ANALYSIS OF FLASH BUTT WELDING CRACKS IN RIM MANUFACTURING

A dissertation submitted to the
Department of Mechanical Engineering of the University of Moratuwa
in fulfillment of the requirements for the
Degree of Master of Engineering in Manufacturing Systems Engineering

SANJEEWA PRASANGA KURUNDUWA HEWAGE

Supervised by : Dr. N. Munasinghe

Department of Mechanical Engineering
University of Moratuwa, Sri Lanka
December 2008

DECLARATION

This Dissertation paper contains no material which has been accepted for the award of any other degree or diploma in any University or equivalent institution in Sri Lanka or abroad, and that to the best of my knowledge and belief, contains no material previously published or written by any other person, except where due reference is made in the text of this Dissertation. I carried out the work described in this Dissertation under the supervision of Dr. N. Munasinghe

UOM Verified Signature 28.04.09

Signature : Date :

Name of Student : S.P.K. Hewage

Registration No : 04/8637

UOM Verified Signature

Signature : Date : 28.04.2009

Name of Supervisor : Dr. N. Munasinghe

Abstract

Flash butt welding is a well established economical process for solid state butt welding. It consists indirect electrical heating of the ends of the work pieces to be welded and forging them together. While heating, a thermal distribution characterized by a steep temperature gradient is established along the axial length of the pieces. Flash butt welding is widely used for steel band welding in wheel industry. Major advantages are economical in operation, suitable for mass production and high in joint strength.

Loadstar (pvt) Ltd has six flash butt machines in different production lines for rim and band manufacturing. The major problem is considerably high amount of scrap percentage due to welding cracks. This problem severely affects the lines which have severe forming or stretching operations in latter stages. For this investigation the line 05 was selected which has high scrap percentage. The main aim of this study is to analyze the flash butt welding cracks in rim manufacturing and to find out the main reasons for the defects.

The analysis of flash butt welding cracks in rim manufacturing is done in five stages. In the first stage, attention is paid to literature survey, in which the present stage of the researches carried out in the industry regarding the flash butt welding is discussed. Only few literature sources are available although there are many wheel manufacturing companies in the world. Certainly there might be a lot of researches carried out under this topic in the history, but due to high competitiveness among the companies the research outcomes might be kept as company secrets. In this project, the analysis of flash butt welding cracks in wheel manufacturing will be discussed in detail.

The second stage is process description and principles of flash butt welding. Third stage is problem identification and the fourth stage is methodology to solve the problem. In methodology it has stated that the identified process variables that affect the welding quality and how further testing are carried out. Experimental work and results are reviewed under the fifth stage. In this chapter, the testing done for research is discussed in detail and final conclusion is on how the increasing advance velocity of the movable jaw of flash butt machine while keeping the same voltage will give better results in weld joints for SS 400 material.

Acknowledgements

I would like to express my sincere gratitude to Mr. Tissa Jinasena, Chief Execute Officer, Loadstar (pvt) Ltd. for giving an opportunity to follow this MEng / PG Diploma in Manufacturing Systems Engineering. Otherwise I never have an opportunity to do this reasearch project.

Also I would like to express my gratitude to Dr. N. Munasinghe, one of the experts in welding and material science who is really busy but accepted my request to supervise this project. Under his guidance this project directed to a meaningful end.

I would like to extend my special thanks to course coordinator, Dr. G .Wathugala, for his guidance and flexible arrangement of course schedule. Also I would like to express my gratitude to all the lecturers who conduct lectures in MEng/PG Diploma in Manufacturing Systems Engineering as their contribution also helped me to make this project a success.

My personal thanks are also specially dedicated to General Manager of Metal Product Division of Loadstar (pvt) Ltd, Mr. H.M.P Jayawardhana for his support by giving permission to use company facilities for my research project.

Also I would like to pay my sincere gratitude to all the staff members and members of line 05 in Loadstar (Pvt) Ltd for the given support to carry out different testing under a lot of difficulties. Also I would like to extend my gratitude to the Head of Materials Engineering Department, Dr. S. U. Adikari for giving permission to use metallurgical laboratory. The support given by Mr. G. U. C. Menaka and Mr. G. H. R. C. Aariyarthana, the trainee undergraduates of Moratuwa University and Mrs. R. A. R. M. P. Ranasinghe are also acknowledged. Finally I would be thankful to all those who have helped me in many ways to complete my research thesis successfully.

