DESIGN OF NEW DIE HOLDER SYSTEM FOR REDUCING DIE EXCHANGE TIME ON 1000 TON HOT FORGING PRESS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

MUHAMMAD AHMAD SIDDIQUE

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
MECHANICAL ENGINEERING

FEBRUARY 2015

Approval of the thesis:

DESIGN OF NEW DIE HOLDER SYSTEM FOR REDUCING DIE EXCHANGE TIME ON 1000 TON HOT FORGING PRESS

submitted by **MUHAMMAD AHMAD SIDDIQUE** in partial fulfillment of the requirements for the degree of **Master of Science in Mechanical Engineering Department, Middle East Technical University** by,

Prof. Dr. Gülbin Dural Ünver
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Tuna Balkan
Head of the Department, **Mechanical Engineering**

Prof. Dr. Mustafa İlhan Gökler
Supervisor, **Mechanical Engineering Department, METU**

Examining Committee Members:

Prof. Dr. R. Orhan Yıldırım
Mechanical Engineering Department, METU

Prof. Dr. Mustafa İlhan Gökler
Mechanical Engineering Department, METU

Prof. Dr. Metin Akkök
Mechanical Engineering Department, METU

Prof. Dr. Haluk Darendeliler
Mechanical Engineering Department, METU

Özgür Cavbozar, M.Sc.
Senior Expert Mech. Design Eng, ASELSAN

Date: February 3rd, 2015

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name: Muhammad Ahmad SIDDIQUE

Signature:

ABSTRACT

DESIGN OF NEW DIE HOLDER SYSTEM FOR REDUCING DIE EXCHANGE TIME ON 1000 TON HOT FORGING PRESS

Siddique, Muhammad Ahmad

M.S., Department of Mechanical Engineering

Supervisor: Prof. Dr. Mustafa İlhan Gökler

February 2015, 82 Pages

In the forging industry, one of the main challenges is the reduction of setup change time which is non-productive time on the forging press. Long non-productive time reduces efficiency and affects profitability of the forging companies. In this thesis study, firstly setup change activities on the 1000 ton forging press of a forging company are observed and analyzed. With the help of these observations, it is seen that the new die holders with cassette holders and the new cassettes are required to reduce the setup change time radically. Different design versions of the new die holders have been studied. A new pair of die holders is designed and manufactured along with the new cassette holders and the new cassettes which hold the forging dies. The factors related to internal setup change operations, which are identified during the time and motion studies and root cause analysis, have been considered during design of the new die holder system.

Several motion and time studies have been conducted to determine the average setup times for usage of new system. The average setup times for the new die holders and the previous die holders used in the particular forging company are compared and considerable reduction in setup time has been achieved. The time spent in mounting and aligning the die-cassette pairs on the die holders is significantly reduced during setup change by the help of the new die holder design. The motion and time study is concentrated on the internal setup change activities other than heating of the dies and cleaning of the forging press. By considering this way, 84% of reduction for the internal setup change time for the die holders with 2 die-sets and 62% of reduction for the internal setup change time for the die holders with 3 die-sets have been achieved on average.

Keywords: Hot Forging, Die Exchange, Die Exchange Time, Die Holder

ÖZ

1000 TON SICAK DÖVME PRESİNDE KALIP DEĞİŞTİRME SÜRESİNİ AZALTMAK ÜZERE YENİ BİR KALIP TUTUCU SİSTEMİ GELİŞTİRİLMESİ İÇİN TASARIM

Siddique, Muhammad Ahmad

Yüksek Lisans, Makina Mühendisligi Bölümü

Tez Yöneticisi: Prof. Dr. Mustafa İlhan Gökler

Şubat 2015, 82 Sayfa

Dövme sanayiinde en büyük zorluklardan birisi, üretim dışı kayıp zamana yol açan kalıp sistemi değiştirme süresinin kısaltılmasıdır. Üretim dışı kayıp zamanın uzun olması verimliliği düşürmekte ve dövme firmalarının karlılığını etkilemektedir. Bu tez çalışmasında ilk olarak bir dövme firmasındaki 1000 tonluk dövme presi üzerindeki kalıp sistemi değiştirme eylemleri gözlemlenmiş ve analiz edilmiştir. Bu gözlemlerin yardımı ile kalıp sistemi değiştirme süresinin temelden azaltılması için kaset tutuculu yeni kalıp tutuculara ve yeni kasetlere ihtiyaç olduğu görülmüştür. Yeni kalıp tutucuların değişik tasarım alternatifleri üzerinde çalışılmıştır. Yeni bir set kalıp tutucu yeni kaset tutucularla birlikte tasarlanmış ve üretilmiştir. Gözlemler sırasında tespit edilen tüm kalıp sistemi değiştirme ile ilgili etmenler ve kök neden analizleri, yeni kalıp tutucu sistemi tasarımında dikkate alınmıştır.

Yeni sistemin kullanımı sırasındaki ortalama kalıp sistemi değişitirme sürelerini belirlemek üzere birçok hareket-zaman analizi çalışması yapılmıştır. Ortalama kalıp sistemi değiştirme süreleri bir dövme firmasındaki mevcut kalıp tutucular ve yeni kalıp tutucular için karşılaştırılmış ve kalıp sistemi değiştirme sürelerinde kayda değer bir azalma sağlanmıştır. Yeni kalıp tutucusu tasarımı ile kalıp-kaset çiftlerinin kalıp tutuculara bağlanması ve hizalanması sırasında harcanan zaman önemli bir şekilde düşürülmüştür. Hareket-zaman analizi, kalıp sistemi değiştirme eylemlerinden kalıpların ısıtılması ve dövme presinin temizlenmesi aşamaları dışında olan ve pres üzerinde uygulanan eylemlere odaklanmıştır. Bu şekilde düşünüldüğünde, kalıp sistemi değiştirme sürelerinde ortalama olarak 2 kalıplı sistemlerde %84, 3 kalıplı sistemlerde %62 oranında bir azalma elde edilmiştir.

Anahtar Kelimeler: Sıcak Dövme, Kalıp Değiştirme, Kalıp Değiştirme Zamanı, Kalıp Tutucusu

To my family,

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude and appreciation to Professor Dr. Mustafa İlhan Gökler for his valuable guidance, advice, criticism and systematic supervision throughout this thesis study. Thank you for providing me with the vision and direction at times when mine was blurriest.

This thesis would not have been possible without the support of AKSAN Steel Forging Company. I thank Mr. Cevat Kömürcü, Mrs. Tülay Kömürcü, Mrs. Tülin Özkan, Mr. Yakup Erişkin, Mr. Rahmi Türkmen, Mr. Budak Erdağlı, Mr. İsmail Burak Çetin and Mrs. Gözde Erdoğan from AKSAN Steel Forging Company Ankara. I thank you all for your technical support regarding forging processes, access to the machines and design facilities, your valuable time and resources. During the thesis related project works at AKSAN, I have found all of the participating members as more than colleagues but rather a family like team. I wish you all the best in your future endeavors. Furthermore, I would like to extend my thanks to METU - BILTIR Research & Application Center for providing me with their facilities and resources in support of this thesis.

I am forever thankful to my parents Muhammad Siddique and Fouzia Siddique for their never ending moral support, love and patience during my studies. I would also like to thank my brothers Dr. Nasir Siddique, Mr. Azhar Siddique and Dr. Talal Siddique for their encouragement and valuable advice during my graduate education and stay in Turkey.

Finally, I would like to thank my very talented colleagues Meriç Uçan, Remzi Çöl, Sevgi Saraç Karadeniz, Başak Güneş Orhan, Kamil Özden, Tuğra Erol and Özhan Geçgel for their invaluable support and assistance.

TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

CHAPTER 1

INTRODUCTION

1.1 Forging

Forging is a metal forming process in which the workpiece is plastically deformed into desired shape by application of compressive forces using various dies and tooling [1]. As a result of this process, grain structure and material properties of the parts are greatly improved. Forged products are among the strongest manufactured parts when compared to other metal products [2]. Forging can be classified into four different category sets:

1. Classification of Forging by temperature as hot, cold and semi-hot (warm) forging
2. Classification of Forging by machine used as hammer, press forging, etc.
3. Classification of Forging by die-set used as open-die forging and closed-die forging
4. Classification of Forging by workpiece material as steel forging, aluminium forging, etc.

1.1.1 Classification of Forging by temperature

Hot forging is the plastic deformation of the metal workpiece at a temperature above its recrystallization temperature such that strain hardening of the metal workpiece is avoided. This temperature is about 1200°C in case of steels. It is easier to achieve large plastic deformation due to high temperatures involved. However, costly heating requirements, extensive scale formation due to oxidation, low dimensional accuracy and large tolerances required for further machining are the key disadvantages of the process.

Cold forging is the plastic deformation of metal at the room temperature. Precise geometries with low tolerances can be achieved during this process. Heating and material costs are saved. However the stresses developed on the dies are high in cold forging due to low temperatures involved. As a result, limited geometries and volumes can be cold forged [3].

Semi-hot forging process exists between the closer tolerance and more costly cold forging process and the lower precision hot forging process. It helps to forge parts of steel alloys with close tolerances that were not possible by cold forging. The components formed are close to final shapes and have good finish compared to those formed by hot forging previously [4]. Another advantage is the reduction of flow stress and hence the forging force required compared to cold forging process [3].

1.1.2 Classification of Forging by type of machine used

Hammers operate by converting the potential energy of the ram into kinetic energy. They are energy restricted machines that work at high speeds. The short process time reduces the cooling of a hot forging part. Low cooling rates thus permit the forming of intricate profiles, especially those with thin and deep recesses. To reach the final shape, many consecutive blows may be made in the same die [1].

Mechanical presses are crank or eccentric type machines that are stroke restricted. This implies that their speed is greatest at the center of the stroke and zero at the end of the stroke. A large flywheel connected to an electric motor generates the energy required by the mechanical press. A clutch engages the flywheel to an eccentric shaft. A connecting rod translates the rotary motion into a reciprocating linear motion. The force available at a time depends on the position of the stroke and becomes extremely high at the end of the stroke. Hence, setup should be made carefully to prevent damage to the dies and tooling. There are numerous advantages of using mechanical presses over other forging machines such as high production rates, easy automation, less operator training required and high precision production of forging parts.

Screw presses generate their energy from a flywheel and are therefore energy restricted machines. A large vertical screw transmits the force, and the ram comes to a halt when the flywheel energy has been dissipated. If the dies do not close at the end of the cycle, the operation is repeated until the forging is completed. Screw presses are used for various open-die and closed-die forging operations. They are suitable particularly for small production quantities, especially thin parts with high precision, such as turbine blades.

Hydraulic presses operate at constant speeds and are load restricted. They stop if the load required exceeds their capacity. Large amounts of energy can be transmitted to a workpiece by a constant load throughout a stroke - the speed of which can be controlled. Because forging in a hydraulic press takes longer than in the other types of forging machines, the workpiece may cool rapidly unless the dies are heated. Compared with the mechanical presses, hydraulic presses are slower and involve higher initial costs, but they require less maintenance [5].

1.1.3 Classification of Forging by type of die set used

Open-die forging involves plastic deformation of the workpiece billet between two flat plates to reduce its thickness [6]. The process is called open-die forging because the workpiece is not confined laterally by impression dies. This process is generally used to upset the initial billet or to gradually shape the starting billet into the desired shape in various steps, most commonly between flat-faced dies.

In closed-die forging, the impression dies usually with two halves are used in a way that the flow of metal from the die cavity is restricted. The excess material flows through a restrictive narrow gap and appears as flash around the forging at the die parting line [7]. Figure 1.1 depicts the stages in the closed die forging of a typical connecting rod.

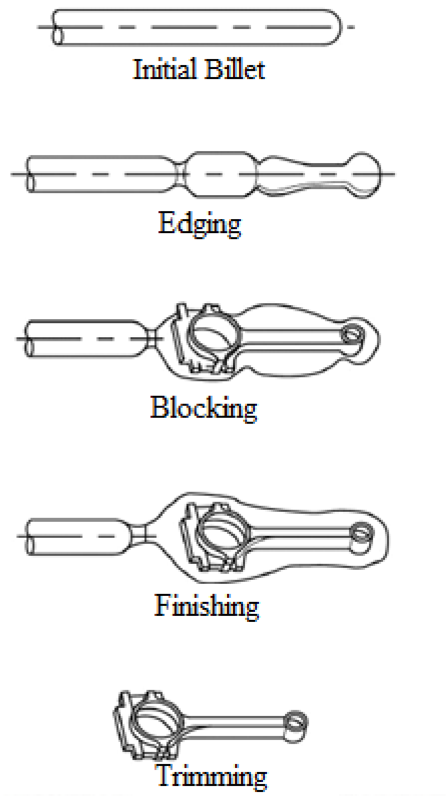

Figure 1.1 Stages in closed die forging of a connecting rod [1]

1.1.4 Classification of Forging by workpiece material

In the forging process, almost all types of metals can be forged. Generally the metals forged are carbon, alloy and stainless steels, very hard tool steels, aluminium, titanium, brass, copper and high-temperature alloys containing cobalt, nickel or molybdenum. Based on the strength or weight desired for each kind of forged part manufactured, the customer decides which type of workpiece material to use in forging [8]. For instance, steel forgings are common in automotive and weapons manufacturing industry, whereas titanium and aluminium forgings are preferred for aerospace parts.

1.2 Forging practice in AKSAN Steel Forging

AKSAN Çelik Dövme Sanayi ve Ticaret A.Ş. is a steel forging company in Ankara, Turkey that focuses on hot impression-die forging process using mechanical forging presses. When a customer first places an order for a forging product, the process engineer designs operation sequence, geometries of the part at the preform stages and the required die cavities on the die block using the Pro-Engineer software and runs the finite element and finite volume analyses of the dies using MSC Superforge software. If the design is approved for manufacturing of the dies, then the tooling department manufactures the die sets accurately. To save the die material costs and to simplify the repetitive setup operation, AKSAN uses the cassettes in which the dies are mounted for the 1000 ton (9806.65 kN) forging press. The cassettes are mounted on their respective upper and lower die holders. During the setup, dies are mounted into the cassettes and then cassettes are mounted to upper and lower die holders using shoes and bolts. There are three different types of cassettes used, each with the same outer dimensions but different inner dimensions. Each type is for accommodating the three sizes of circular die sets. No cassettes are used for rectangular dies, as they are directly mounted on the die holders.

To level and align the die sets, workers currently use plates of different thickness and sizes under the cassettes and between the cassettes and shoes. This task is very challenging and time consuming as there is no standard procedure adopted for doing it. The available die holder system also does not have sufficient locating features that can assist the setup operations.

The setup operations can be categorized into two groups – internal setup operations and external setup operations. External Setup operations involve activities which can be performed while the forging press is working. These include the preassembly of dies to the cassettes. The necessary components and equipment should be identified, brought about and put together with preparation of all conditions necessary just before the forging process stops. Internal setup involves all those activities that require the forging press to be stopped; therefore the press is kept idle during the internal setup. This is the actual downtime of the machine. It includes the mounting of die-cassette pairs to the die holder accurately and the alignment of upper and lower die sets. It also includes the die heating time [9].

1.3 Problem Statement and Previous attempt for the solutions

The difficulties in reducing setup time on all forging presses exist primarily in the die holder, the clamping mechanism used, the assembly sequence of the parts fitting together, and the training of workers to follow the procedure carefully. On the 1000 ton forging press of AKSAN, the current setup activities take approximately 2 to 3 hours while the press is kept idle, which is the time when the press is not producing acceptable quality parts. This directly increases the cost of forging and ultimately the parts being produced. Table 1.1 shows the initial time study for setup change of a typical part on 1000 ton forging press in AKSAN.

Table 1.1 Initial data of time study of a typical part on 1000 ton forging press in AKSAN

Operation Number	Operation	Press	Time (minutes)
1	Dismounting previous die-cassette set	Off	40
2	Mounting new die-cassette set	Off	60
3	Heating	Off	30

One way to reduce the setup time is by applying the technique called Single Minute Exchange of Dies (SMED) which aims to perform setup operations within a single digit value of time in minutes [10]. Together with quick changeover (QCO) technique, SMED significantly tackles with most of the upfront problems, thereby reducing considerable amount of setup time.

Özgür Cavbozar [11] studied the design of fixturing system for forging dies on the 1000 ton forging press of AKSAN, which attempted to solve various problems regarding setup time. However some of the proposals have not been implemented by AKSAN due to various reasons as discussed in related chapters. However, there is potential to reduce the setup time by changing the setup equipment such as die holders, cassettes, etc. [9].

1.4 Scope of the Thesis

Minimizing the internal setup time means directly reducing the cost per unit manufactured of the forging process, increasing the flexibility of the system to produce more variety of parts in less batch sizes, increasing profits and attracting more customers. During the die exchange process, external setup activities should be increased by converting the internal setup items to the external setup items as much as possible. While the press is running, the internal setup time which causes non-productive time is reduced by preassembling the dies to the cassettes. The purpose of this thesis study is to reduce the internal setup time, by redesigning the die holders and the related parts. Modular fixture design is considered when designing the die holder to make it more efficient and convenient to use.

In Chapter 2, literature survey related to the thesis study is conducted. Furthermore, current factors related to setup change in a forging company are observed, results and application of solutions to problems previously studied are analyzed, and alternative solutions developed and applied by the engineering department of the particular company are discussed in Chapter 3. There are multiple steps involved during observation and data collection such as motion and time study analyses, root cause analysis using cause-effect diagram and the five-why technique as presented in the same chapter. In Chapter 4, different versions of die holders are studied and a new die holder system is designed along with cassette holder and new cassettes using Computer Aided Design software. All of the components related to the new die holder assembly are modeled. In Chapter 5, manufacturing and assembling of the new die holder are covered. Motion and time studies are conducted after mounting the new die holders to the forging press. Averages of the setup change times obtained using previous and the new die holders are compared. In Chapter 6, results are discussed and the recommendations for future studies are given.

CHAPTER 2

LITERATURE SURVEY

The problem of setup time comprises of multidimensional issues. To address these challenges, the collected observational data is used by a thorough research on possible solution techniques and tools to be used in the solution. For the given purpose, an in depth literature survey is carried out to facilitate the research and development process involved in the reduction of setup time for the 1000 ton forging press. The paragraphs and topics that follow in this chapter include information that is used to approach and tackle the problems at hand. Various books, academic journals, research publications, industrial sources, theses and internet sources were researched to find relevant methods and techniques put together to practically solve specific problems.

2.1 Setup time

It is the time elapsed from the moment a machine finishes one job, until it starts working again producing quality items for the next job. Reducing setup time increases the quality of operation. Setup operations are often associated with wasted time due to preparation of machine and the readjustments required as a result of improper initial test production. Hence some parts initially produced may be wasted due to inaccurate setup. However it is possible to reduce the amount of wasted parts and wasted time by improving setup process. In other words, setup reduction leads to better results. Some techniques which can be used in reducing setup time are given in the following sections.

2.2 Single Minute Exchange of Dies (SMED)

After the Second World War, the Japanese had embarked on a national movement to improve quality. The Japanese dealt with setup reduction since as early as the seventies, as a result of this movement. At the heart of the setup reduction effort is a method called SMED (Single Minute Exchange of Dies) which evolved by the work of a Japanese industrial engineer called Shigeo Shingo. Though the name SMED implies a limitation to presses, for which the method was originally developed, SMED can be applied to setups other than die changes. The successes achieved in applying SMED were revolutionary [12].

Steps involved in SMED:

1. Observe the current methodology: Current procedures of all the changeover process are generally recorded on video. This covers the complete changeover from one model to another model.

2. Separate the internal and external activities: Internal activities are those that can only be performed when the process is stopped, whereas external activities can be done while the last batch is being produced or once the next batch has started.

3. Streamline the process of changeover: For each iteration of the above process, a substantial improvement in setup times should be expected so it may take several stages to cross the ten minute line.

4. Continuous training: After the successful first iteration of SMED application the prime requirement becomes the training of all the operators of the cell [13].

Separating Internal and External Setup is assisted with using a checklist to determine availability of correct number and type of parts, performing function checks to ensure that the parts are in good working condition and improving transportation of dies and other parts.

Next, converting internal setup stage to external setup stage involves function standardization, reducing internal setup adjustments, preparing operating conditions in advance, and preheating of dies etc. Function standardization is very useful as when there are standard sizes and dimensions of the parts, the operator can follow a standard procedure during setup change without any chance of ambiguity or mistake.

Streamlining all aspects of the setup operation is very important as after everything is prepared and kept ready in good working order, the internal and external operation activities must be synchronized to work flawlessly and in right order [14]. Figure 2.1 shows the sequence and steps involved in the SMED process.

