing the Tool

While reducing the time it takes to change the tool should not be the initial focus, based on the solutions presented it is possible to reduce the time it takes to change the tool from 1 hour 43 minutes to 1 hour. Estimated time savings on the critical path is detailed in Table 2.

<table>
<thead>
<tr>
<th>Improvement</th>
<th>Estimated time saved (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tong gauge block</td>
<td>4</td>
</tr>
<tr>
<td>Changing V-station</td>
<td>2</td>
</tr>
<tr>
<td>Torque wrench</td>
<td>4</td>
</tr>
<tr>
<td>Removing bolts</td>
<td>1</td>
</tr>
<tr>
<td>Lock nuts</td>
<td>3</td>
</tr>
<tr>
<td>Oven shelf</td>
<td>1</td>
</tr>
<tr>
<td>Relocate oven</td>
<td>4</td>
</tr>
<tr>
<td>Multi-connect</td>
<td>4</td>
</tr>
<tr>
<td>Lower lubrication</td>
<td>1</td>
</tr>
<tr>
<td>Changeover trolley</td>
<td>4</td>
</tr>
<tr>
<td>Standard process and co-ordination</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>40</strong></td>
</tr>
</tbody>
</table>

4.1.2 Reduction in Adjustment Time

While it is hypothetically possible to eliminate the adjustment time by gaining complete control of the forge settings, the forge is over 33 years old and will always present some adjustment difficulties. The average adjustment time based on a conservative estimate is...
currently 1 hour and 35 minutes. By proactively managing settings and adjustments and changing the focus of the tool change from speed to quality this time can be reduced to an average of 45 minutes per tool change.

This suggests that the total production to production changeover time can be reduced from 3 hours 20 minutes to 1 hour 45 minutes. A total time estimated saving of 90 minutes.

4.2 Reduced Inventory

The time reduction of 90 minutes means that the total production to production changeover time which is currently 3 hours and 20 minutes can be halved. Theoretically this equates to being able to do twice the number of changeovers in a month without losing any production time. Being conservative, the company can move from doing an average of five changeovers in a month to eight. With eight changeovers, the required inventory needed within work in progress to sustain downstream processes can be reduced by 24%. This will free up a significant amount of working capital, and space in the plant.

4.3 Increased Capacity

Instead of using the reduction in changeover time to perform more changeovers, the same number of changeovers could also be performed which result in an increase in the overall forging capacity by over 7000 parts per month, equivalent to an extra shift per month. The spare capacity presents an opportunity to make more sales or removes the need for running overtime shifts when behind schedule.

5 CONCLUSION

The need to improve the forge’s changeover performance is highlighted by the large amount of inventory in the plant, the difficulties in planning production and the large variation in changeover times. By improving changeover times, smaller batch runs can be considered, shorter internal lead times will be possible and ultimately inventory levels can be reduced. This means that the manufacturer will be able to supply existing customer orders in a more efficient and cost effective manner.

The design solutions presented will each provide small benefits to improving the forge’s changeover quality, and reducing the changeover and adjustment time. If the company wishes to sustain these gains, a unified approach is required. This can be achieved by implementing the designs as part of an incorporated changeover project.

6 REFERENCES