S. P. K. Hewage
December 2008

Content

List of Figures

List of Tables

1.0 Introduction

1.1 Introduction to the Organization

Loadstar (Pvt) Ltd. was incorporated in 1984, as a joint venture between the Jinasena Group of Companies in Sri Lanka, and Solideal Ltd. of Belgium. The joint venture has brought together the proven engineering and management skills of the Jinasena Group of Companies with the technical know-how in Tyre and Wheel production as well as the capability to market the product globally brought in by Solideal Limited.

As per the joint venture agreement entered into between the partners and the local collaborators who largely handle the production and the engineering functions of the operations while the foreign collaborators handle the designing and the marketing functions of the products.

At present Loadstar (pvt) Limited is the world market leader in the Solid Tyres Segment (acquired 20% of the world solid tyre market) and holds the third and fourth places in the world respectively for Rubberized Tracks and Industrial Wheels. In addition to the above achievements Loadstar is the largest contributor for the National Exports of Sri Lanka as a single company (2.09% from the National Exports) being using more than 65% of the Sri Lankan natural rubber as its one of the main raw material. Loadstar (pvt) Limited is an ISO 9001 : 2000 and ISO 14001 : 2004 certified company.

1.2 Products

The products and services supplied by the company at present are as follows and shown in fig 1.1.

(a) Industrial & Construction Pneumatic tyres

(b) Solid rubber tyres

(c) Rubberized Tracks

(d) Industrial and Construction wheels and Rims

Figure 1.1 : Products

1.3 Industrial and Construction Wheels and Rims

There are four factories for construction Wheels and Rims.

- Kyoto wheel division
- Steel band division
- Ekala metal product division (EMPD)

1.4 Kyoto Line Description*

When the Kyoto wheel division is considered, it has fourteen production lines.

i. Line 01 - dish nave press line

ii. Line 02 - Construction wheel welding line

iii. Line 03 - Tubeless wheel & multi piece welding line

iv. Line 04 - Industrial rim line

v. Line 05 - Construction rim line

vi. Line 06 - Tubeless drop center line

vii. Line 08 - Components line

viii. Line 09 - Powder coating line

ix. Line 10 - Wet paint line

x. Line 11 - Steel band Line

xi. Line 12 - Split wheel line

xii. Line 13 - Machine shop

xiii. Line 15 - Tool room

xiv. Line 17 - Steel band section

* Note : Line 07, Line 14 and line 16 are not available.

1.5 Products of Kyoto Wheel Division

Kyoto Wheel plant basically produces four types of wheels as shown in fig. 1.3, fig. 1.4, fig. 1.5 and fig. 1.6.