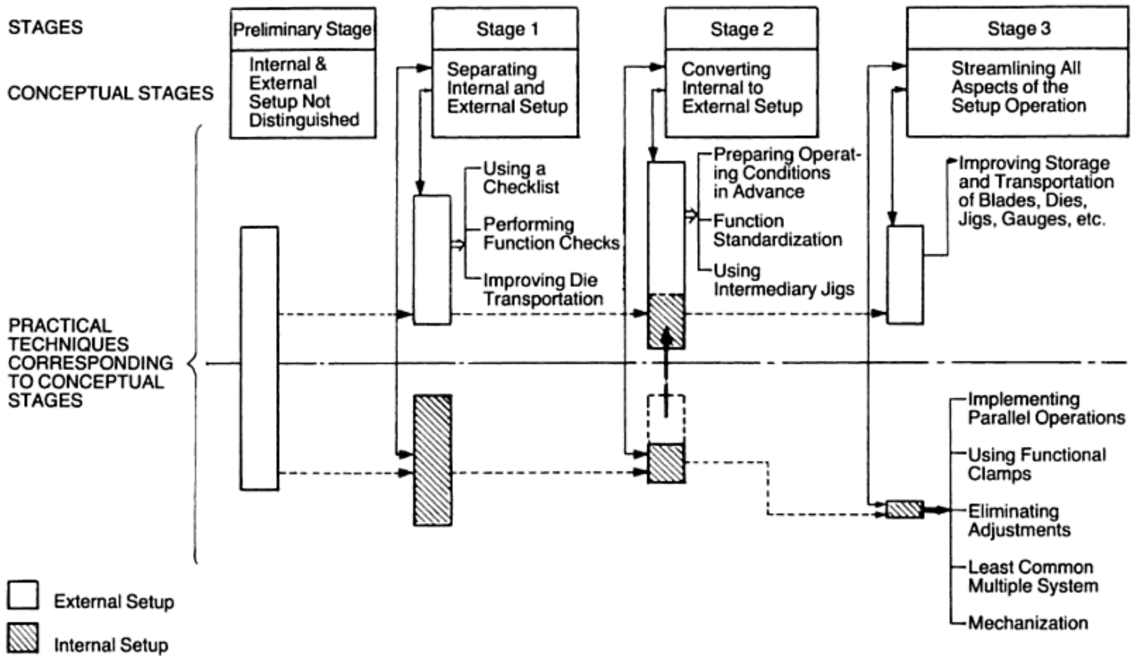

Figure 2.1 Single-Minute Setup (SMED): Conceptual Stage and Practical Techniques [14]

2.3 Quick Change Over (QCO)

Quick changeover incorporates proven, simple process orientated systems and methods to reduce tools, plant or equipment changeover times to facilitate increased capacity, smaller batch sizes, more agility to changing demands, lower inventory and reduced lead times. Most of the companies face this business paradigm, where they have ever increasing requests for smaller and more frequent deliveries, changing demands requested at short notice and orders for special parts or some form of uniqueness and customization of the products and services they provide and at low price. The solution is in batch size reduction, quick response and flexibility, through mastering quick changeover and standardization. The keys to quick changeover are as follows:

1. The ideal setup change takes place within seconds.

2. Ensuring that all tools are always ready and in perfect condition.

3. Blowing a whistle and have a team of workers respond to each changeover.

4. Establishing goals to reduce changeover times, record all changeover times and display them near the machine.

5. Distinguishing between internal and external setup activities and try to convert internal setup to external setup [15].

2.4 Locating Principle (3-2-1)

In fixture design, the first step is to restrict the six degrees of freedom of the part. For this purpose, it is possible to apply six individual locating points but the six degrees of freedom can be restricted in many ways, each of which is geometrically equivalent to the six locating points.

The six degrees of freedom of a rectangular block are considered as shown in Figure 2.2. It is made to rest on several points on the fixture body. Provide a rest to workpiece on three points on the bottom *x*-*y* surface. This will stop the movement along *z*-axis in one direction, rotation with respect to *x*-axis and *y*-axis. Supporting it on the three points is considered as better support then one point or two points. Rest the workpiece on two points of side surface (*x*-*z*), this will fix the movement of workpiece along *y*-axis in one direction and rotation with respect to *z*-axis. Provide a support at one point of the adjacent surface (*y*-*z*) that will fix other remaining free movements along x. This principle of location of fixing points on the workpiece is also known as 3-2-1 principle of fixture design as number of points selected at different faces of the workpiece are 3, 2 and 1 respectively [16].

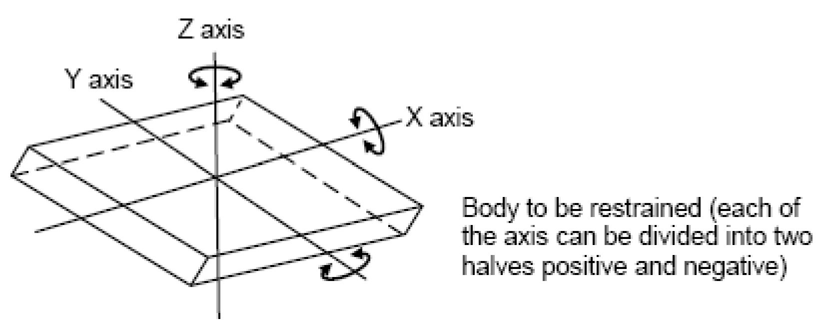

Figure 2.2 Available degree of freedom of rectangular block [16]

The 3-2-1 principle represents minimum requirements for locating elements. The locators, together with the clamps (represented by arrows C in the Figure 2.3) which hold the part in place, provide equilibrium of all forces, but do not necessarily also guarantee stability during machining. Usually, stability is satisfactory if the three base buttons are widely spaced and the resultant cutting force hits the base plane well within the triangular area between the buttons. If it hits outside of this area, then it generates a moment which tends to tilt or overturn the part. The pressure and frictional forces from the clamps may be able to counteract this moment, but this solution is not considered good practice, because vibrations and shocks from machining can cause the part to slip in the clamps [17].

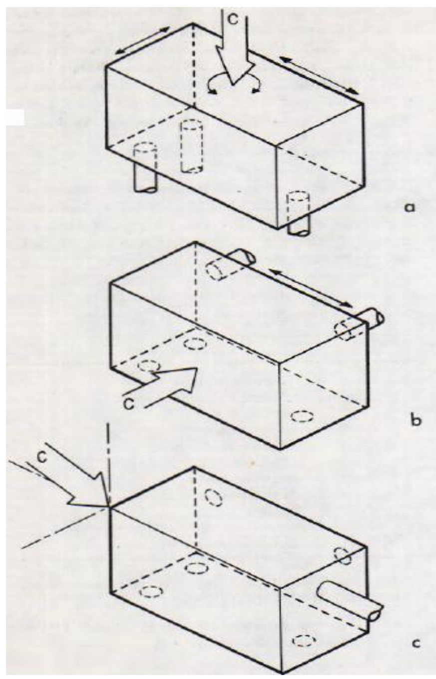

Figure 2.3 Principle of locating a part by 3-2-1 method [17]

2.5 The 5S Technique

5S is a lean manufacturing technique used to reduce waste and optimize productivity through maintaining an orderly workplace and using visual cues to achieve more consistent operational results. Implementation of this method "cleans up" and “organizes” the workplace basically in its existing configuration.

The 5S pillars - Sort, Straighten, Shine, Standardize and Sustain (Seiri, Seiton, Seiso, Seiketsu and Shitsuke in Japanese respectively) - provide a methodology for organizing, cleaning, developing, and sustaining a productive work environment. In the daily work of a company, routines that maintain organization and orderliness are essential to a smooth and efficient flow of activities. This lean method encourages workers to improve their working conditions and helps them to learn to reduce waste, unplanned downtime, and in-process inventory.

A typical 5S implementation helps reduce the space needed for existing operations. It would organize tools and materials into labeled and color coded storage locations, as well as "kits" that contain just what is needed to perform a task. 5S provides the foundation on which other lean tools, such as Total Preventive Maintenance (TPM), Cellular Manufacturing and Just-In-Time production may be introduced. Figure 2.4 shows the overall 5S cycle.

“Sort” helps to eliminate unnecessary items from the workplace that are not needed for current production operations. An effective visual method to identify these unneeded items is called "red tagging", which involves evaluating the necessity of each item in a work area and dealing with it appropriately. A red tag is placed on all items that are not important for operations or not in the proper location or quantity. Once the red tag items are identified, these items are then moved to a central holding area for subsequent disposal, recycling, or reassignment. Organizations often find that sorting enables them to reclaim valuable floor space and eliminate such things as broken tools, scrap, and excess raw material.

“Straighten” focuses on creating efficient and effective storage methods to arrange items so that they are easy to use and to label them so that they are easy to find and put away. Straighten can only be implemented once the first pillar, Sort, has cleared the work area of unneeded items. Strategies for effective use of “Straighten” include painting floors, affixing labels to designate proper storage locations and methods, outlining work areas and locations, and installing modular shelving and cabinets.

“Shine” means to clean the work area. Once the clutter that has been clogging the work areas is eliminated and remaining items are organized, the next step is to thoroughly clean the work area. Daily follow-up cleaning is necessary to sustain this improvement. Working in a clean environment enables workers to notice malfunctions in equipment such as leaks, vibrations, breakages, and misalignments. These changes, if left unattended, could lead to equipment failure and loss of production. Organizations often establish shine targets, assignments, methods, and tools before beginning the shine pillar.

“Standardize” creates a consistent approach with which tasks and procedures are done. Once the first three S's have been implemented, the next pillar is to standardize the best practices in the work area. The three steps in this process are assigning 5S (Sort, Straighten, Shine) job responsibilities, integrating 5S duties into regular work duties, and checking on the maintenance of 5S. Some of the tools used in standardizing the 5S procedures are: job cycle charts, visual cues (such as signs, placards, display scoreboards), scheduling of 5S, and check lists. The second part of Standardize is prevention - preventing accumulation of unneeded items, preventing procedures from breaking down, and preventing equipment and materials from getting dirty.

“Sustain” is about making a habit of properly maintaining correct procedures. It is often the most difficult S to implement and achieve. Changing entrenched behaviors can be difficult, and the tendency is often to return to the status quo and the comfort zone of the "old way" of doing things. Sustain focuses on defining a new status quo and standard of work place organization. Without the Sustain pillar the achievements of the other pillars will not last long. Tools for sustaining 5S include signs and posters, newsletters, pocket manuals, team and management check-ins, performance reviews, and department tours. Organizations typically seek to reinforce 5S messages in multiple formats until it becomes "the way things are done” [18].

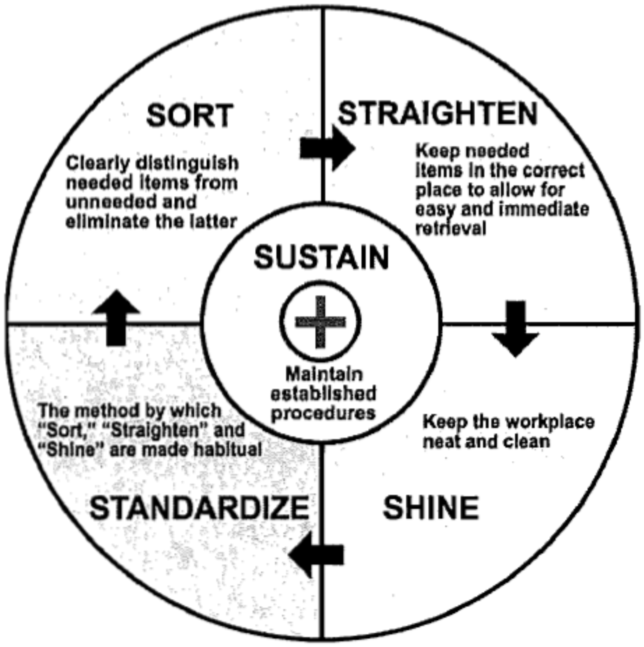

Figure 2.4 The 5S cycle [18]

CHAPTER 3

OBSERVATIONS AND STUDY OF SETUP CHANGE ACTIVITIES ON 1000 TON FORGING PRESS

3.1 Previous study related to setup change

Previously, Gökler and Cavbozar [11] carried out a study on the 1000 ton hot forging press. They attempted to reduce the setup time by designing a fixturing system for the dies. The problems related to setup change on the 1000 ton press in AKSAN were taken into consideration. The proposals would solve the problems successfully and some of the proposals were implemented in AKSAN and some of them were not applied. In this section, the solutions that were suggested by the previous study [11] for the problems related to long setup change time will be reviewed. The alternative solutions applied for some of the problems by the AKSAN Engineering Department will also be discussed. Table 3.1 lists the problems and solutions studied by Özgür Cavbozar [11].

The first problem in Table 3.1 was about the horizontal misalignment of upper and lower dies in X- and Y-axes as shown in Figure 3.1 and was successfully solved. Male and female features were incorporated in upper and lower dies. This solution has been implemented on all the dies of forging presses in the factory.

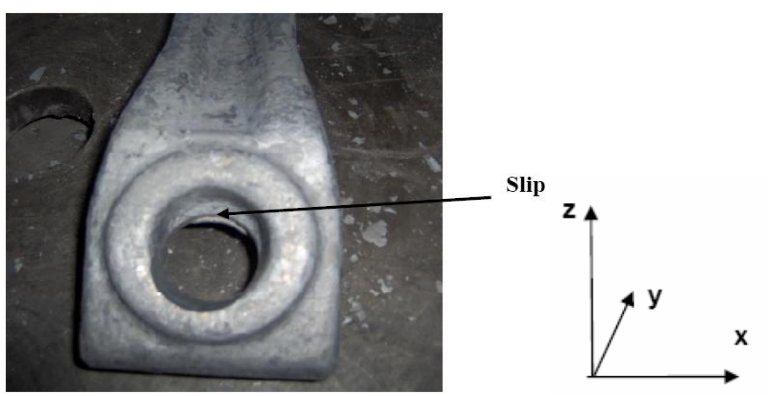

Figure 3.1 Slip problem due to horizontal misalignment [11]

Table 3.1 Problems and solutions in setup change of 1000 ton forging press in the previous study [11]

Problem Number	**Problems studied earlier**	**Solutions proposed earlier**	**Remarks**
1	Upper and lower dies were misaligned in horizontal axes, causing the upper half to be slipped on lower half.	Provide corner shaped positioning features (male on upper and female on lower die surfaces). (See Figure 3.1)	The solution was applied.
2	Upper and lower dies slipped relative to each other about the vertical axis causing rotational misalignment.	Machine planar forms on dies and cassettes to restrict their rotational and angular movements relative to each other. (See Figure 3.2)	The alternative solution using key was applied.
3	During die changing operations, significant amount of time was spent in mounting and dismounting the dies to or from the cassettes.	Machine through-hole with a step inside cassette. Machine external step on the die. Insert die from bottom of cassette. As the die sits on the inner step of cassette, it is automatically fastened. (See Figure 3.2)	The solution was not applied.
4	Difficult to locate the die cavity when mounting it on CNC and EDM for re-machining. This was crucial because die dimensions and profile must remain correct otherwise forging would be flawed.	Design a square-shaped reference pocket on specific locations of die surfaces. Hence, same electrodes in EDM & same codes in CNC can be used again.	The alternative solution was applied.
5	Difficult to obtain additional material to put under the dies to elevate them to previous level after dies were re-machined.	Systematically machine the die to standard depths. Hence standard elevation plates with standard height under the re-machined dies are used during mounting. (See Figure 3.4)	The solution was applied by welding plates with non-standard thickness.

Table 3.1 Problems and solutions in setup change of 1000 ton forging press in the previous study [11] (continued)

Problem Number	**Problems studied earlier**	**Solutions proposed earlier**	**Remarks**
6	Difficult to obtain additional material for tightening when cassettes were mounted to die holders. Plates were inserted between the shoes and cassettes to ensure tight and secure fastening.	Standardize the external dimensions of cassettes and the sizes of shoes so that there is no need to use the fastening plates to fill the empty gaps while mounting cassettes to die holder. (See Figure 3.5)	The solution was applied.
7	Operator could make a mistake and mount the upper die to the lower cassette or vice versa.	To differentiate between upper and lower dies, die surfaces should be marked on top after being produced or re-machined.	Solution was applied by marking on the side external surfaces.
8	Operator could not differentiate between the orientations of cassettes and made a mistake during mounting.	Mark the cassettes on their top surfaces indicating their orientations. This helps understand which sides of the cassette are front, back, right and left. (See Figure 3.6)	The solution was not applied.
9	Misalignment occurred due to improper positioning of cassettes on die-holders.	Use three separate plates instead of using a single flat plate. The V- and flat-shaped pockets are designed in these plates for positioning cassettes on die holders accurately (See Figure 3.7)	The solution was not applied.
10	Operator could not know when and how many times at-most could a die be sent for revision.	Mark the number of times a die has been re-machined over its top surface after each re-machining operation.	Solution was applied by marking on the side external surfaces.

The solution to second problem of rotational misalignment about z-axis, as shown in Figure 3.2, was not applied. Although the solution intelligently eliminates rotational misalignment by using planar forms on the external surface of the die and internal surface of the cassette, AKSAN Engineering Department evaluated that it would have some difficulties in practical implementation. Machining the planar forms precisely using CNC machine would not be only complicated but also expensive. Also the planar forms might get damaged with time, leaving the die useless for further forging operations. Alternative solution, by using key and keyway between cassettes and dies to prevent rotational misalignment, was applied by AKSAN Engineering Department. The usage of key is very effective. If it wears with time, it can be easily replaced.

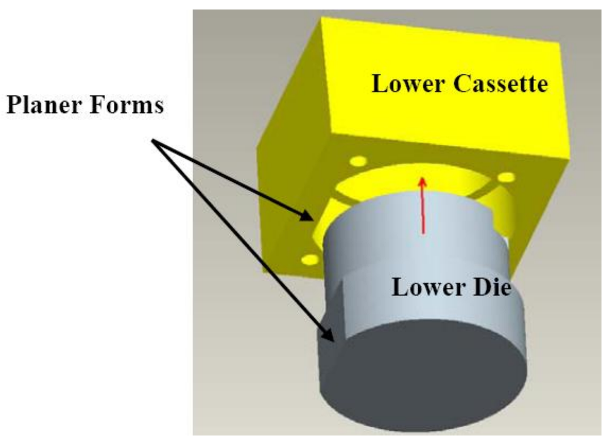

Figure 3.2 Planar forms suggested to eliminate rotational misalignment [11]

In the third problem, a step was proposed at outer diameter of the die and the inner diameter of cassette having a through hole. This modification eliminates die-cassette assembly time since no shoes and bolts are utilized. However, AKSAN Engineering Department did not implement this proposal. This department believe that a gap due to cyclic thermal and mechanical loading in forging process, would be introduced between the die and cassette with time, that might lead to uncontrollable misalignment issue. Therefore, the conventional method which uses shoes and bolts, continues to be used in AKSAN. Figure 3.3 shows the conventional method of fastening the dies in cassettes using internal shoes and bolts.

The fourth problem is about the difficulty in locating the die blocks on CNC machine during remachining. It is critical that after remachining of dies, the die cavity and other referencing features do not get modified as it would affect the forging geometries. A square-shaped referencing pocket would have been machined to help locate the die precisely for each remachining operation. However, it is not implemented because sometimes there is no extra space on the die top surface to machine the square pocket. Instead, they prefer to apply referencing for circular dies from the three points on the diameter and referencing for rectangular dies from their corners using the probe on the CNC machine tool which will be used for remachining of the die.

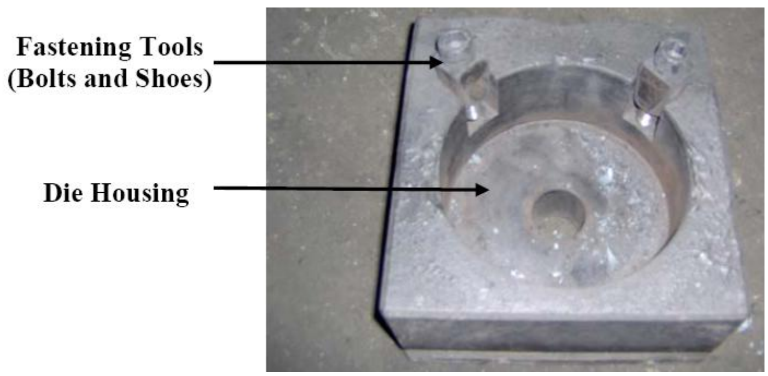

Figure 3.3 Conventional cassette design currently used for mounting the dies by using shoes and bolts in die housing [11]

The fifth problem of compensating the reduced height of the die after remachining was approached by using standardized plates of 1, 2 or 5 mm thickness, as shown in Figure 3.4. For this reason, the die would always be machined to a standard depth each time. However some thicknesses are too little for the releveling plates. AKSAN Engineering Department evaluated that the plates may get deformed easily after few successive forging strokes and this may cause misalignment problems leading to defected forged parts. Therefore, AKSAN applied an alternative solution by welding plates with non-standard thickness.

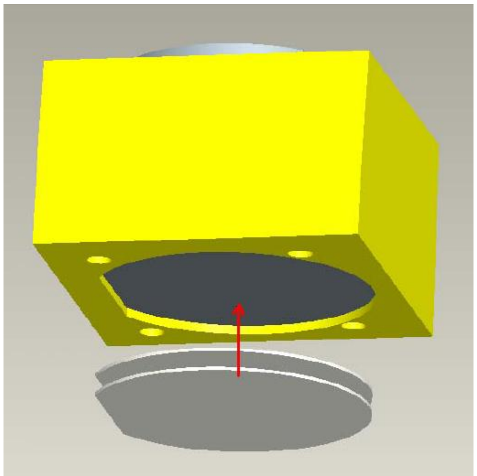

Figure 3.4 Height adjustment plates [11]

In the sixth problem, while fastening the cassettes to die holder with shoes, some additional plates are used to fill the gap between the shoes and cassettes. Variable thickness plates are tried to see which ones fit the best to fill the gap, as shown in Figure 3.5. This problem is solved by standardizing the shoes used for each size of cassette. This was suggested by the previous study and applied in AKSAN.

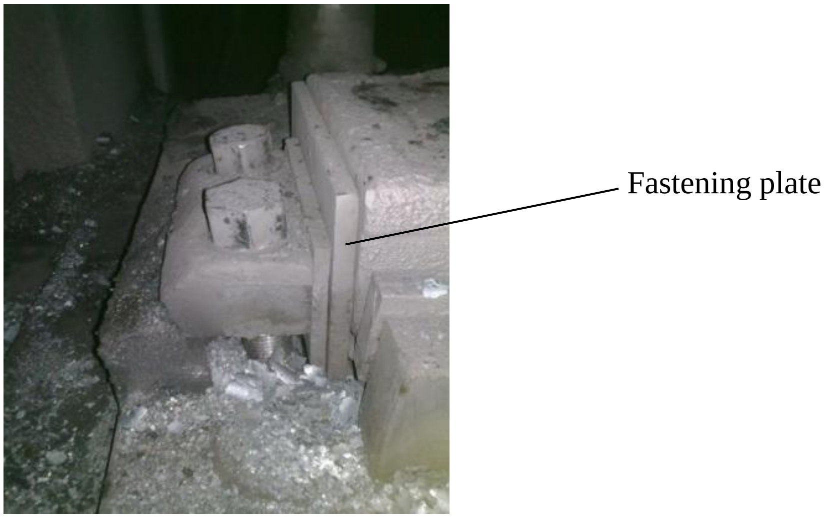

Figure 3.5 Use of fastening plates to fill the gap between shoes and cassettes

The seventh problem was that during the mounting procedure, operators could have been confused as to which die is for the upper cassette and which one for lower cassette. Instead of marking on the top surface, AKSAN prefered to do the markings on the side surfaces to avoid renewing the markings during remachining of top surfaces of the dies. Therefore the correct configuration and orientation for mounting dies was achieved during setup changes.

The solution to the eighth problem, as shown in Figure 3.6, was related to the orientation of the new cassettes with through-holes and planar forms suggested by the previous study [11]. However it has been observed that AKSAN Engineering Department preferred to use their current cassettes to avoid the allocation of budget for the new cassettes without any change in the die holders.

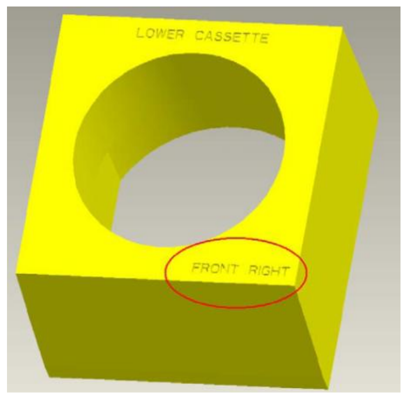

Figure 3.6 Marking for correct orientation of cassettes [11]

The ninth problem was about a misalignment issue related to the improper positioning of the cassettes on the die holder. It was due to lack of sufficient locating features and worn base plate under the cassettes. To resolve this issue, three separate base plates each with its own locating features were designed for use under every individual cassette [12]. Figure 3.7 (a) shows the die holder with three base plates in their housing. One such plate is shown in Figure 3.7 (b). If a base plate required replacement, it would be easy to change that specific plate under the particular cassette. Also the locating features reduce the setup time by allowing easy alignment of the cassettes to their designated positions. Figures 3.7 (c) and 3.7 (d) further show the locating features and alignment method proposed. AKSAN Engineering Department did not implement this proposal due to some very practical reasons. They prefer to use a single base plate rather than three separate base plates. However, the motion and time study which will be given in Section 3.2, implies that a new die holder and a new cassette system with the cassette holder are required instead of using single flat base plate to reduce the setup time.

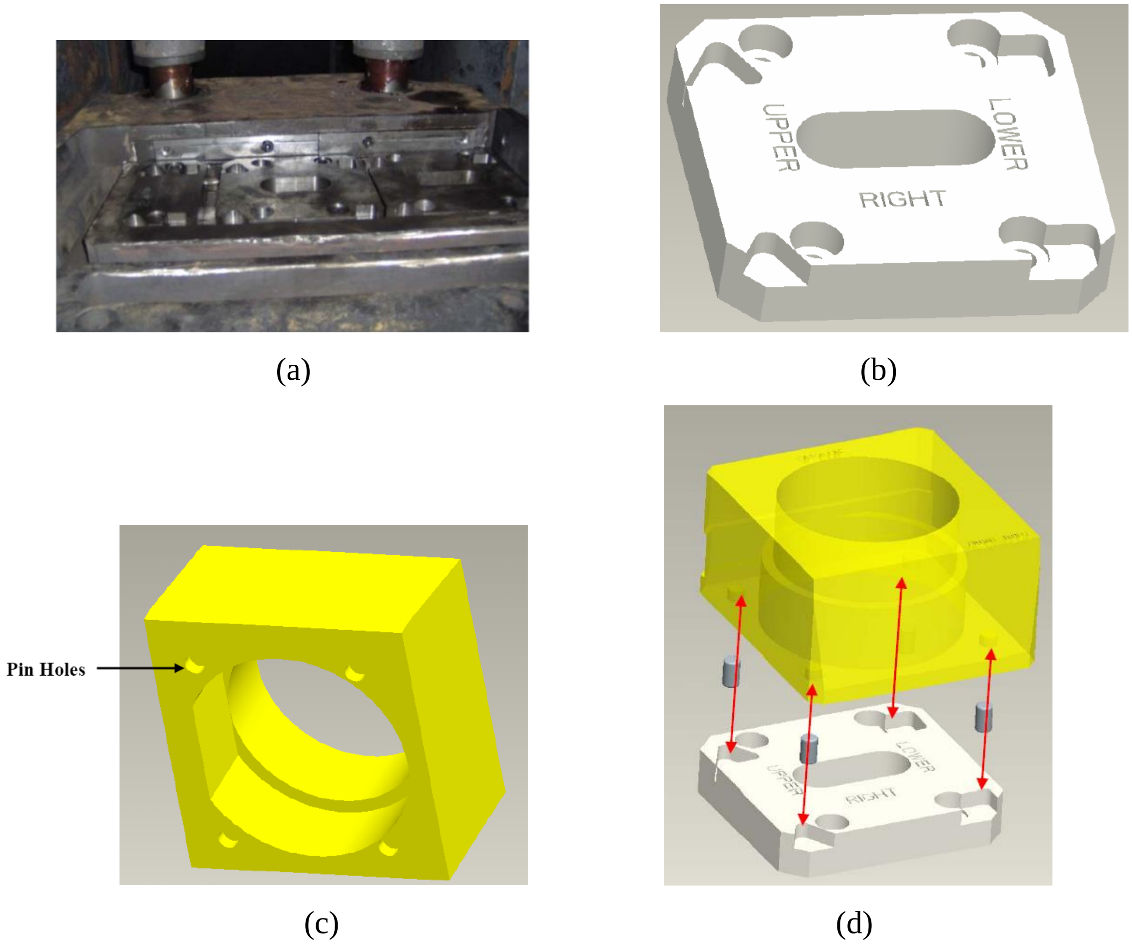

Figure 3.7 Proper positioning of the cassettes on die holder [11]

In the tenth problem, it was required by operators to understand clearly how many times and with what frequency should a die be sent for revision. So after each revision, it was suggested to mark the number of remachining times of the die on the top surface. AKSAN has applied this proposal by marking on the side surfaces of the die.

3.2 Motion and Time Study analyses

At AKSAN Steel Forging, there are a large variety of parts forged at the 1000 ton forging press. Each of these parts have their own unique characteristcs. They may have different dimensions, geometries and material properties. There are three main types of forging operations – upsetting, preforming and finishing. Based on the finite element analysis performed by the process engineer, the sequence and types of different number of forging operations are determined. For example, a simple part may only require one upset and one finish forging operation, whereas a more complicated part may require one upsetting, two preforming and one final finishing operation. The upset dies are usually open dies with flat surface. They are generally used to remove the scale from the workpiece and reduce the thickness or height of the initial billet. One or more of the preform operations are required before the finishing stage. Preform dies are generally closed (i.e. impression) dies. Finishing dies are impression dies that are used to give the part its final shape.

Process design is required for each particular product. The setup change duration varies from part to part depending on the number of dies required for forging it. The sequence of setup change operations is given in Figure 3.8.

Setup change starts from dismounting of the cassettes used in the previous batch of production. This procedure has five main steps. First the operator removes the bolts and shoes from the lower die-cassette pairs. Then the ram is lowered, until upper die-cassette pairs are just over the lower die-cassette pairs. Afterwards, the bolts and shoes of the upper die-cassette pairs are removed. This releases and drops the upper die-cassette pairs on the lower die-cassette pairs. By raising the ram, the operator removes all cassettes one by one. The press is then cleaned thoroughly and the guide pin lubricant is reapplied. The dies are dismounted from cassettes by removing the small shoes in the cassettes. The next phase in setup change is to mount the new dies into cassettes, and the die-cassette pairs onto the forging press with shoes and bolts. Leveling plates are used under lower cassettes and between cassettes to adjust the positioning of the upper and lower die-sets. During the five steps of the mounting process for the current batch, the operator spends significant time searching for the correct components for the assembly. This includes the leveling plates and the cassettes necessary for fitting the parts correctly. Finally, when the adjustment and secure fastening is completed, the dies are heated. It usually takes 30 minutes to 45 minutes to heat the dies after the mounting of cassettes to die holder.

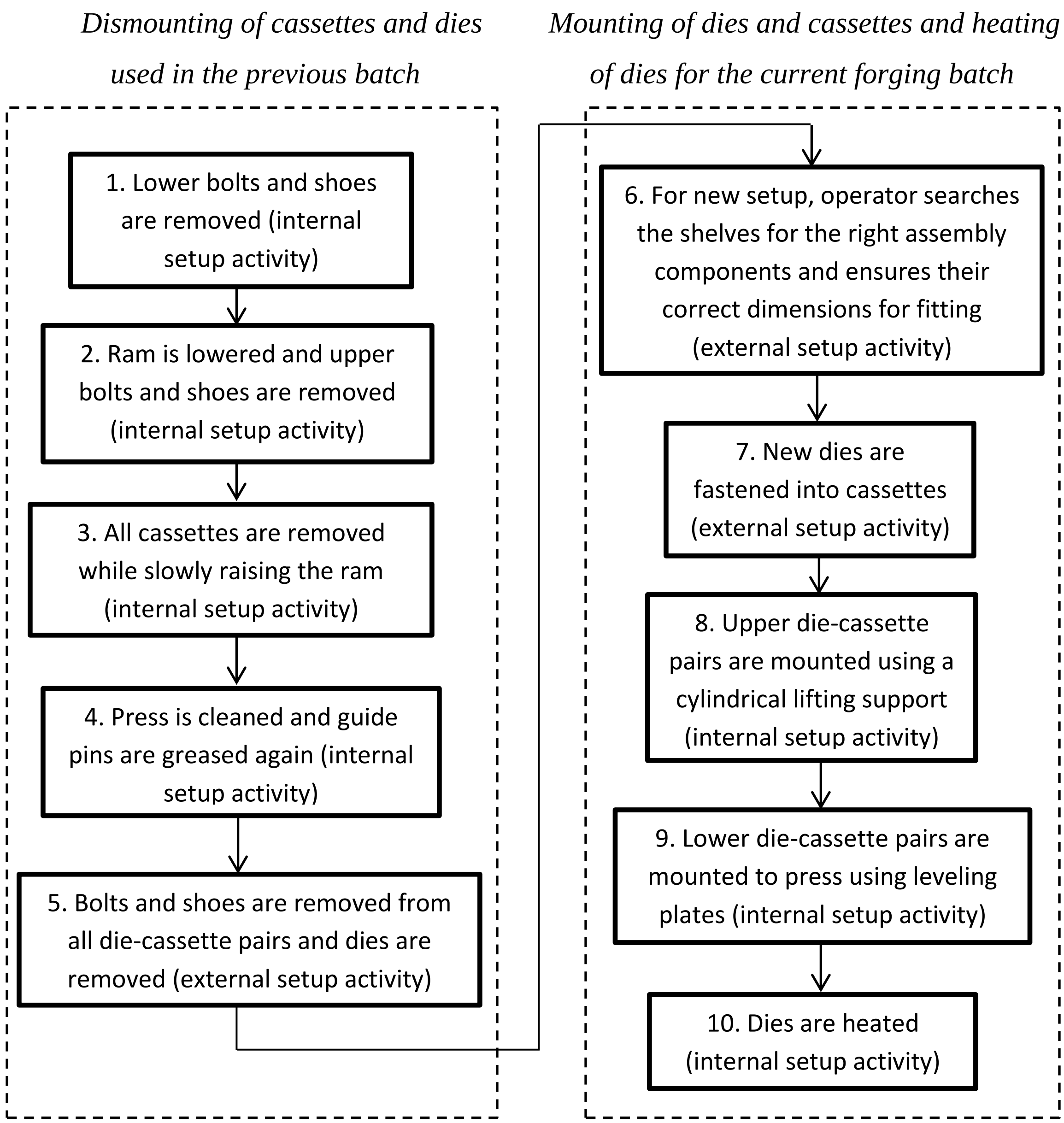

Figure 3.8 Sequence of setup change operations

Different setup changes take different times. Setup for a new production can have two die-pairs, three die-pairs or four die-pairs. After studying each of the steps in the Figure 3.8, the time study is carried out for each of the steps. Time study data is collected on three different setup changes of each type of die-pairs, as shown in the Tables 3.2, 3.3 and 3.4. In case of two die-pairs, one of the die-sets can be for upsetting operation and the other die-set is for finish-forging operation. The data is collected for three different setup changes having two die-sets, as shown in Table 3.2.

The times for each of the operations are observed to be varying randomly from each other. It is mostly due to the pace at which operator is working. It is also dependent on the fitting of the parts during setup change or finding the right components and tools needed during setup change. Due to confidentiality required by AKSAN, the photographs and drawings are not given for any parts.

Table 3.2 Time study of setup change for Part-A, Part-B and Part-C requiring 2 die pairs

	TWO DIE PAIRS IN SETUP	Part-A	Part-B	Part-C
Number	**Setup Change Activity**	**Time (seconds)**		
	Dismounting Operations			
1	Removing bolts and shoes from lower die holder (internal setup operation)	94	104	87
2	Removing bolts and shoes from upper die holder (internal setup operation)	311	308	324
3	Removing upper and lower cassettes from the die holder (internal setup operation)	465	452	409
4	Cleaning press and re-greasing guide pins (internal setup operation)	897	748	695
5	Removing shoes and bolts from die-cassette pairs and removing dies (external setup operation)	503	526	514
	Mounting and Heating Operations			
6	Making necessary preparations for new setup (external setup operation)	634	581	628
7	Mounting dies to cassettes (external setup operation)	347	364	337
8	Mounting upper die-cassette pairs to die holder (internal setup operation)	583	598	546
9	Mounting lower die-cassette pairs to die holder (internal setup operation)	429	476	431
10	Heating the dies (internal setup operation)	1800	1800	1800
	TOTAL	6063	5957	5771

In case of three die-pairs, there can be one upset die, one preform die and one finishing die. The time studies for three of the setup changes having three die pairs have been conducted and the data collected is shown in Table 3.3.

Table 3.3 Time study of setup change for Part-D, Part-E and Part-F requiring 3 die pairs

	THREE DIE PAIRS IN SETUP	Part-D	Part-E	Part-F
Number	**Setup Change Activity**	**Time (seconds)**		
	Dismounting Operations			
1	Removing bolts and shoes from lower die holder (internal setup operation)	126	131	147
2	Removing bolts and shoes from upper die holder (internal setup operation)	348	343	336
3	Removing upper and lower cassettes from the die holder (internal setup operation)	535	542	551
4	Cleaning press and re-greasing guide pins (internal setup operation)	884	869	930
5	Removing shoes and bolts from die-cassette pairs and removing dies (external setup operation)	627	653	589
	Mounting and Heating Operations			
6	Making necessary preparations for new setup (external setup operation)	649	651	712
7	Mounting dies to cassettes (external setup operation)	429	485	463
8	Mounting upper die-cassette pairs to die holder (internal setup operation)	614	656	671
9	Mounting lower die-cassette pairs to die holder (internal setup operation)	634	675	639
10	Heating the dies (internal setup operation)	2700	2700	2700
	TOTAL	7546	7705	7738

The time for setup change operations increases with the increase in number of die pairs assembled or disassembled. This is because more dies need to be mounted to cassettes with accuracy. The alignment of dies and adjustment time increases with increase in number of die sets. The number of bolts and shoes required to fasten the dies to cassettes and the die-cassette pairs to die holders are also increased. With the increase in die sets, the time required to heat the more number of die sets also increases from 1800 seconds to 2700 seconds.

In case of four die-pairs, there can be two upset dies, one preform die and one finishing die or one upsetting die, two preform dies and one finishing die. The time studies for three of the setup changes having four die pairs have been conducted and the data collected is shown in Table 3.4.

Table 3.4 Time study of setup change for Part-G, Part-H and Part-I requiring 4 die pairs

	FOUR DIE PAIRS IN SETUP	Part-G	Part-H	Part-I
Number	**Setup Change Activity**	**Time (seconds)**		
	Dismounting Operations			
1	Removing bolts and shoes from lower die holder (internal setup operation)	164	107	128
2	Removing bolts and shoes from upper die holder (internal setup operation)	372	334	355
3	Removing upper and lower cassettes from the die holder (internal setup operation)	583	492	576
4	Cleaning press and re-greasing guide pins (internal setup operation)	872	865	604
5	Removing shoes and bolts from die-cassette pairs and removing dies (external setup operation)	597	576	584
	Mounting and Heating Operations			
6	Making necessary preparations for new setup (external setup operation)	680	1329	670
7	Mounting dies to cassettes (external setup operation)	457	607	326
8	Mounting upper die-cassette pairs to die holder (internal setup operation)	873	627	1490
9	Mounting lower die-cassette pairs to die holder (internal setup operation)	842	870	1272
10	Heating the dies (internal setup operation)	2700	2700	2700
	TOTAL	8140	8507	8705

To represent the data of the three categories of die-sets in a more useful way, averages of each type are calculated and the results are presented in Table 3.5 for an easy comparison. It can be seen that, in general, the time for setup change operations increases depending on the number of die pairs assembled. However, some general operations, such as heating of dies and cleaning of the forging press, usually take similar amount of time during each setup change. The heating times are dependent on the type of equipment and technique used for heating the dies. If the equipment is upgraded, the heating time can reduce accordingly. Similarly, the technqiue and tools used by the worker to clean and prepare the forging press for the next production batch determines the cleaning time.

Table 3.5 Average setup change times

	Number of die pairs in setup	2	3	4
Number	**Setup Change Activity**	**Time (secs)**		
	Dismounting Operations			
1	Removing bolts and shoes from lower die holder (internal setup operation)	95	135	133
2	Removing bolts and shoes from upper die holder (internal setup operation)	314	342	354
3	Removing upper and lower cassettes from the die holder (internal setup operation)	442	543	550
4	Cleaning press and re-greasing guide pins (internal setup operation)	780	894	780
5	Removing shoes and bolts from die-cassette pairs and removing dies (external setup operation)	514	623	586
	Mounting and Heating Operations			
6	Making necessary preparations for new setup (external setup operation)	614	671	893
7	Mounting dies to cassettes (external setup operation)	349	459	463
8	Mounting upper die-cassette pairs to die holder (internal setup operation)	576	647	997
9	Mounting lower die-cassette pairs to die holder (internal setup operation)	445	649	995
10	Heating the dies (internal setup operation)	1800	2700	2700
	TOTAL	5930	7663	8451

From the time study of setup change activities, it is seen that internal setup operations take a significant amount of time during setup change. The mounting and dismounting of die-cassette pairs and their alignment and adjustment takes the majority of the time. Therefore, an improvement in system is required to reduce this long internal setup time. To further investigate the problem of long setup time, root cause analysis is conducted. In Tables 3.2 to 3.5, the setup change activities 1, 2, 3, 8 and 9 represent internal setup activities. The activities 4 and 10 which are cleaning and die heating respectively are also internal setup activities. The activities 5, 6 and 7 represent external setup activities. If activities 1, 2, 3, 8 and 9 are considered, which consist of mounting and dismounting of cassettes to the die holders, the total average setup times for these activities can be calculated as 1872, 2316 and 3029 seconds for the setup with 2 die-sets, 3 die-sets and 4 die-sets respectively. This shows that there is a considerable potential to reduce these times by speeding up mounting and dismounting of cassettes to die holders.