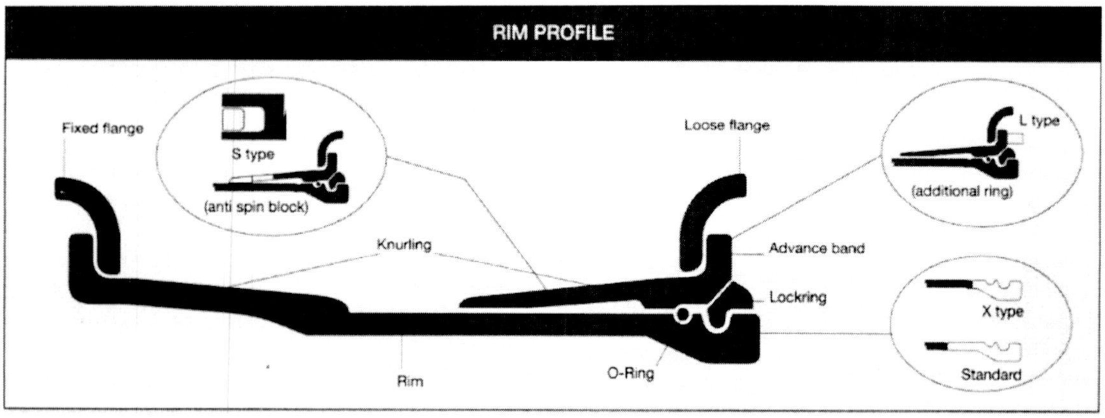


Figure 1.3 : Schematic Diagram of Construction Wheel Sizes

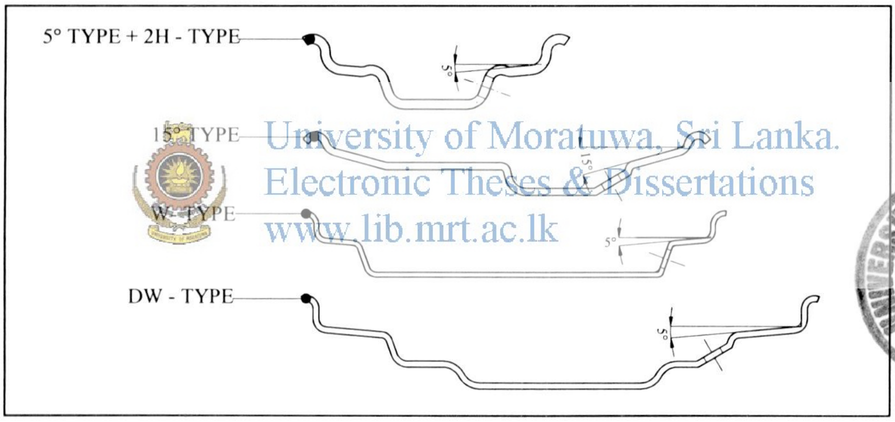


Figure 1.4 : Schematic Diagram of Tubeless Wheels

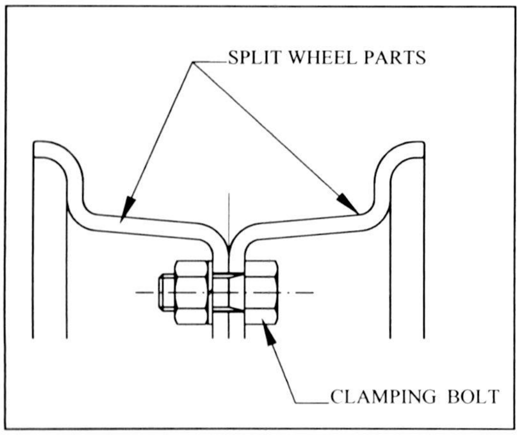


Figure 1.5 : Schematic Diagram of Split Wheels

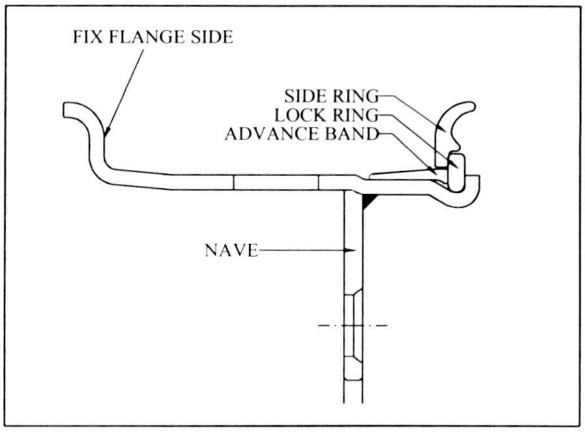


Figure 1.6 : Schematic Diagram of Multi Piece wheels

1.6 Construction Rim Production

Construction Rims are produced by welding different components called fix flange, intermediate band and loose flange. Rim and wheels are two production categories and the difference is the availability of the nave plate. The base product is rim and once fixed the nave plate for axle studs it called the wheel as shown in fig 1.7. This company produces 46 different varieties of rims and wheels for the customers in world wide.

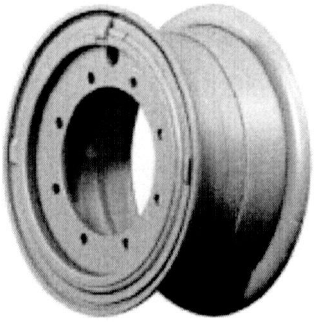


Figure 1.7 : Construction wheel

These rims are exported to different foreign manufactures to make wheels. Construction wheels straightaway exports to original equipment manufactures (OEMs) like Toyota-Japan, Nissan-Spain, TCM-Japan, CNH-USA, OTR- USA etc. The overall monthly production capacity is around 3600 wheels and currently the company produces 2000 wheels monthly.