3.3 Root cause analysis

Fishbone diagram may be utilized to identify the root cause of the problem. It is possible to do so by asking the question "why" several times. The last "why" should reveal the main cause of the problem. To illustrate the results based on observations in forgeries, the Fishbone diagram is presented in Figure 3.9.

To begin with the analysis, it has been started by analyzing a simple fact - there is a long internal setup time on the 1000 ton forging press as revealed by the time study data. From the analysis of this fact based on the observations, five major reasons are identified. Each one is presented in the Fishbone diagram in Figure 3.9.

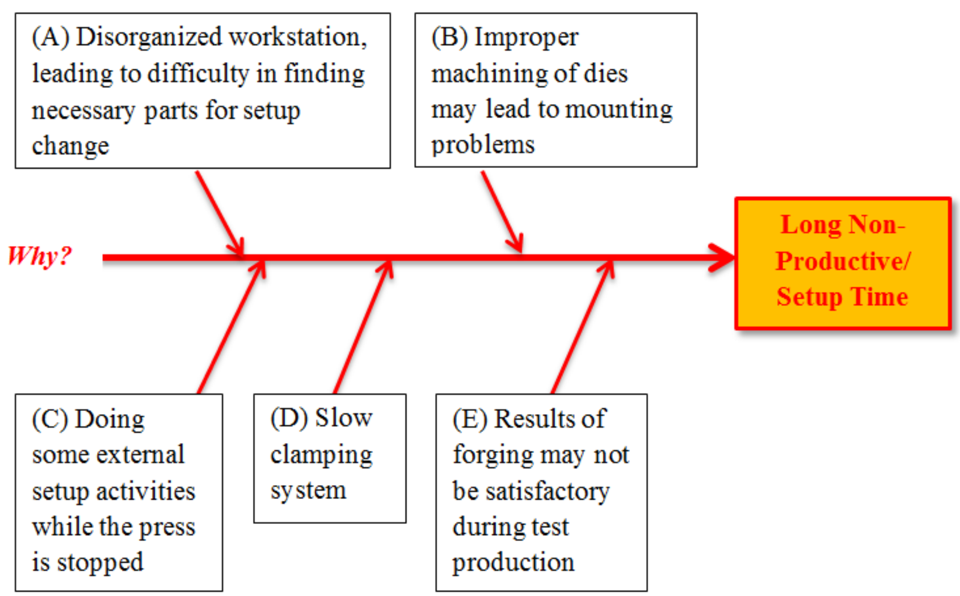

Figure 3.9 Fishbone diagram for the causes of long setup time on the 1000 ton forging press

To reach the root cause of each identified reason, the question “why” is asked multiple times, as below:-

(A) It is difficult to find necessary parts during setup change.

1. Why? The components and tools needed during setup change take long time to collect and use.

2. Why? Their location is far from the work station or scattered around the forging area.

3. Why? They are not stored in well-maintained dedicated shelves which are clearly labeled and well positioned.

4. Why? There is not enough space near the workstation for organizing all the equipment in one place.

This is one of the root causes identified. Even though the space around the press is congested, it is possible to reduce some amount of time by organizing the essential equipment in clear order.

(B) If machining of dies is improperly done, it may increase setup time

1. Why? The upper and lower die sets do not align and fit together.

2. Why? If the vital features of the upper and lower dies are not machined accurately in relation to each other or if during re-machining of dies, the dies will not align or fit together well.

3. Why? Sometimes the quality control of the die pairs is not done carefully enough or effectively to ensure that both dies fit together well during setup change.

This root cause can be tackled by the management by improving the performance of the employees or upgrading quality control tools to reduce chances of mistake in machining of dies.

(C) Some setup activities which should be done externally are performed during internal setup.

1. Why? Because there is not enough manpower to do those activities externally.

2. Why? People think working at forging industry is a tough job involving high risk and requiring high skill, therefore it is difficult to find new workers.

3. Why? Forging requires physical strength in handling heavy equipment during forging or setup, as well as to work near high temperatures. It is also tiring to be in a constantly noisy environment. The factory area is not so clean due to the oily industrial grease, industrial dust, metal scrap and black soot around forging presses. Hence multiple factors make it difficult to acquire new manpower suitable for the job.

The root cause of man power availability is the challenge of management or human resource department, which might need to provide enhanced incentives to the workers with physically demanding jobs.

(D) The clamping system is slow and inefficient

1. Why? Workers take long time in clamping the cassettes using shoes and bolts.

2. Why? The shoes and bolts are not quick clamping devices, and manual work is always slow.

3. Why? There are multiple threads on the bolts that require it to be turned multiple times to be tightened.

4 Why? Whenever bolts are used, they need to have sufficient number of threads to provide enough clamping force to the shoes that hold the cassettes in place.

5. Why? Bolts are mechanical components and this is their natural limitation.

This is one of the major technical root causes identified. It can be addressed by upgrading the clamping system from conventional shoes and manually operated bolts to quick acting clamping systems. Another root cause is identified when the situation is analyzed from the design perspective.

(E) During test production, the results of forging may not be satisfactory.

1. Why? There are multi-axes misalignment problems among lower and upper dies and between upper and lower die pairs.

2. Why? It is difficult to position and align the die-cassette pairs accurately on the die holder during setup change.

3. Why? There are no locating and positioning features in the fixturing system to assist the accurate positioning of dies or cassettes during each setup change.

4. Why? The design of the die holder is very old and outdated. It is also old-fashioned to accommodate for new forging trends and to cope with the modern pace of the forging industry.

The greatest potential to reduce internal setup time and increase the reliability in forging emerges from the designing of a new fixturing system. It also helps establish a standardized procedure and approach to changing the setup of tooling each time. Hence it is concluded that the most crucial root cause of the long setup change time comes from the design of the die holder and the setup technique. Therefore a new die holder must be designed to solve the problem fundamentally.

3.4 Conclusion of observations and study of setup change on the 1000 ton forging press

The die holder currently being used in AKSAN has many drawbacks. Although it is a durable design which has been used for long time, it is not very efficient. According to the modern forging industry trends and its competitive pace, there are not sufficient locating features and guides available to mount the die-cassettes quickly to the die holder. There are also some major design limitations due to the nature of the hot forging process. The immense cyclic mechanical and thermal loading means that the dies, cassettes, locating pins, holes and features used are subjected to heavy wear over time. The more the features there are, the more is the probability of misalignment with time due to the large extent of tolerances involved.

One of the worst challenges currently during setup change is the use of several thin sheet metal plates used in the alignment and adjustment of die-cassettes. These plates are put under the cassettes or between cassettes and shoes for making adjustments during setup operation. Figure 3.10 shows how the plates are used. During the first setup attempt, the worker does not have a clear idea of how well the upper and lower dies have aligned. Then he securely fastens the cassettes to die holder with shoes and bolts. Afterwards, he rechecks alignment by lowering the ram and observing if the upper die and lower die operate smoothly without getting stuck into each other due to the male and female features used. If so, the operator makes the final full tightening of the bolts and shoes when it is sure that the upper and lower dies had been aligned well. If not, he has to loosen the bolts and hammer in the gap and reposition the cassettes and shoes. This process goes on until the alignment is ensured. Finally when the heating is turned on and the dies are heated to 250 – 300 °C, test run is carried out on a few number of heated billets. This ensures quality in full production run. However it is quite often seen that there may be misalignment and therefore out of production tolerance on the forged parts. This forces to halt the production process and the forging press for readjusting the cassettes by putting or removing plates, grinding the plate or cassette surface, or by simply repositioning the cassettes and refastening the bolts tightly into correct position.

All of these are frustrating and time consuming tasks leading to long non-productive time that has an undesirable cost for the company to pay for.

Sheet metal plates used for adjustment of cassettes

Figure 3.10 Sheet metal plates used between cassettes for intuitive adjustment

CHAPTER 4

PROPOSED METHOD AND SOLUTIONS

In Chapter 3, the problems related to the setup change on the 1000 ton press were discussed. In Section 4.1, variation of the dimensions of the parts manufactured on 1000 ton press will be presented. In Section 4.2, the new die holders and cassettes developed for reducing setup change time will be introduced in detail. In Section 4.3, components of the new die holders will be described.

4.1 Currently manufactured parts on 1000 ton press in AKSAN

An observation has been completed on the parts forged in AKSAN between the years 2013 and 2014. There were 47 different parts forged on the 1000 ton hot forging press during this period. A total number of about 230000 of these parts were forged through a total of 121 setup changes on the 1000 Ton Forging Press [9]. There were 40 non-circular parts and 7 circular parts. To understand the sizes of dies necessary to produce these parts, each of the part drawings have been studied. The outer dimensions of the circular and non-circular parts were determined and categorized. The numbers of circular and non-circular parts forged according to their dimensions are given in Tables 4.1 to 4.4.

Table 4.1 Distribution of Non-Circular Part Geometries according to x-dimension (width) [9]

x-dimension (width) intervals (mm)	**Numbers of different part geometries**
$0 < X \leq 30$	0
$30 < X \leq 60$	5
$60 < X \leq 90$	9
$90 < X \leq 120$	11
$120 < X \leq 150$	9
$150 < X \leq 180$	2
$180 < X \leq 210$	4
	Total = 40

The x-dimension represents the width of the parts, y-dimension represents the length and the z-dimension represents height. It may be referred to Appendix A for the raw data collected at AKSAN.

Table 4.2 Distribution of Non-Circular Part Geometries according to y-dimension (length) [9]

y-dimension (length) intervals (mm)	Numbers of different part geometries
0 < Y ≤ 30	1
30 < Y ≤ 60	25
60 < Y ≤ 90	11
90 < Y ≤ 120	3
	Total = 40

Table 4.3 Distribution of Circular Part Geometries according to diameter, Ø [9]

Diameter intervals (mm)	Numbers of different part geometries
0 < Ø ≤ 30	0
30 < Ø ≤ 60	0
60 < Ø ≤ 90	2
90 < Ø ≤ 120	5
	Total = 7

Table 4.4 Distribution of Circular and Non-Circular Part Geometries according to z-dimension (height) [9]

z-dimension (height) intervals (mm)	Numbers of different part geometries
0 < Z ≤ 30	25
30 < Z ≤ 60	18
60 < Z ≤ 90	4
	Total = 47

The data given in Tables 4.1 to 4.4 will help in determining the size of the new cassettes that will be accommodated on the new die holders while designing the new die holders.

4.2 Development of the new die holder system and cassettes

A forging press has an anvil and a ram. The anvil is a non-moving part that is fixed on top of the base while the ram is the vertically moving component which imparts the load on the workpiece. The die holders are fixtures that hold the dies and cassettes firmly in correct places. The die holders are mounted on anvil and ram of the forging press. The purpose of developing a new die holder is to reduce the setup change time by simplying the mounting of assettes to die holders, difficulties in mounting and dismounting die-cassette pairs, and by reducing the workload and level of difficulty on the machine operator. The development stages of various designs leading to the final die holder design are discussed in terms of versions of the new die holder with modified cassette geometries in the following subsections.

4.2.1 Version-1 of the new die holder

In the first design, the idea of using the cassettes with dovetail base was considered. These cassettes would be inserted into their dovetail channels on the die holder, as shown in Figure 4.1. The purpose of using the dovetail channel was to simplify the mounting and dismounting of cassettes and to reduce setup time.

There are three types of dies used during the forging process – upset, preform and finishing dies. Considering the sizes of the parts forged [9], their dies and cassettes currently used on the forging press, three of these dovetail channels were designed to accommodate all possible types and sizes of dies used in AKSAN on the 1000 ton forging press. For each of the channels, there were T-slots designed for using with the T-bolt clamps. The insertion of the bolts would have been adjacent to the dovetail channels.

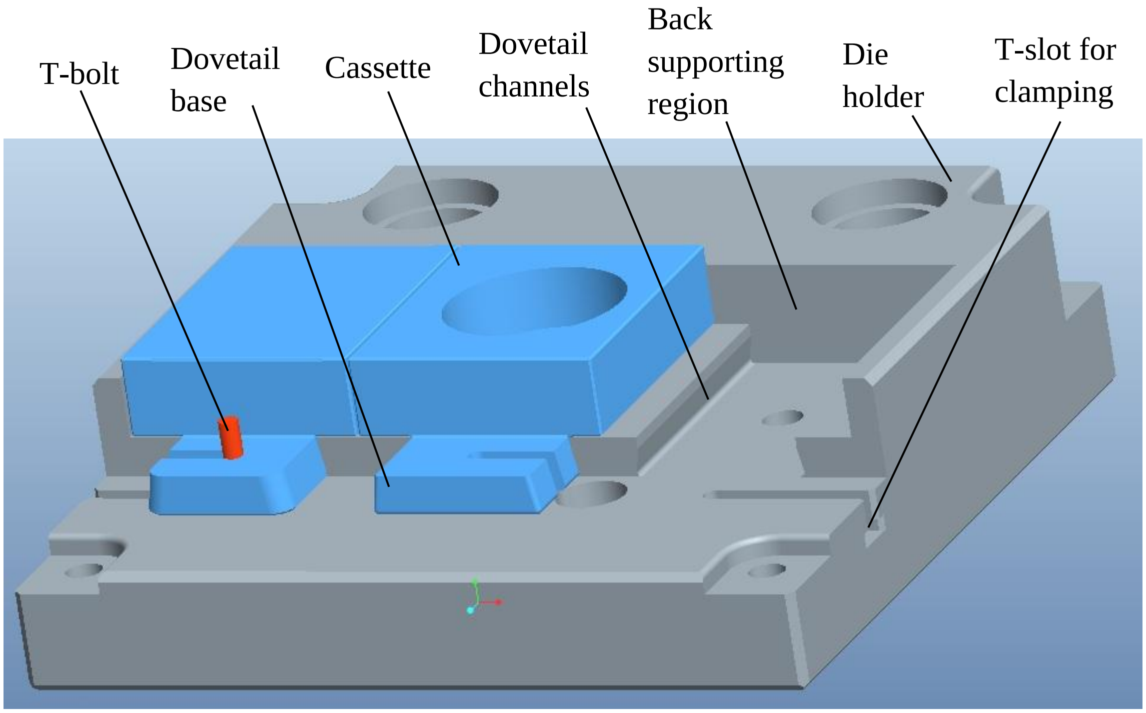

Figure 4.1 Die holder with dovetail form (Version-1)

In the first version, the dovetail channels are an integral part of the die holder. In the hot steel forging process, there is risk of a high degree of deformation and wear on the die holder components. After sometime, the dovetail channels would get damaged and the whole of the die holder would need to be replaced. During the vertical loading, there are also some horizontal forces arising that may cause wear on the back supporting regions of the die holder which support the cassettes. The damage to this region could not be rectified easily but require the entire die holder to be changed. Thus, the design was further modified and these critical parts were made modular so that they could be easily replaced in case they were damaged. This new version of the die holder is explained in the following section as Version-2.

4.2.2 Version-2 of the new die holder

The new modular parts are named “cassette holder” and “back supporting module”. Figure 4.2 shows the modified die holder with the replacable modules. The cassette holder, as shown in the Figure 4.2, is fixed to its dedicated housing area on top surface of the die holders. The back support module is provided to support and hold the cassettes from the rear while fastening. Over a period of time, when the back supporting module gets damaged due to cyclic loading from the cassettes, it can simply be replaced by a new one. The hidden lines in Figure 4.2 are used to show the fitting of the cassettes to the cassette holder. In addition to the modular design, the T-bolt slot was redesigned to be along the direction of the dovetail channels. This was done to quickly fasten the cassettes by using the quick acting clamps. A global market research was carried out to discover any possible solution to reducing the clamping time during setup changes. The new orientation of the T-slots was chosen along the dovetail channels because each of the three quick acting clamps would operate along them without interfering with each other. The clamps available in the market are designed to function in this manner.

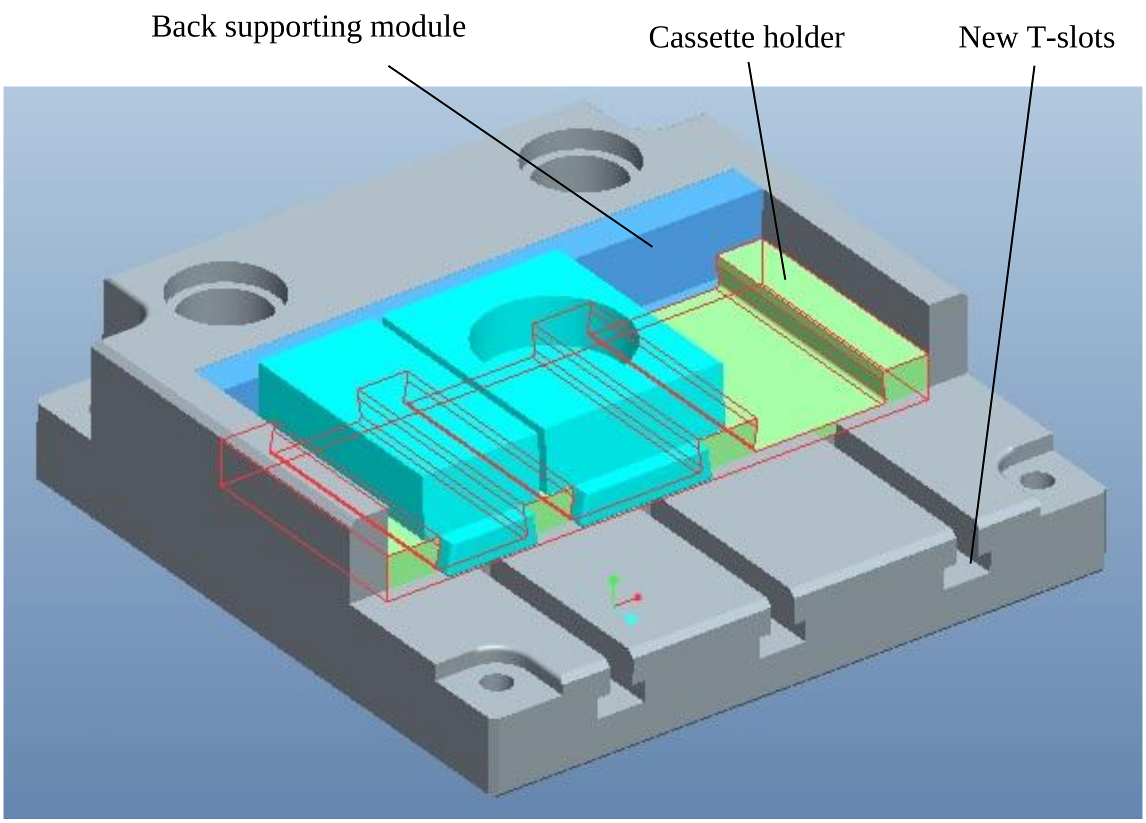

Figure 4.2 Dovetail cassettes, cassette holder, and back supporting module (Version-2)

For demonstration purposes, a mockup of the Verison-2 was hand-modeled using styrofoam, as shown in Figure 4.3. Die holder Version-2 is the basis of the further design development.

Figure 4.3 Demonstration model of the Version-2

4.2.3 Version-3 of the new die holder

Considering the manufacturing process, it was discovered that there are certain challenges related to the use of dovetail channels in the design. Due to the machining difficulty and complexity of the dovetail cassette-base and channels, the dovetails were changed to T-channels. Accordingly, the base of the cassettes was changed as well. The benefit of this change is ease of manufacturing and reduction in design complexity. It is also easier to manage the effect of thermal expansion and contraction during the hot forging stages using the T-channel design. Figure 4.4 shows the new design of the cassette holder. The red dotted lines show the fitting of the cassette to the cassette holder.

The cassette holder, shown in Figure 4.4, is fastened down to the die holder using eight bolts in total. This provides safe and sufficient clamping force. The cassette holder, the cassette and the die have the uniaxial holes for ejector pin to operate through.

Another modification in the design, is the elimination of some side supporting material from the top surface of the die holder where the housing area for cassette holder is designed. This allows the cassette holder to expand and contract sideways during thermal expansion and contraction. Another advantage of this change is the possibility to increase the size of the cassettes used and the T-shaped supporting elements of the cassette holder that hold the cassettes from T-channels.

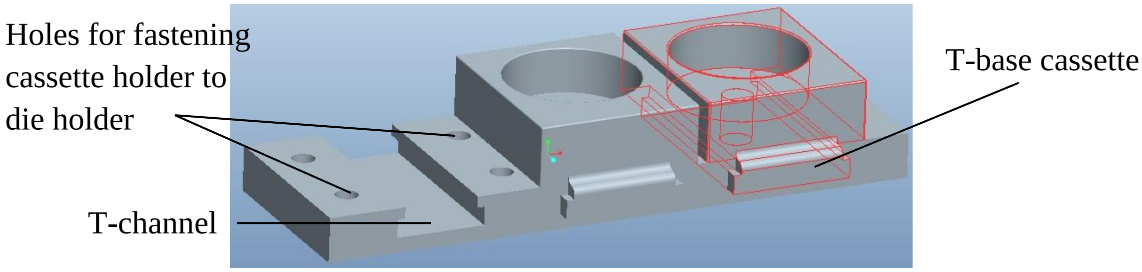

Figure 4.4 Cassette holder with T-channels (For Version-3)

Quick acting clamps were also considered and inquired for reducing the setup time. These are special clamps which are very beneficial in the implementation of the Quick Change Over. The companies that were contacted for quick clamping systems and the information gathered are given below:

1. Serapid – a French company that deals with quick die exchange systems. They offer a clamp called TBHS Escaping Arc Clamp [19]. It is a shock-resistant clamp with curved-motion wedge. However it is hydraulically operated and requires large space for assembly on the die holder. Due to these reasons, it is not suitable to use for reducing setup time on the 1000 ton hot forging press under study. Serapid claims that it is able to provide this clamp with a special cooling system to prevent the risk of hydraulic malfunction [20]. However, this makes the assembly of six clamping units with their dedicated cooling systems difficult due to very limited space on the die holder.
2. Pacesetter Systems – an American company that produces hydraulic and mechanical die clamps. Their equipment cannot work at high working temperatures of 250 to 300°C [21].
3. AGAB – a Swedish company that also deals with quick die exchange systems. They recommended some mechanical clamps. They referred to their Turkish dealer, ÖZALP Mühendislik ve Makina Dış Tic. San. Ltd. Şti. However, no suitable clamps were found for hot forging conditions [22].

4. Forwell – a Taiwanese company that specializes in the production of quick die/mold change systems [23]. Their quick operated clamps were not suitable for hot forging application in AKSAN.

5. Hilma-Roemheld – a German multinational company that provides quick clamping systems. Its systems are provided in Turkey through its dealer HIDKOM. Several solutions were discussed through private communications and meetings with Hilma-Roemheld and Hidkom [24]. The applicability of quick clamps of Hilma-Roemheld will be described in the following paragraphs in detail.

After consulting with Hilma-Roemheld Company [24], the suppliers of quick die change mechanisms, it was discovered that, six quick acting clamps would be necessary in total to provide sufficient clamping force to the heavy die-cassette pairs. Each of the three cassettes would be fastened by two clamps, one from front and one from rear, while being supported by T-channels from the left and right sides. Therefore, the cassette would have two steps for the clamps, one at front and one at rear end. Figure 4.5 depicts how the quick acting hydraulic clamps would secure the cassettes. For simplicity of demonstration, some features such as the back supporting module, the cassette holder, guide pin holes and some T-slots are eliminated from the model.

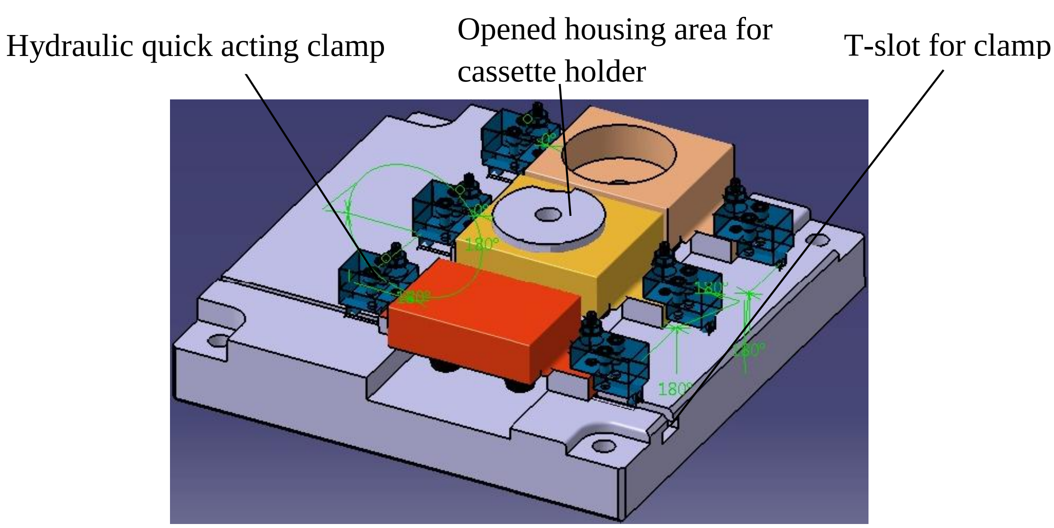

Figure 4.5 A view of the multiple quick acting hydraulic clamps used on the die holder (Version-3)

A safety concern related to accidental slippage of clamps during heavy forging loads lead to the elimination of the T-slots in front of each T-channel. Additionally, the guide pins at the rear of the die holder hindered the use of T-slots from the rear end. Instead, T-slots were designed on the back support module and the die holder, perpendicular to the T-channels of the cassette holder, for fastening the cassettes from both front and rear-ends with quick acting T-slot clamps. The clamping step at the rear of the cassette was accordingly modified. Figure 4.6 shows the updated Version-3 of the die holder design.

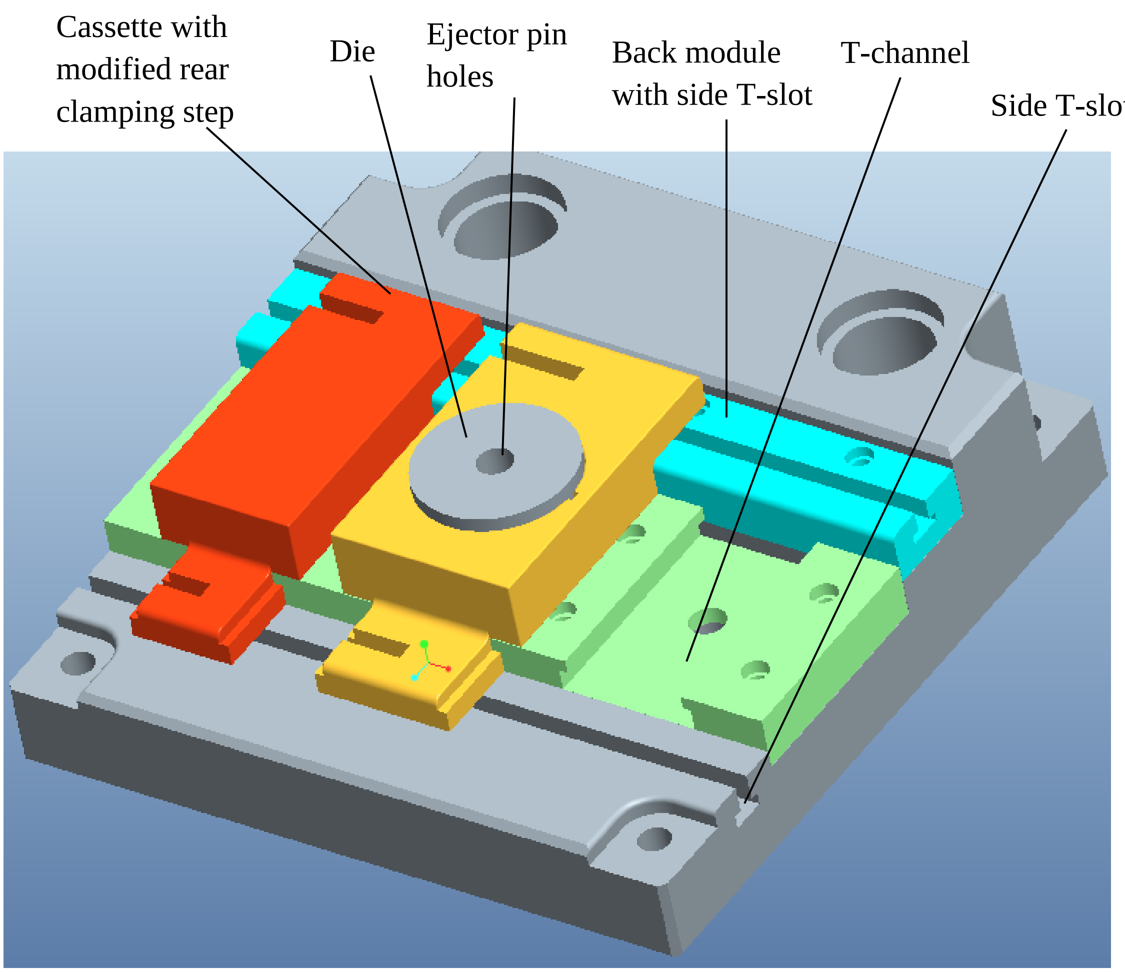

Figure 4.6 A view of the cassettes, cassette holder with T-channels, side T-slots and back support module (Version-3)

A different type of clamp called Power Screw was recommended by Hilma-Roemheld GmbH Company [24]. The benefit of this clamp is its small size and simplicity while providing large clamping force. However, the power screws holding the cassettes from the rear-end were being projected beyond the top surface of the dies. This did not let the dies to close properly. Hence power screws could not be used with this design. Figure 4.7 shows the design model with the Power Screws.

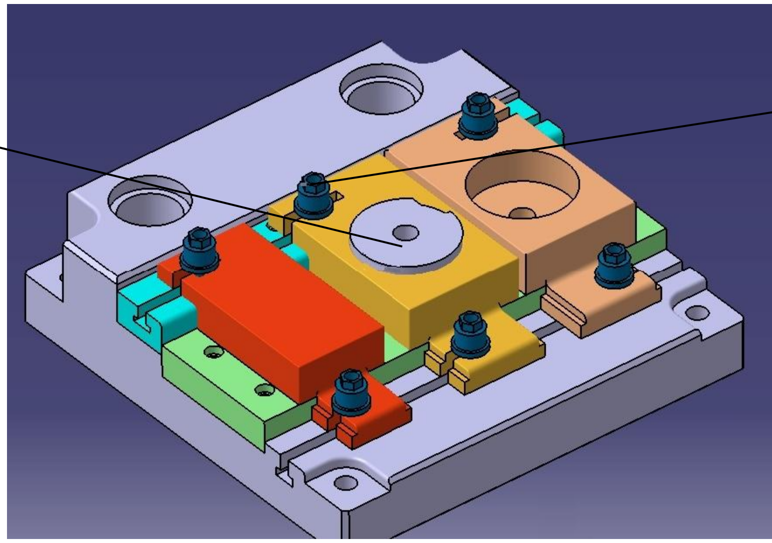

Figure 4.7 A view of the quick acting clamp (Power Screw) on the die holder

Hilma-Roemheld [24] suggested one of their safest clamps, called wedge clamp, which do not need slots for clamping. The wedge clamp has two parts - hydraulic and mechanical. Each of the six wedge clamps is bolted to remain fixed on the die holder mechanically. The hydraulic part of the wedge clamp is operated to clamp or release the cassettes quickly. In case of malfunction of the hydraulic unit, the mechanical fixed part prevents the cassettes from falling out. The wedge clamps are shown in Figure 4.8.

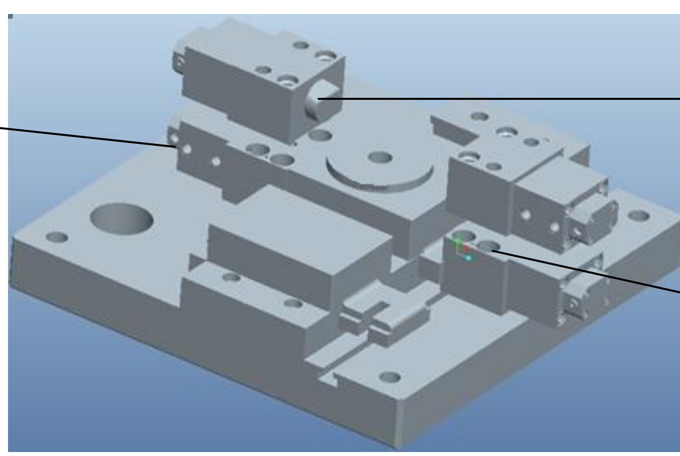

Figure 4.8 A view of the wedge clamps on the die holder

There are many challenges in using the quick acting clamps in this particular study. For example, the wedge clamps in Figure 4.8 stay attached to the die holder. During setup changes, the die-cassette pairs need to be changed by retracting the hydraulic clamping part of the wedge clamp. After insertion of new cassettes, the clamp again fastens the cassettes while maintaining its bolted position on the die holder. However, since it is a big clamp, it occupies a lot of space on the die holder. This does not allow the cassettes to be removed from or inserted into the T-channels of the cassette holder while the wedge clamps are fixed on the die holder. The only way to do setup change is by fastening and unfastening the wedge clamps entirely from the die holder during each each setup change. Therefore, the use of wedge clamps does not help to reduce setup change time in this study even though they are quick acting clamps.

After a thorough market research on quick die change systems and clamping systems, it was discovered that quick acting clamps are generally available in hydraulic mechanism and not mechanical mechanism [19, 21-24]. Their assembly is either complicated or occupies large space on the die holder. The hydraulic system is not suitable for the hot forging applications, as the hydraulic fluid can leak or cause an explosion risk in hot working conditions.

No quick acting clamps were found suitable with sufficient clamping forces for the 1000 ton hot forging press. Hence, the option of using quick acting clamps was dropped and the mechanical shoe clamps were kept for use with a single shoe slot.

4.2.4 Version-4 of the new die holder

Using the mechanical clamping shoes, the cassettes were given an angle of 10 degrees on their front face, which would engage with the shoe having the draft angle of 10 degrees. A feature is added to the back support module to hold the cassettes from the rear end. For each shoe, one hole is provided on the die holder for fastening with bolts. The lower die holder model has two parts – lower die holder and anvil adapter. Anvil adapter is a plate designed to be fixed on the press anvil for long term. It features guide and back support rails which help in guiding and positioning the lower die holder assembly on the anvil adapter to save mounting time. It opens new possibities of reducing internal setup time by directly changing the preassembled die holders. It is upto AKSAN to apply this option or not, as it might need a purchase of additional equipment to handle the heavy die holders during each setup change. Also two pairs of die holder sets would have to be manufactured for this option to work effectively. Figure 4.9 shows the finalized die holder concept.

To sum up, this type of design allows for preassembly of dies and cassettes during external setup. During internal setup, the cassettes can be quickly and accurately mounted to the die holders using the T-channels provided in the cassette holders, as they eliminate alignment time. This design only requires clamping from one side. Therefore, it further reduces clamping time. Additionally, quick acting clamps were researched for quickly fastening these cassettes, therefore reducing the time even further. However, due to certain limitations in this design and lack of market availability, these clamps were not chosen.

Alternatively, the die holders can be completely pre-assembled during external setup, and by using a pair of two die holder sets, the setup change time can be further reduced by removing and remounting the entire die holder assembly during setup change. Then the internal setup only comprises of stopping the press for removing the used die holder,

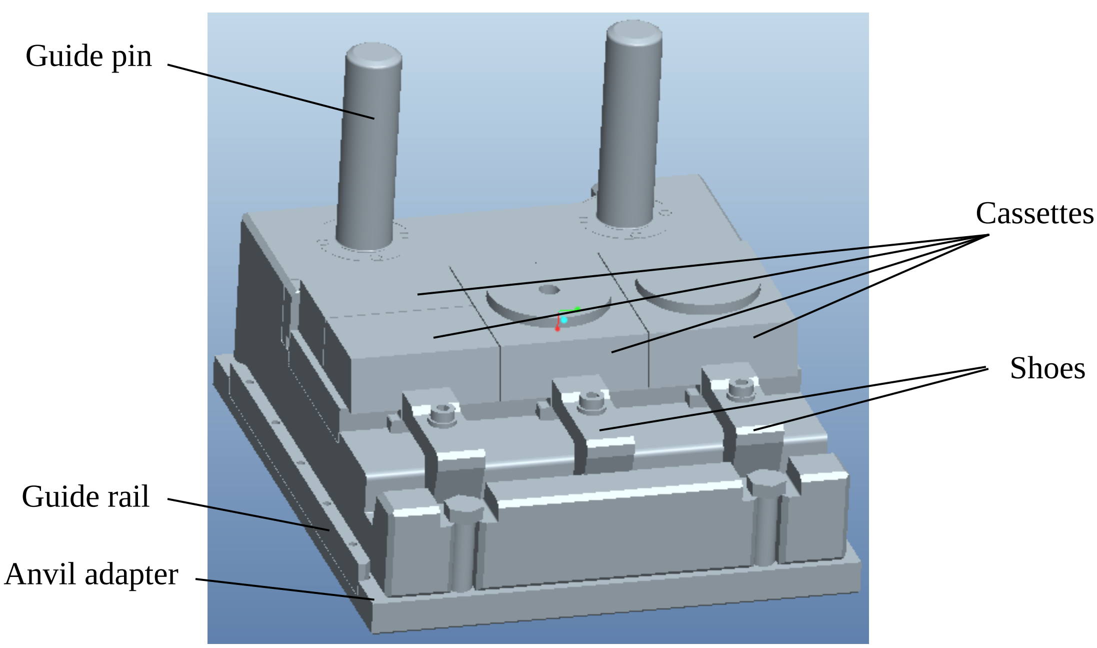

Figure 4.9 A view of the final die holder design (Version-4)

assembling and mounting the new die holder, by using guide rails and support provided on the anvil adapter, and by tightening the eight bolts in total to clamp the die holders. Figure 4.10 shows the mounting and dismounting of the die holder assembly from the anvil adapter during setup changes by this technique.

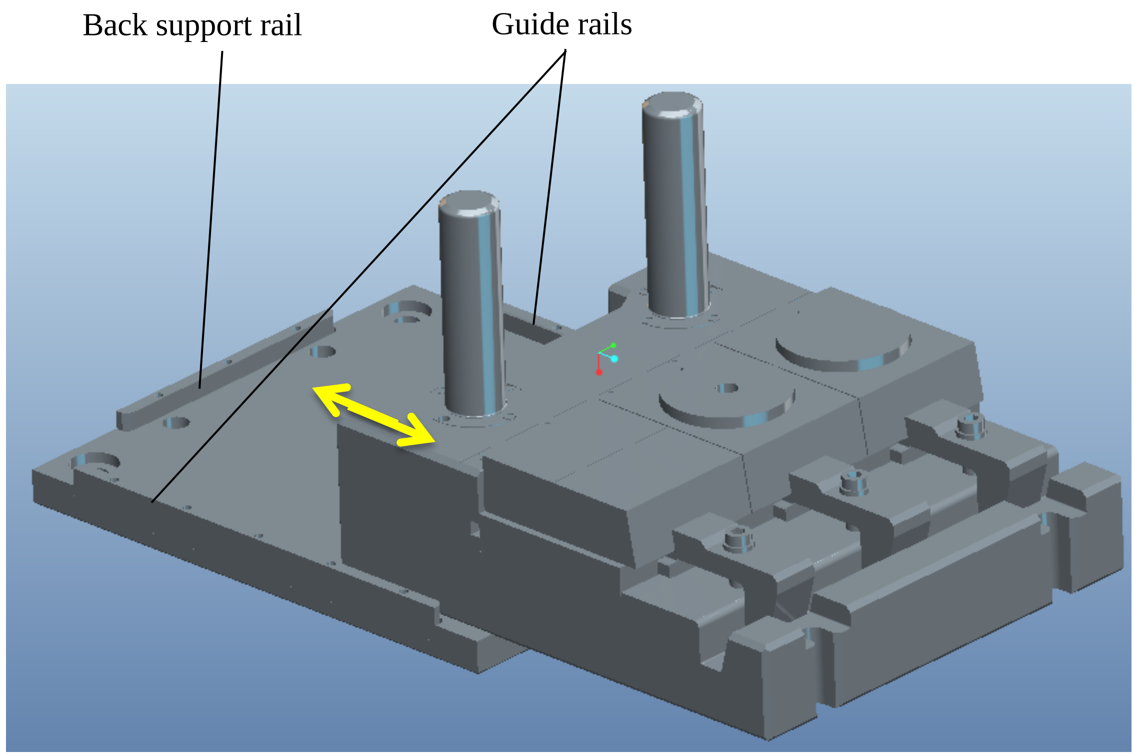

Figure 4.10 A view of the mounting or dismounting the die holder assembly from the anvil adapter

The outer dimensions of the lower die holder are 775x680x235 mm, as (length)x(width)x(height) respectively. On the other hand, the outer dimensions of the upper die holder are 720x720x235 mm, as (length)x(width)x(height) respectively. The outer dimensions of the cassettes are chosen as 275x218x115 mm to accommodate three sets of cassettes on the die holders at the same time while considering the sizes of all the parts being manufactured in AKSAN on the 1000 ton hot forging press.

4.3 Components of the new die holder assembly

Table 4.5 lists the components for the new die holder assembly. Furthermore each component is modeled and shown in Figures 4.11 to 4.31 and explained in the following paragraphs. However, due to confidentiality required by AKSAN, the detailed drawings and dimensions of the components are not given for any parts.

Anvil adapter is a plate that helps to quickly mount and dismount the die holder assembly to the forging press accurately. It is fixed to the anvil of the forging press by four main bolts. Its material is chosen for higher strength and lower hardness than the die holder material DIN 1.2714, because impact toughness is more important property for its function than hardness. Once the anvil adapter is mounted to the anvil, then it is very easy and quick to mount or dismount the entire die holder assembly to the press with the help of 8 main bolts. Figure 4.11 shows the anvil adapter and its main features.