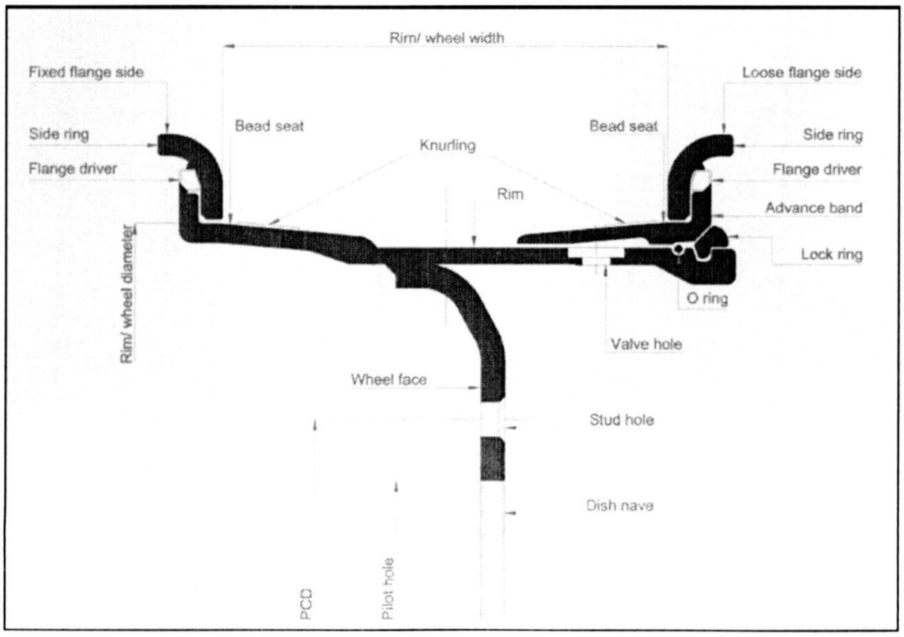


Figure 1.8 : Schematic Diagram of a Construction Wheel

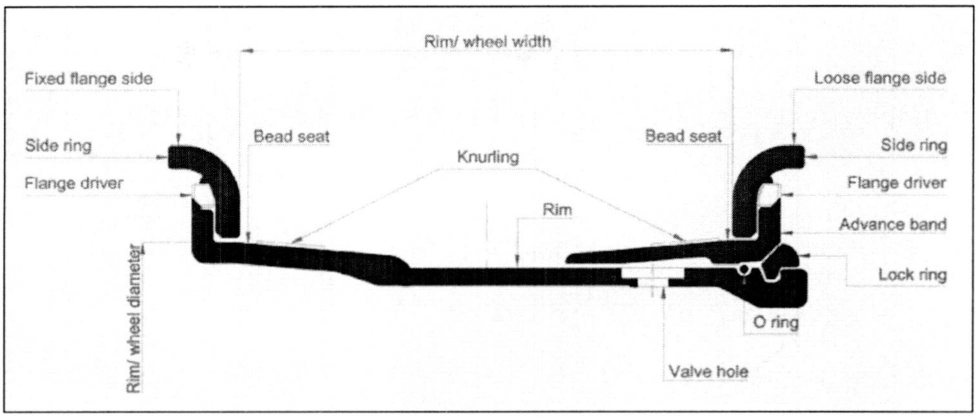


Figure 1.9 : Schematic Diagram of a Construction Rim

The construction wheel and rim shown in fig. 1.8 and fig. 1.9. The difference between construction rim and construction wheel is wheel having a nave plate. Since the rim is the base even for the wheel, from this point onwards the discussion will continue with construction rims.