Table 4.5 Components of the new die holder assembly

Number	**Components fastened to the ram**	**Quantity**	**Components fastened to the anvil**	**Quantity**
1	-		Anvil Adapter	1
2	-		Guide rails for anvil adapter	2
3	-		Back support rail for anvil adapter	1
4	Upper die holder	1	Lower die holder	1
5	Upper cassette holder	1	Lower cassette holder	1
6	Upper back support module	1	Lower back support module	1
7	T-base cassettes	2	T-base cassettes	2
8	Main shoes	3	Main shoes	3
9	Bronze inserts	2	Guide pins	2
10	Bushings for bronze inserts	2	Guide pin bushings	2
11	Back cover plates under bronze bushings	2	Guide pin locking back plates	2
12	Top closing flanges for bronze bushings	2	Top closing flanges for guide pin bushings	2

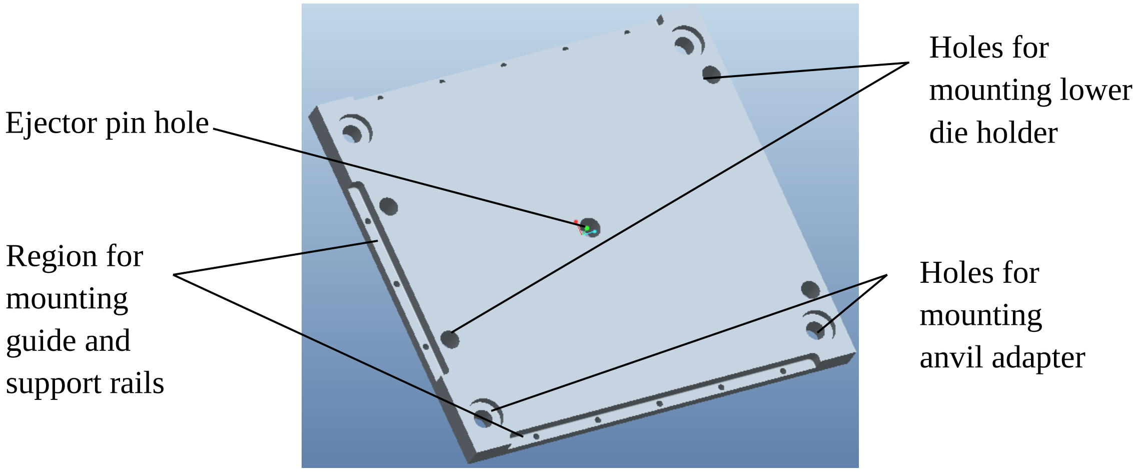

Figure 4.11 A view of the anvil adapter

At the left side, right side and back side of the anvil adapter there are features provided to which guide and support rails are bolted. These rails enable the quick and accurate mounting or dismounting of the die holder assemblies from the press. Figure 4.12 shows one of the side rails of the anvil adapter. This design allows to simplify the internal setup to mounting and dismounting the die holder assembly with eight bolts in total. The rails make it simple to guide and locate the die holder assembly on the anvil adapter, eliminating alignment time.

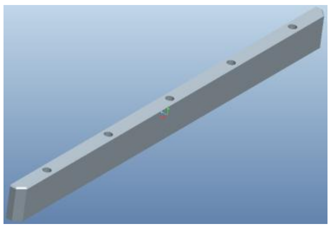

Figure 4.12 Side rail for guiding die holder on anvil adapter

Four U-shaped through-holes are provided on the lower die holder to allow for its easy mounting and dismounting from the anvil adapter, as shown in Figure 4.13. Two locating pin holes are also provided on the die holder to allow for exact and quick positioning of the cassette holder while mounting. The locating pins also serve to prevent misalignment of the cassette holder on the die holders. The design of anvil adapter leads to the reduction of the lower die holder thickness in order to maintain the shut height.

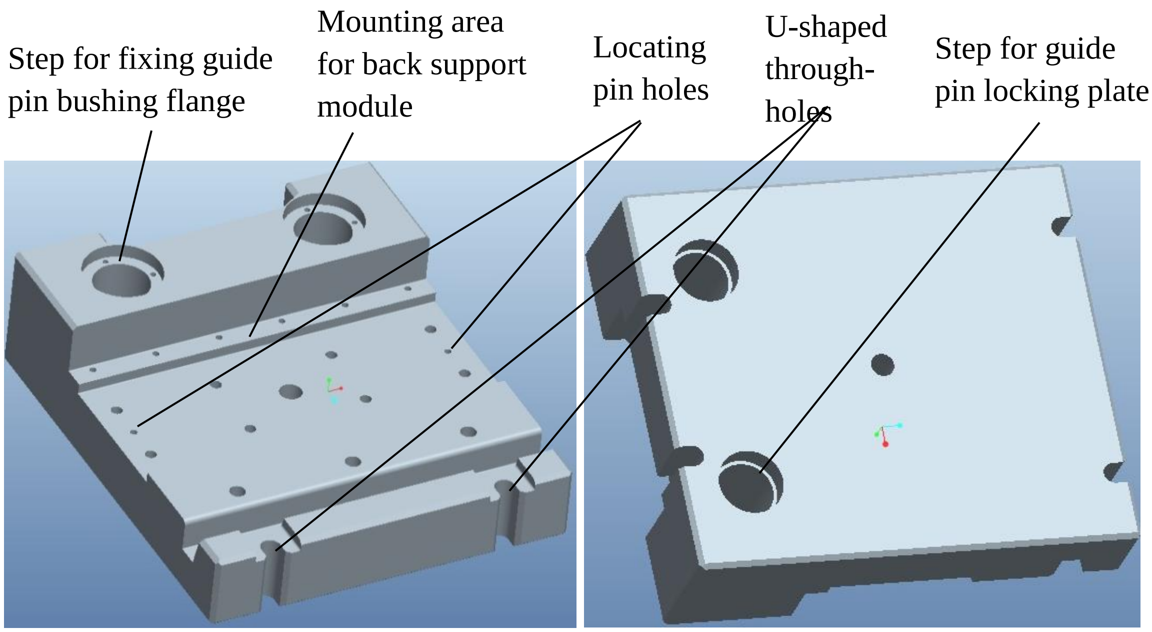

Figure 4.13 A view of the lower die holder

The back supporting module for the cassettes is mounted to the die holder using six screws. It helps to hold and support the cassette from the rear-end. Figure 4.14 shows the back support module used for fastening the module on die holder.

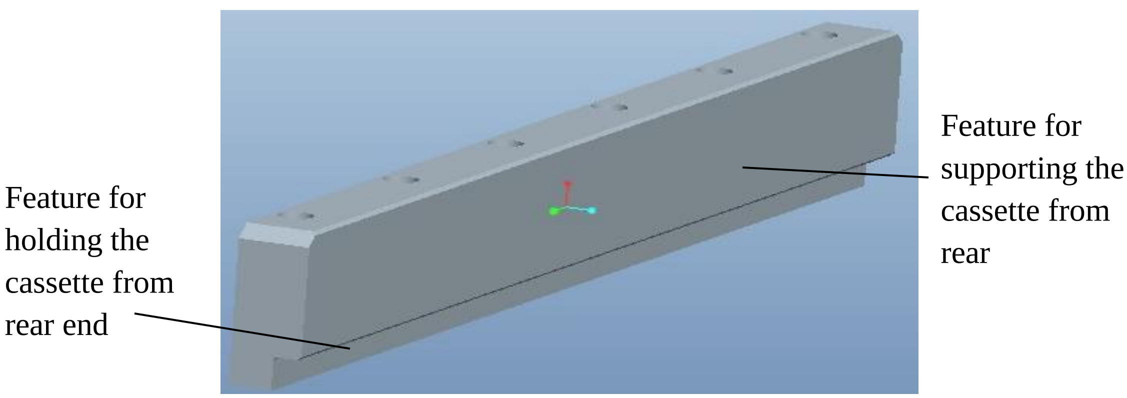

Figure 4.14 A view of the back support module

The cassette holder is one the most critical components of the new design. Figure 4.15 shows its key features. It is mounted to the die holder with eight bolts. There are three T-channels to accommodate three cassettes without needing to adjust them during setup.

Two threaded holes are provided on top surface to allow lifting and handling of the cassette holder. There are also two locating pin holes at the bottom of the cassette holder to allow its accurate positioning in its housing area on the die holder.

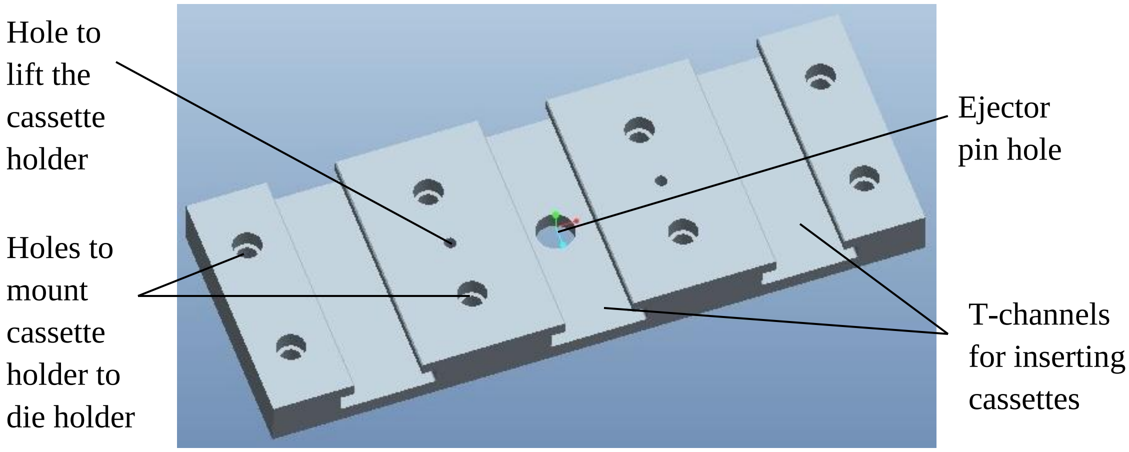

Figure 4.15 A view of the cassette holder

The cassettes have been redesigned keeping in mind that all sizes and types of dies currently being used in AKSAN on the 1000 ton hot forging press can be used in the new design. The T-base of the cassettes is one of the main features that accurately holds and guides the cassettes into the cassette holder. The T-base is extended from the rear end of the cassette to fit under the back supporting module. The cassette design is shown in the Figure 4.16.

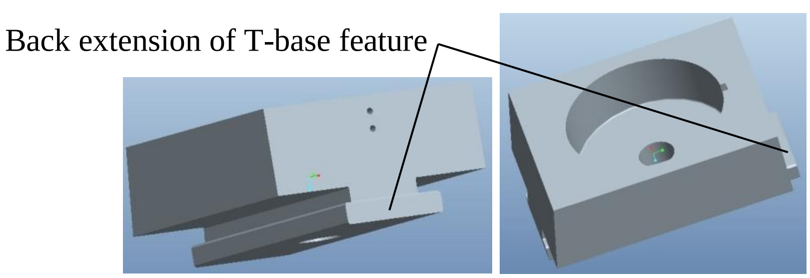

Figure 4.16 Views of the cassettes

Another main feature of the new cassettes is the draft on the front of the cassettes to allow for clamping them with shoes that also have the same draft. Figure 4.17 illustrates this feature on the upsetting die or cassette.

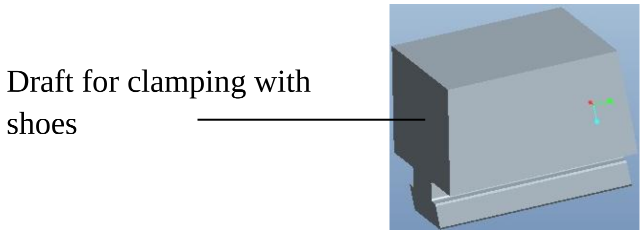

Figure 4.17 A view of the upsetting die

The shoes are redesigned to be compatible with the new cassettes and the die holders. All of the new shoes have a draft on the front end that engages with cassettes. Figure 4.18 shows the key features of the shoe clamps. The shoe base fits in the shoe slot on the die holder.

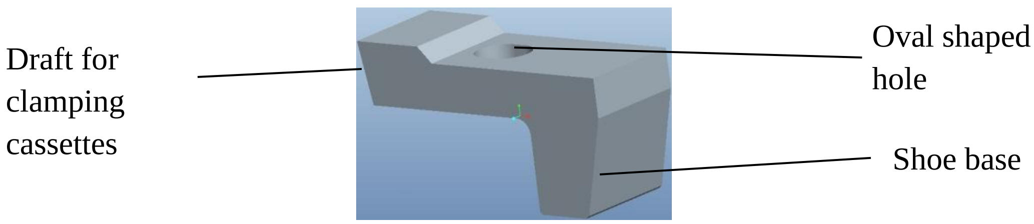

Figure 4.18 A view of the shoe for clamping cassettes

The shoe has an oval-shaped hole which allows for small adjustments to be made during fastening process.

Another critical element of the die holder assembly is a guide pin. The guide pins are important because they ensure the upper and lower die holders operate uniaxially during the forging process. They help keep the upper and lower dies aligned during the vertical forging strokes so that the parts are forged accurately. Without guide pins, accuracy would be lost. Therefore, it is vital to design and manufacture guide pins carefully so that they can perform the alignment perfectly. The conical part of the guide pin pillars are positioned and locked in the lower die holder using a shoulder type bushing. The bushing itself is press-fit in the die holder bushing holes. In the upper die holder, there are also bushings which are press fit, and they contain a bronze insert. During the vertical ram movement, the top part of guide pins experiences contact with the bronze inserts that also create some friction. Figure 4.19, Figure 4.20 and Figure 4.21 show the guide pin, guide pin bushing and guide pin locking plate, respectively.

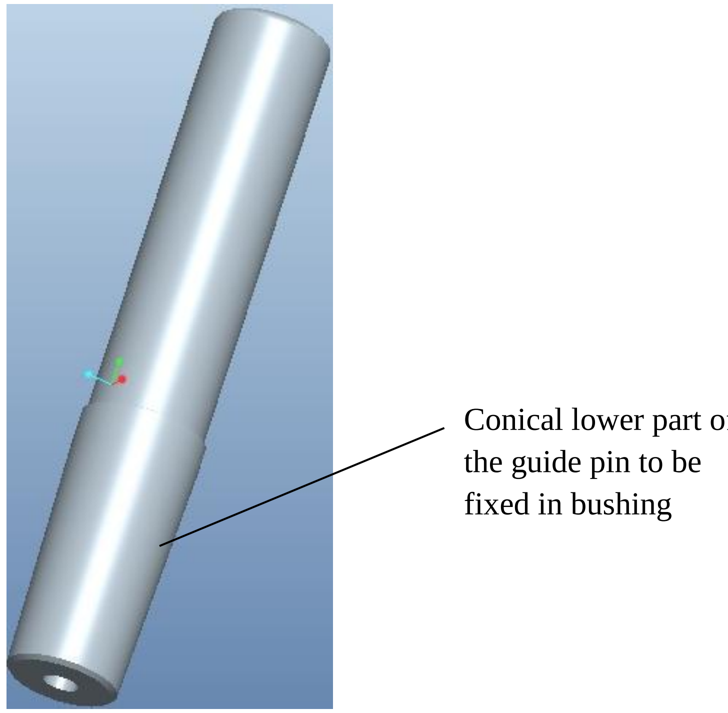

Figure 4.19 A view of the guide pin

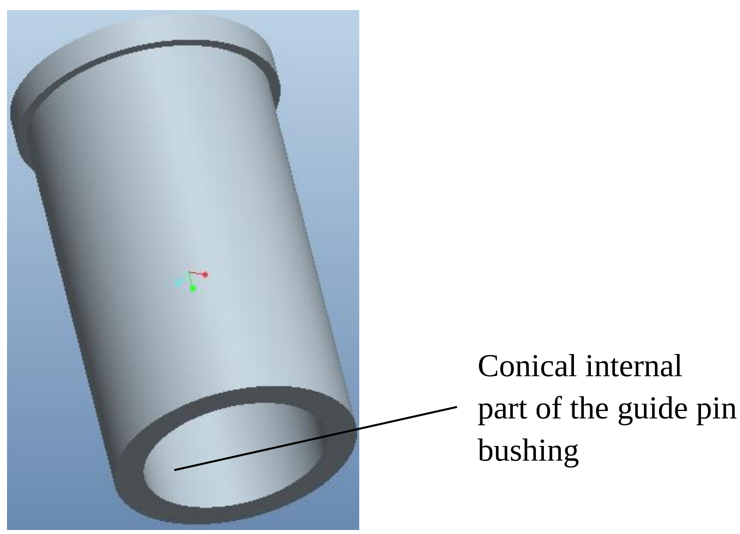

Figure 4.20 Guide pin bushing

Figure 4.21 Plate for locking guide pin on lower die holder

After the guide pin and bushing are fit together and locked in the lower die holder, the assembly is closed from the top by the flange using four screws. Figures 4.22 shows the flange.

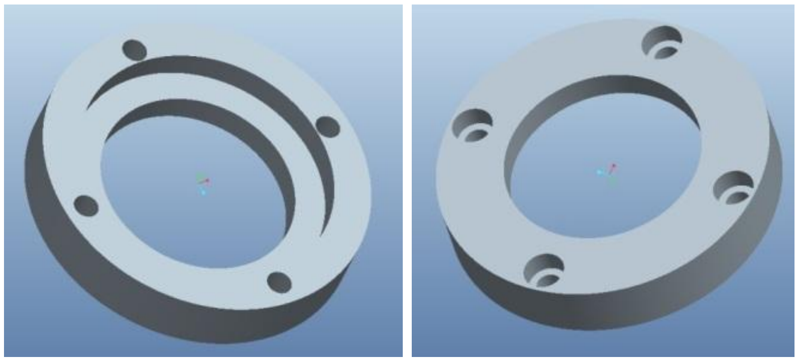

Figure 4.22 Top closing flange for guide pin bushing

The lower die holder assembly is shown in Figure 4.23, with the guide and support features of the anvil adapter. Gap is provided to the rear of the lower die holder specially to allow fastening the bolts easily.

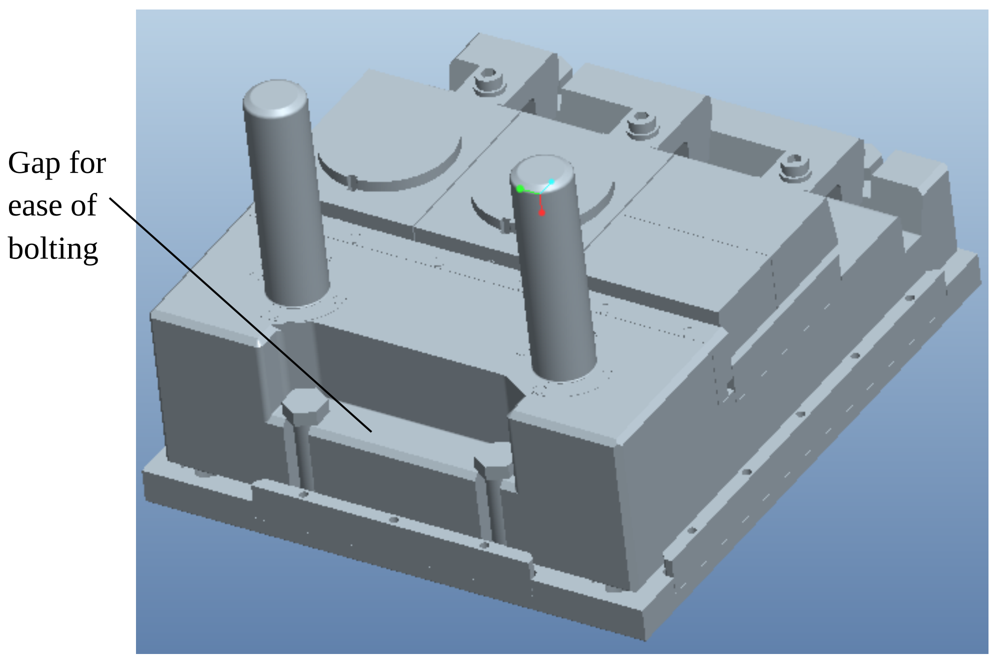

Figure 4.23 Lower die holder assembly

For the upper die holder assembly, a bronze inserted bushing is used through which the guide pins operate. The bushing is closed on top with a flange using six screws. The insert material is deliberately chosen to be bronze because it is softer than the guide pin material. This allows bronze insert to wear faster than guide pins, therefore guide pins can be used longer. This decision is made because guide pin material, machining and heat treatment processes are time-consuming and expensive. However it is easier to replace the bronze insert when it wears. The interior of the bronze insert has helical grooves that are used to lubricate the guide pins in order to reduce the friction during ram movement. Figure 4.24, Figure 4.25 and Figure 4.26 show the bronze insert, the bushing and the top closing flange, respectively.

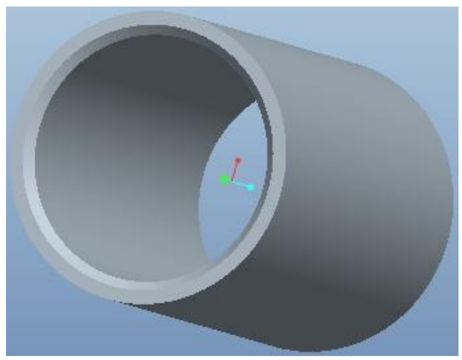

Figure 4.24 Bronze insert

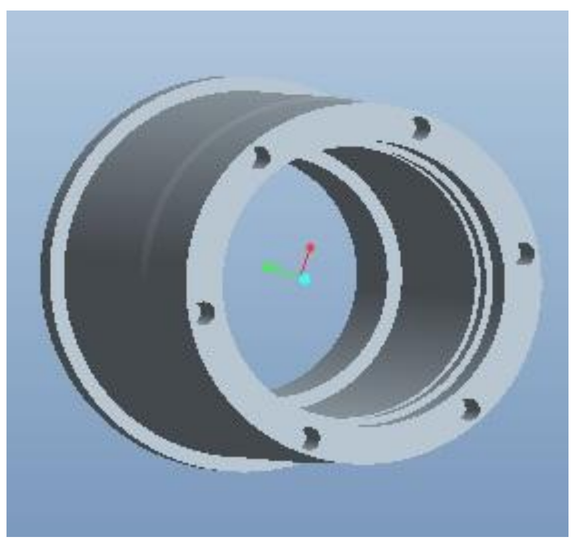

Figure 4.25 Bushing for bronze insert

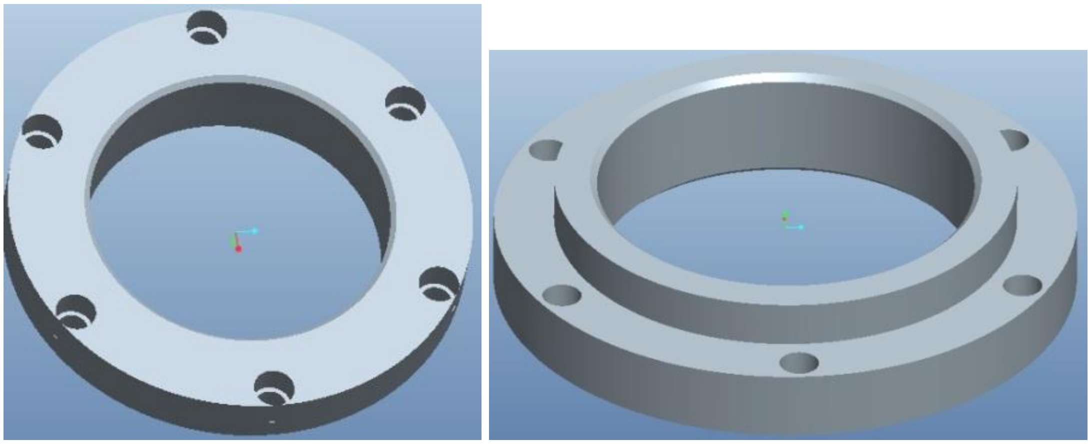

Figure 4.26 Top closing flange for bronze insert bushing

The upper die holder outer dimensions are different than the lower die holder outer dimensions because of the difference in sizes of ram and anvil. However, the critical upper and lower components that have to be aligned perfectly during the forging are designed with same sizes and at same locations on the upper die holder as on the lower die holder. These components include the guide pin holes, mounting area for back supporting module, cassette holder housing area, ejector pin hole, shoe slot and shoe fastening holes. There are four bolts used to mount the upper die holder to ram. These features are shown in the Figure 4.27.

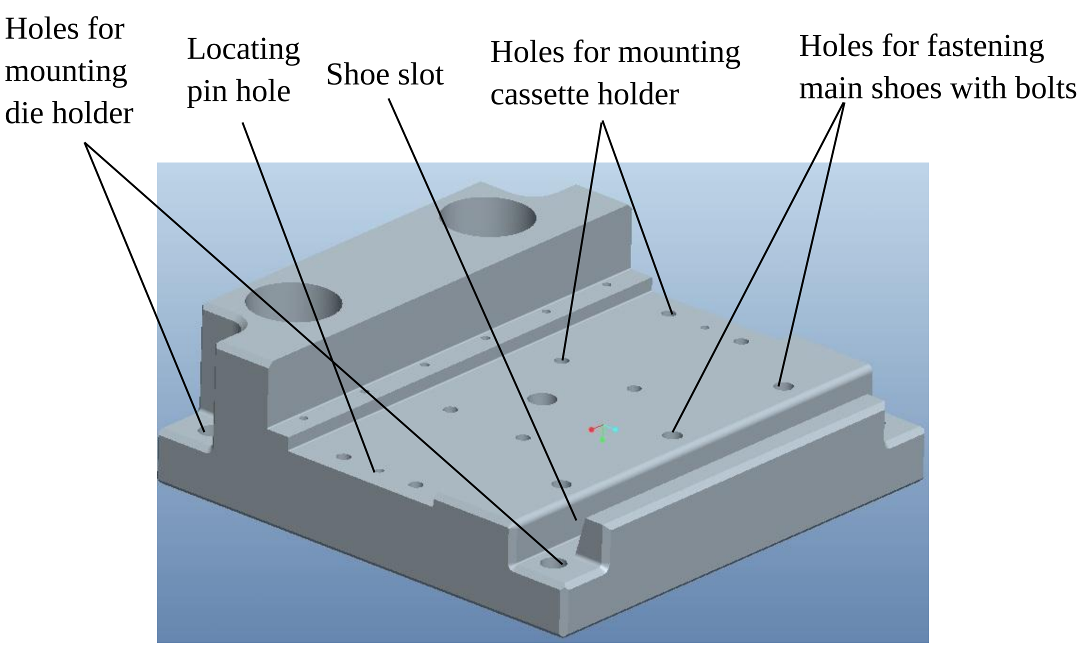

Figure 4.27 Solid model of the upper die holder

The bottom of the upper die holder, as shown in Figure 4.28, is used to close the housing area for bronze bushing with back cover plate using four screws. Figure 4.29 shows the back cover plate. The thin back cover plate is only required to close the through-holes on the upper die holder.

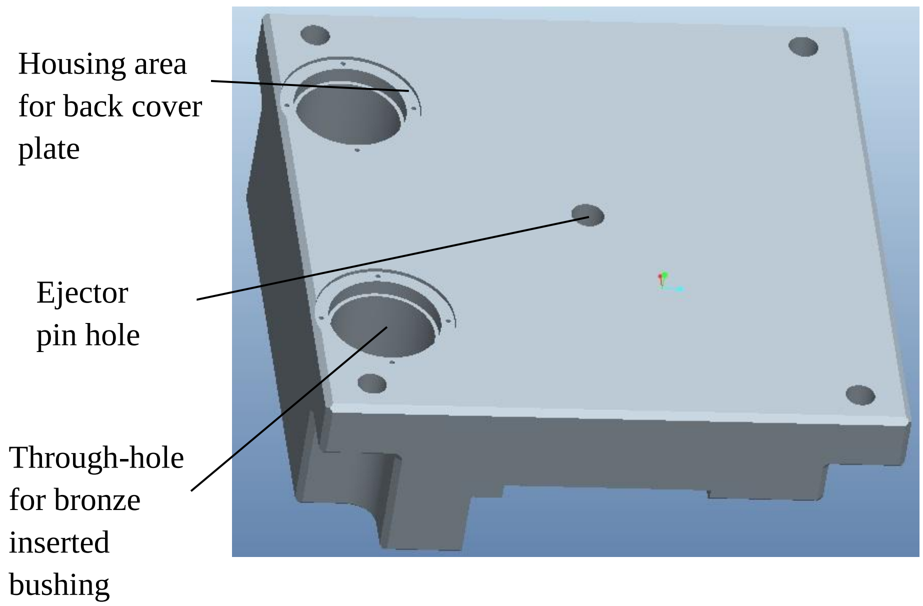

Figure 4.28 Upper die holder (rear view)

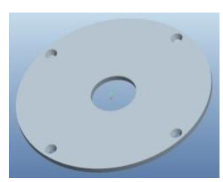

Figure 4.29 Back cover plate under bronze insert bushing

Figure 4.30 shows the completed upper die holder assembly after mounting all the components. After the upper and lower assemblies of die holders are prepared, there are two approaches for doing setup change. One is to separately mount the upper and lower die holders to the ram and anvil and perfect setup changes by only exchanging die-cassette pairs from the cassette holders. The other is to preassemble the upper die holder to the lower die holder in external setup and mount the entire assembly on the press by placing it on the anvil adapter first. The lower die holder is bolted to the anvil and then the upper die holder is bolted to the ram. The ram is then raised and the assembly is completed. Figure 4.31 shows the completed assembly of the die holders.

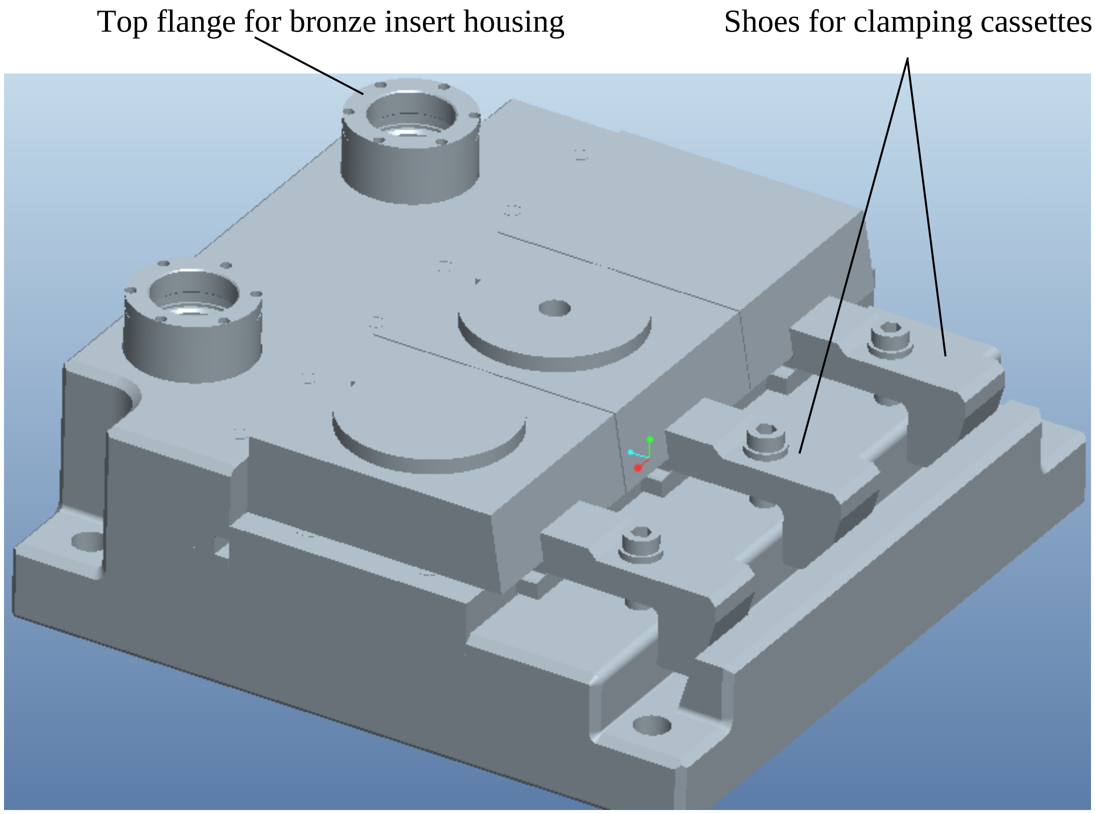

Figure 4.30 Solid model of the upper die holder assembly

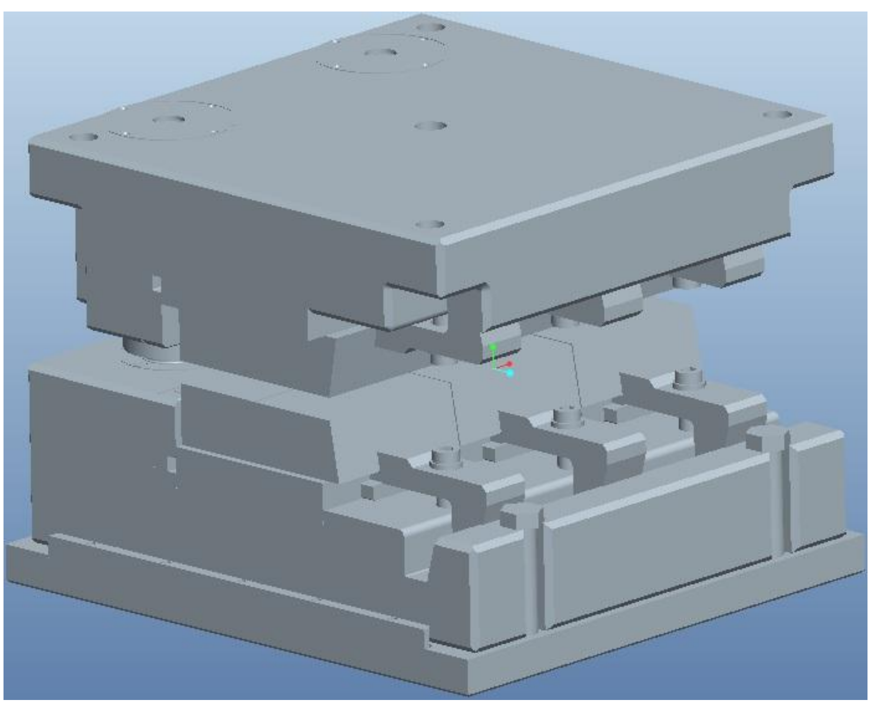

Figure 4.31 Solid model of the die holders complete assembly

The materials of the major components for the new die holders are given in Table 4.6. The materials chosen for the anvil adapter and the cassette holders are not mentioned in the table due to the confidentiality of AKSAN Steel Forging Company.

Table 4.6 Materials used for major components of the new die holder assembly

Component name	**Material**
Guide pins	C45
Guide pin bushing	C45
Guide pin bushing top closing flange	C45
Guide pin locking plate	C45
Bushing insert in upper die holder	Bronze
Bushing for bronze insert	C45
Bronze bushing top closing flange	C45
Bronze bushing back cover plate	C45
Anvil adapter	Hot working die material
Die holder	1.2714
Cassette	1.2714
Cassette holder	Hot working die material

CHAPTER 5

MANUFACTURING AND TESTING OF THE NEW DIE HOLDER

5.1 Manufacturing and assembling of the die holder components

The solutions for reduction of setup change time which have been achieved through the designing and detailing of the new die holders are presented in Chapter 4. Every part related to the die holders has been designed. In this chapter, the manufacturing of the designed components of the die holders and the implementation in AKSAN Steel Forging will be given.

First, the initial machining of raw materials for the die holders and anvil adapter is completed. After the completion of rough outer profiles, the parts are heat treated. After the heat treatment and hardening to the desired values, the upper and lower die holders are accurately machined. Figure 5.1 shows the manufactured die holders.

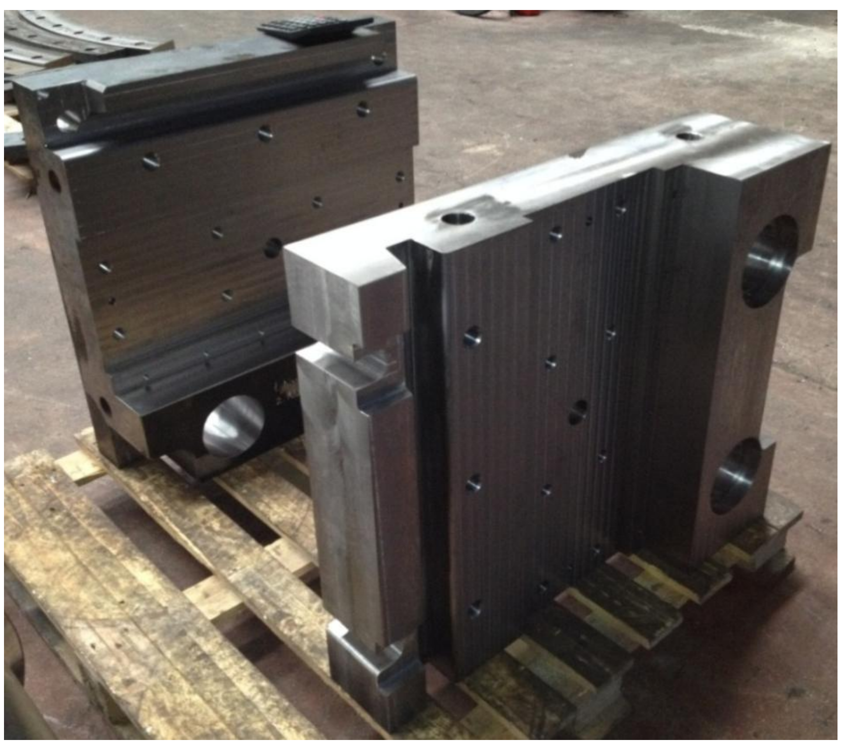

Figure 5.1 A view of the die holders

Figures 5.2 shows the machined housing for bronze insert and the machined bronze insert with internal helical grooves to carry oil for lubrication of the guide pin.

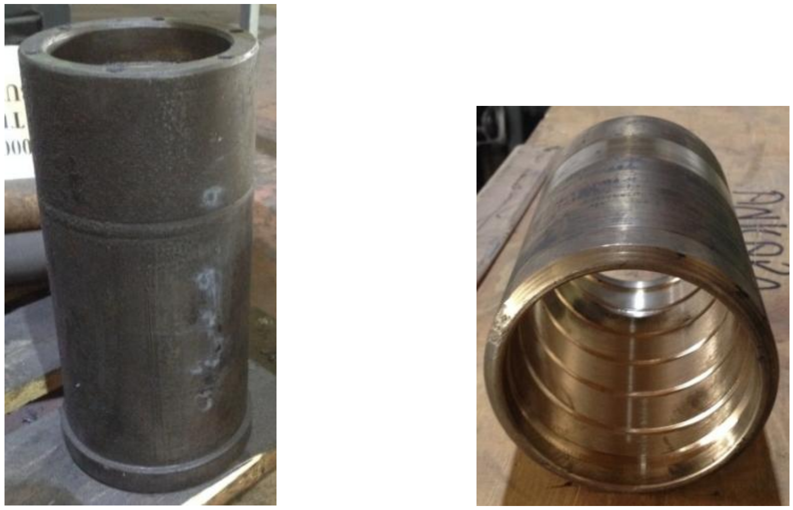

Figure 5.2 A view of the housing for bronze insert and the bronze insert

The bronze inserts are thermally fitted inside their housings by heating the housing. Figure 5.3 shows the housing with bronze insert fitted inside it. This will be assembled into the upper die holder.

Figure 5.3 A view of the bronze insert fitted inside housing

Figure 5.4 shows the final form of the machined guide pin bushings that are also thermally fitted inside the bushing holes in the lower die holder.

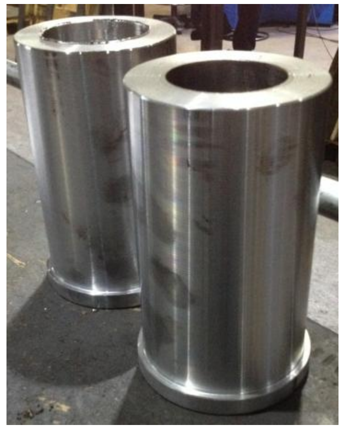

Figure 5.4 A view of the guide pin bushings

Figure 5.5 shows the machined pair of guide pins that are also heat treated and ground. These guide pins are inserted in the guide pin bushings and locked in their position from the rear end of the lower die holder using a locking plate and bolt.

Figure 5.5 A view of the guide pins

Figure 5.6 shows the upper and lower cassette holders machined accurately. As shown in Figure 5.6, the lower cassette holder is wider than the upper cassette holder, since the lower die holder is wider than the upper die holder. They are one of the most critical components of the new die holder design, that enable the accurate positioning and clamping of the cassettes. Cassettes holders ensure that the upper and lower die sets are perfectly aligned. Therefore, their accurate machining within the tight tolerances is very critical.

Figure 5.6 A view of the cassette holders

All the parts of the lower and upper die holders are fully assembled externally, as shown in Figures 5.7 and 5.8, before being put on the forging press. AKSAN has chosen to keep the die holders fixed on the forging press and not to change the entire die holder assembly during setup changes. Therefore, once the die holders are fastened to the forging press, internal setup times for the die holders are not taken into account during time study of setup changes. The dies are mounted into the cassettes externally and the cassettes having dies (i.e. die-cassette pairs) are mounted into the die holders internally. Therefore, the external setup change time for the mounting of the dies into the cassettes and the internal setup change times for mounting of cassettes into the die holders are considered.

Figure 5.7 A view of the fully assembled lower die holder

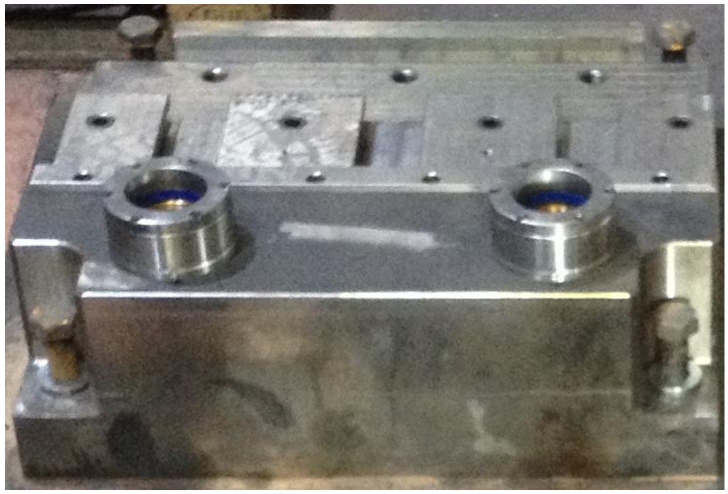

Figure 5.8 A view of the fully assembled upper die holder (rear view)

Figure 5.9 shows the die holders including all components assembled in full and final configuration to the 1000 ton hot forging press. During setup change, die-cassette pairs will be mounted to the T-channels of the cassette holders and clamped using the shoes. Figure 5.10 shows the die-cassette pairs mounted on the forging press for production.

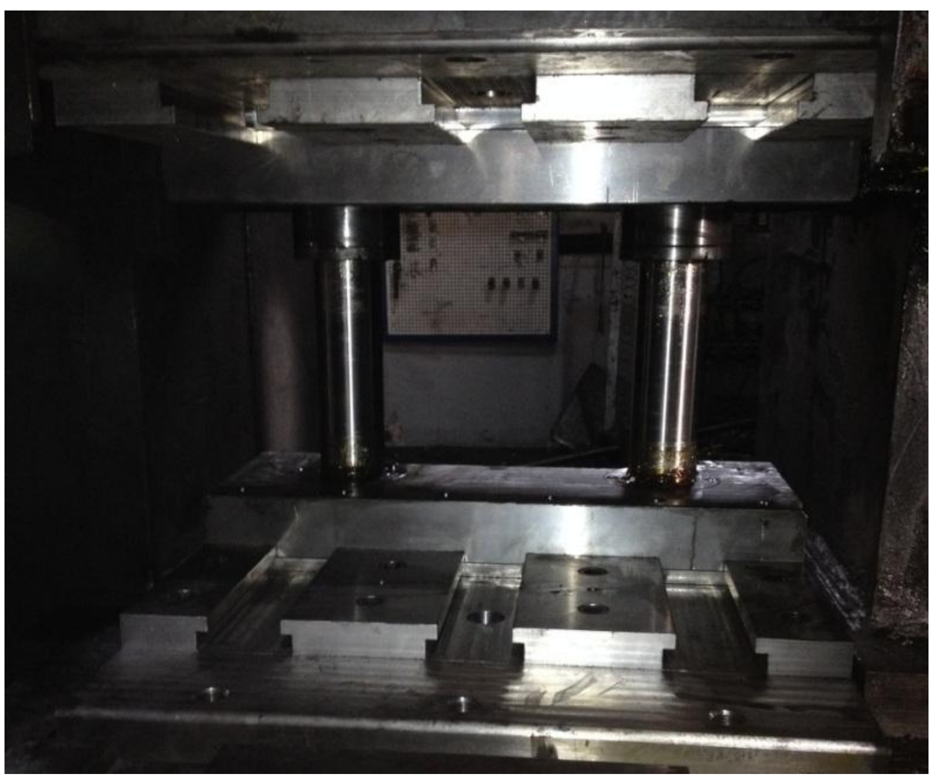

Figure 5.9 A view of the die holders assembled on the forging press

Figure 5.10 Die holders fully assembled with upper and lower die-cassette pairs on the 1000 ton hot forging press for production

The die-cassette pairs are easily and quickly mounted on the 1000 ton hot forging press. There is no need to adjust or align the cassettes and dies during setup change due to the benefit of using new die holder design.

In the following section, the results of the motion and time study are presented to compare the average setup change times for the old and the new die holder systems.

5.2 Comparison of setup change times for the previous and new die holders

As discussed in Chapter 3, the motion and time study has been carried out for Part-A, Part-B, Part-C which require 2 die-sets, Part-D, Part-E, Part-F which require 3 die-sets and Part-G, Part-H, Part-I which require 4 die-sets by using the previous die holders. For the purpose of comparison, the motion and time study is realised for Part-A, Part-B, Part-C which require 2 die-sets and Part-D, Part-E, Part-F which require 3 die-sets by using the new die holder. The motion and time study for Part-G, Part-H, Part-I which require 4 die-sets could not be realised on the new die holders since some modifications on the currently available dies of these parts are required to be used in the new die holders. AKSAN will produce this additional tooling in the future when the need arises and motion and time study for them can be conducted in the future. The sequence of setup change operations for the new die holder system is similar to the sequence given in Figure 3.8. However, the operations such as heating of dies and cleaning of the press are disregarded during the comparison. These operations are expected to be same for both systems (i.e. previous and new die holder systems). Therefore, the setup times which includes mounting of dies to cassettes, mounting die-cassette pairs to die holders, dismounting of die-cassette pairs from die holders and removing dies from cassettes are taken into account for comparison purposes. The motion and time study data given in Tables 5.1 are for Part-A, Part-B and Part-C which require 2 die-sets. As seen in the table, the average setup time excluding heating and cleaning times is calculated as 608 seconds.

Table 5.1 Time Study of setup change for Parts A, B and C requiring 2 die-sets in the new die holder

	Part	**A**	**B**	**C**
Number	**Operation**	**Time (seconds)**		
1	Mounting dies to cassettes (external setup operation)	135	142	126
2	Mounting cassettes to upper cassette holder (internal setup operation)	94	113	104
3	Mounting cassettes to lower cassette holder (internal setup operation)	65	59	56
4	Dismounting cassettes from lower cassette holder (internal setup operation)	57	50	55
5	Dismounting cassettes from upper cassette holder (internal setup operation)	81	79	86
6	Dismounting dies from cassettes (external setup operation)	147	206	168
	Total	**579**	**649**	**595**
	Average	**608**		

The motion and time study data given in Tables 5.2 are for Part-D, Part-E and Part-F which require 3 die-sets. As seen in the table, the average setup time excluding heating and cleaning times is calculated as 1780 seconds.

The setup change times vary from part to part and based on the training level of the operators. Each setup team comprises of two operators. The fluctuating values are also a result from the physical condition and motivation level of the operators performing setup change. Experienced operators systematically and unambiguously assemble the dies, cassettes, shoes, washers and bolts everytime. A clear difference in setup change time is observed when an inexperienced operator performs setup change for part E. Table 5.3 shows the time study data collected during setup change by the inexperienced team who are unaware of the proper procedure to do the setup change with the new die holder system and by the experienced team who are aware of the procedure related to the new die holder design. Table 5.3 shows importance of training of the operators to reduce the setup time. It should be mentioned that the data given in Table 5.1 and Table 5.2 are based on observation during activities of the experienced team of operators.

Table 5.2 Time Study of setup change for Parts D, E and F
requiring 3 die-sets in the new die holder

	Part	**D**	**E**	**F**
Number	**Operation**	**Time (seconds)**		
1	Mounting dies to cassettes (external setup operation)	413	478	459
2	Mounting cassettes to upper cassette holder (internal setup operation)	357	372	384
3	Mounting cassettes to lower cassette holder (internal setup operation)	268	241	255
4	Dismounting cassettes from lower cassette holder (internal setup operation)	95	88	92
5	Dismounting cassettes from upper cassette holder (internal setup operation)	175	148	146
6	Dismounting dies from cassettes (external setup operation)	438	454	476
	Total	**1746**	**1781**	**1812**
	Average	**1780**		

Table 5.3 Time Study of setup change for Part E on the 1000 ton hot forging press by experienced and inexperienced operators using the new die holder

		Inexperienced Operators	Experienced Operators
Number	**Operation**	**Time (seconds)**	
1	Mounting dies to cassettes (external setup operation)	548	478
2	Mounting cassettes to upper cassette holder (internal setup operation)	432	372
3	Mounting cassettes to lower cassette holder (internal setup operation)	296	241
4	Dismounting cassettes from lower cassette holder (internal setup operation)	122	88
5	Dismounting cassettes from upper cassette holder (internal setup operation)	302	148
6	Dismounting dies from cassettes (external setup operation)	678	454
	Total	**2378**	**1781**

Table 5.4 shows comparison of average values of total setup change times for parts requiring two die-sets and three die-sets during setup change for previous and new die holders. In the table, the setup times excluding die heating and forging press cleaning operations are taken into account. In other words, the times for steps 4, 6 and 10 given in Table 3.5 are disregarded. Therefore, the setup time excluding die heating and forging press cleaning operations are calculated as 2735 seconds for the setup change with 2 die-sets and 3398 seconds for the setup change with 3 die-sets. The average setup times for the new die holders are 608 and 1780 seconds as seen in Table 5.1 and 5.2 respectively. By using the new die holders, 78% reduction for setup change time with 2 die-sets and 48% reduction for setup change time with 3 die-sets as averages have been achieved.

Table 5.4 Comparison of average values of total setup change times for parts requiring two die-sets and three die-sets during setup change for previous and the new die holders

Types of Setup change	**Averages of Total Setup Times**		**Percentage Reduction**
	Previous die holders	**New die holders**	
Setup change with 2 die-sets	2735	608	78%
Setup change with 3 die-sets	3398	1780	48%

The total setup change times including the internal and external setup change times have been compared until Table 5.4. Now, only the internal setup change times are compared using previous and the new die holders in the Tables 5.5 to 5.7.

Table 5.5 Comparison of internal setup change times for Parts A, B and C requiring 2 die-sets using previous and the new die holders

	Part	**A**		**B**		**C**	
Number	**Operation**	**Internal Setup Time (seconds)**					
		Old	New	Old	New	Old	New
1	Mounting cassettes to upper cassette holder	583	94	598	113	546	104
2	Mounting cassettes to lower cassette holder	429	65	476	59	431	56
3	Dismounting cassettes from lower cassette holder	326.5	57	330	50	291.5	55
4	Dismounting cassettes from upper cassette holder	543.5	81	534	79	528.5	86
	Total	**1882**	**297**	**1938**	**301**	**1797**	**301**
		Old Average: 1872			**New Average: 300**		

Table 5.6 Comparison of internal setup change times for Parts D, E and F requiring 3 die-sets using previous and new die holders

	Part	D		E		F	
Number	**Operation**	**Internal Setup Time (seconds)**					
		Old	New	Old	New	Old	New
1	Mounting cassettes to upper cassette holder	614	357	656	372	671	384
2	Mounting cassettes to lower cassette holder	634	268	675	241	639	255
3	Dismounting cassettes from lower cassette holder	393.5	95	402	88	422.5	92
4	Dismounting cassettes from upper cassette holder	615.5	175	614	148	611.5	146
	Total	**2257**	**895**	**2347**	**849**	**2344**	**877**
		Old Average: 2316			**New Average: 874**		

Table 5.7 Comparison of average values of total internal setup change times for parts requiring two die-sets and three die-sets during setup change for previous and new die holders

Types of Setup change	**Averages of Total Internal Setup Times**		**Percentage Reduction**
	Previous die holders	**New die holders**	
Setup change with 2 die-sets	1872	300	84%
Setup change with 3 die-sets	2316	874	62%

As it is seen in Tables 5.5 to 5.7, the machine downtime or internal setup change time has been reduced as average by 84% and 62% using the new die holders for setup change with 2 die-sets and 3 die-sets, respectively.

CHAPTER 6

CONCLUSIONS

6.1 Discussion of results

In this thesis, the factors related to the setup change on the 1000 ton hot forging press available in AKSAN Steel Forging Company have been systematically studied. The factors related to difficulties in setup change, which had been previously studied [11], were analyzed. Motion and time study analyses are further conducted on current setup change operations. Root cause analysis is conducted to investigate the major operations that take significantly long time. After the analysis, it is decided that the new die holders with cassette holders and the new cassettes are required to reduce the internal setup change time radically.

In Chapter 4, the different design versions of the new die holders are given. Version 3 of the new die holders used quick acting clamps to minimize clamping time but due to inapplicability of the clamps, the idea was dropped. The final die holder design utilizes a new idea in which the cassette holder is designed with T-channels and new cassettes are designed to fit in these T-channels to eliminate the die misalignments completely. By this way, the internal setup change time is reduced. The different components for the die holder assemblies have also been designed.

All the designed components of the new die holders have been manufactured and assembled. After the completion of the manufacturing and ensuring all dimensions are machined correctly, the die holders are externally assembled outside the forging press. Then the assembled die holders are mounted on the 1000 ton hot forging press of AKSAN Steel Forging. The dies for the several production batches are externally mounted into and dismounted from the newly designed and manufactured cassettes.

The new die holder has been carefully designed. It is made sure that the new die holder requires minimum effort and time to be spent during setup changes to reduce the non-productive time. Several motion and time studies, to determine the average total setup change times and internal setup change times in case of using of the new system, have been conducted. The average setup change times for the new die holders and the previous die holders are compared and considerable reduction in setup change time has been achieved. On the average, 78% reduction for total setup change with 2 die-sets and 48% reduction for total setup change with 3 die-sets have been obtained by excluding times for die heating and forging press cleaning operations which are assumed to be same for the both cases. The internal setup change times excluding press cleaning and die heating times are reduced by 84% and 62% for setup changes with 2 die-sets and 3 die-sets respectively.

The new setup change enables the production planning department to better manage unexpected changes in the production planning schedule, since the time spent in mounting and aligning the die-cassette pairs on the die holders is significantly reduced during setup change by the help of the new die holder design.

During the motion and time study, it is observed that level of the experience of the operator in the setup change team is also quite important. As discussed in Chapter 5, quite different setup change times are measured for the setup change made by different operators for the same part. This shows that it is necessary to train the operators and utilize the experienced operators to do the setup changes, although the setup change is now a more easier and standardized procedure for the operators at AKSAN.

It has been also observed that it takes long time to fasten and unfasten the bolts for holding the cassettes with shoes during the setup changes with previous and new die holders. To tighten the bolts faster, a powered wrench can be used to further reduce the setup change time.

The cassettes have been redesigned to a large extent and have special features compared to previously used cassettes. T-channels require the operator to precisely insert the cassettes in their dedicated locations on the cassette holder. Since mass of the new die-cassette pairs is about 40 kilograms, it is an energy consuming task for the operator to manually lift the heavy die-cassette pairs and insert them on the upper cassette holder with precision. A suitable material handling equipment will greatly reduce the effort required by operator and also it will reduce the risk of injury to the operator.

Some dies take longer time to be inserted into the cassettes or to be removed from the cassettes during setup change operations. This is because of some dies that have been remachined several times. After each remachining, their height reduces. To compensate for the reduced die height, plates are welded on the die base instead of using the releveling plates under the dies. This helps in re-adjusting the die height, however the rough surface of the welded plate at the die periphery increases friction with the cassettes. This may lead to difficulty in mounting and dismounting the dies from cassettes and increases setup change time. To fix this problem, careful machining should be performed and the die periphery may be lubricated to reduce the mounting and dismounting times.

6.2 Recommendations for future studies

Some of the studies which may be extensions of this current work or other possible future studies are mentioned as follows:

1. In the current study, motion and time study has been conducted for a limited number of parts due to the practical reasons such as production schedule of the company. Motion and time study for setup times with the new die holder system should be repeated for a certain period including a reasonable number of the forging batches on the particular forging press to find more accurate average setup change times.
2. The similar studies may be applied to other forging presses with higher capacities.
3. 5S technique may be studied to organize the toolings more effectively and to utilize the available workspace around the forging presses.
4. A study may be conducted to design work handling devices for quick die exchange. These systems will further reduce the effort required by operators and the setup change time. The risk of injury will also be reduced to the operator.

5. New and quicker methods of heating dies can be studied to further reduce the setup change time.
6. The cleaning of the forging press currently takes significant amount of time. A study can be conducted to improve the techniques to clean the forging press and prepare it for the new production batch. Motion and time study may be done to reduce the time spent for these activities.

REFERENCES

[1] Serope Kalpakjian, Steven Schmid, "Manufacturing Engineering and Technology", Pearson Prentice Hall, Singapore, 2006

[2] Manufacturing Process, http://thelibraryofmanufacturing.com/forging.html, Last Accessed: 05.05.2014

[3] Sevgi Saraç, "Design and Thermo-Mechanical Analysis of Warm Forging Process and Dies", M.S. Thesis, Middle East Technical University, Ankara, Turkey, September 2007

[4] Forging Industry Association, https://www.forging.org/design/525-warm-forging-process, Last Accessed: 07.05.2014

[5] DeGarmo E. P., Black J. T., Kohser R.A., "Materials and Processes in Manufacturing", Prentice-Hall International Inc., New York, 1997

[6] William O. Fellers, William W. Hunt, "Manufacturing processes for technology", Prentice-Hall Inc., New Jersey, 1995

[7] Taylan Altan, Gracious Ngaile, Gangshu Shen, "Cold and Hot Forging: Fundamentals and Applications", ASM International, Ohio, 2005

[8] Forging Industry Association, https://www.forging.org/forging-facts, Last Accessed: 07.05.2014

[9] Personal contacts and private communications with AKSAN Steel Forging Company

[10] Domingos Ribeiro, Fernando Braga, Rui Sousa, S. Carmo-Silva, "An Application of SMED Methodology in an Electric Power Controls Company", Proceedings of International Conference On Innovations, Recent Trends And Challenges In Mechatronics, Mechanical Engineering And New High-Tech Products Development, MECAHITECH'11, Vol. 3, 2011

[11] Özgür Cavbozar, “Design of Fixturing System for Forging Dies”, M.S. Thesis, Middle East Technical University, Ankara, Turkey, December 2008

[12] Dan Trietsch, “Some Notes on the Application of Single Minute Exchange of Die (SMED)”, Naval Sea Systems Command, 1992

[13] Yash Dave, Nagendra Sohani, “Single Minute Exchange of Dies: Literature Review”, International Journal of Lean Thinking, Vol 3, Issue 2, 2012

[14] Shigeo Shingo, “A Revolution in Manufacturing: The SMED System”, Productivity Press, Portland, Oregon, 1985

[15] Nystha Baishya, Sathish Rao U, “Applying SMED/QCO Tool to Improve the Productivity at Screwing Station of HFR assembly – A Study at Robert Bosch (i) Limited”, International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231-6477, Vol-3, Iss-1, page 34, 2013

[16] Erik K. Henrikson, “Jig and Fixture Design Manual”, Industrial Press Inc., New York, 1973

[17] Edward Hoffman, “Jig and Fixture Design”, Delmar Publishers Inc, 2004

[18] 5S, Lean Manufacturing and the Environment, US EPA, http://www.epa.gov/lean/environment/methods/fives.htm, Last Accessed: 16.04.2014

[19] SERAPID, http://www.serapid.com/en/industrial-equipment/quick-die-change/die-clamping/ledge-wedge-and-escaping-clamps/, Last Accessed: 20.11.2014

[20] Private communication with Serapid Personnel

[21] Private communication with Pacesetter Systems Corp.

[22] Private communication with AGAB Press Automation and ÖZALP Mühendislik ve Makina Dış Tic. San. Ltd. Şti

[23] Private communication with Forwell Precision Machinery Co., Ltd

[24] Communications and meetings with Hilma-Roemheld GmbH and Hidkom Türkiye

APPENDIX A

OUTER DIMENSIONS OF THE PRODUCTS FORGED BY AKSAN STEEL FORGING

Table A.1 The outer dimensions of the products forged by 1000 Ton Press during 2013 and 2014 in Aksan Steel Forging Company

Part Number	Width, x (mm)	Length, y (mm)	Height, z (mm)	Diameter, Ø (mm)
1	72	45	25.5	
2	87	53	12	
3	67	44	26	
4	46	35	22	
5			26	100
6	84.7	55.5	31	
7	96	60	32.5	
8			65.2	99
9	97	65	33.5	
10	83	51	14	
11	109	70.5	32.5	
12			15	116
13	137	48	23	
14	106	70.5	35	
15	127	82	33.5	
16	59	40	25	
17			75	95.4
18	62	75.5	22	
19	168	32	22	
20	72	50	20	
21	125	90	55	
22			34.5	75.8
23	115	56	10	
24	108.5	88.5	28	
25	138	76	28	
26	194.5	43	43	
27	183	61	28	
28	132	38	28.5	

Table A.1 The outer dimensions of the products forged by 1000 Ton Press during 2013 and 2014 in Aksan Steel Forging Company (continued)

29	129	39.5	31	
30	181	25.5	20	
31			58	73.6
32	53.1	46	26	
33	125	102	34	
34	107	42	40	
35	148	70	71	
36	201	84	56	
37	113	47	43	
38	98	53	24	
39			73.5	95.3
40	120	113	46	
41	120	46	41	
42	163	97	24	
43	193.5	38	26.5	
44	135.5	33.3	20	
45	35	35	17	
46	40	40	20	
47	75	46	32	