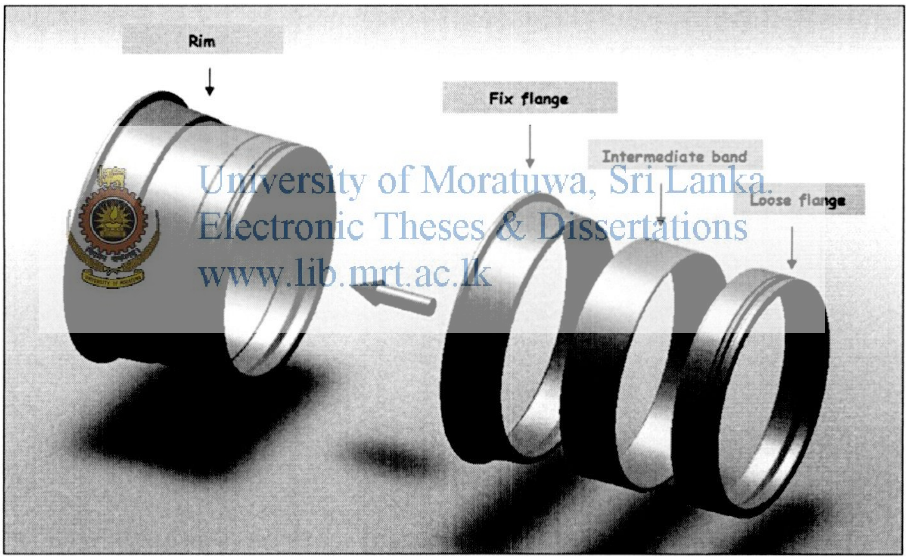


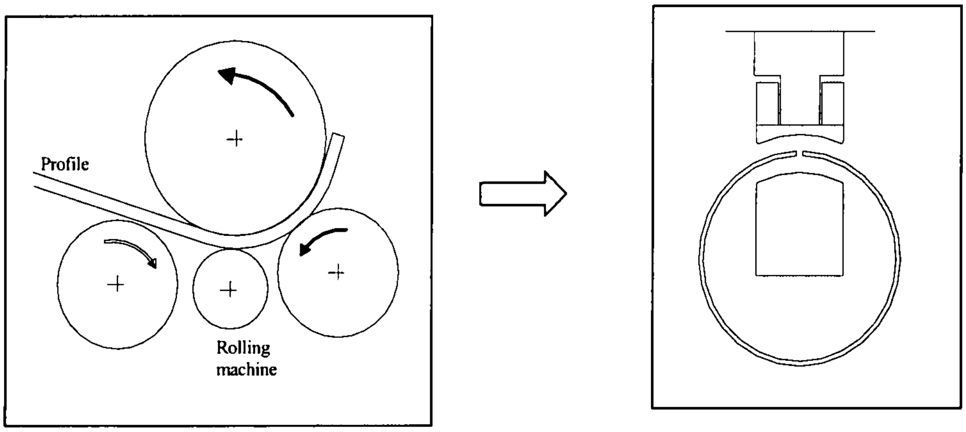
Figure 1.10 : Components of a Construction Rim

Basically a construction rim consists of loose flange, intermediate band and fixed flange as shown in figure 1.10. Line 05 of Kyoto plant produces all the flanges and Line 01 produces all intermediate bands required for construction rims. Assembling and welding processes are carried out at Line 02.

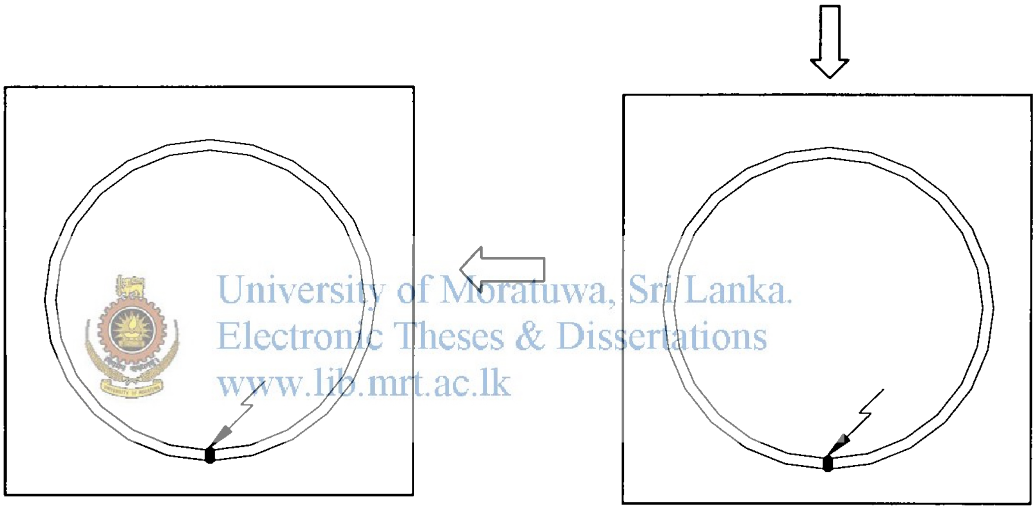
1.6.1 Flange Production Process

Steel profile strips which are imported from Germany, China and India fed to the production line as inputs. Basically all flanges under go several basic operations mentioned below and depending on the product features there might be minor operations specific to the flange type.

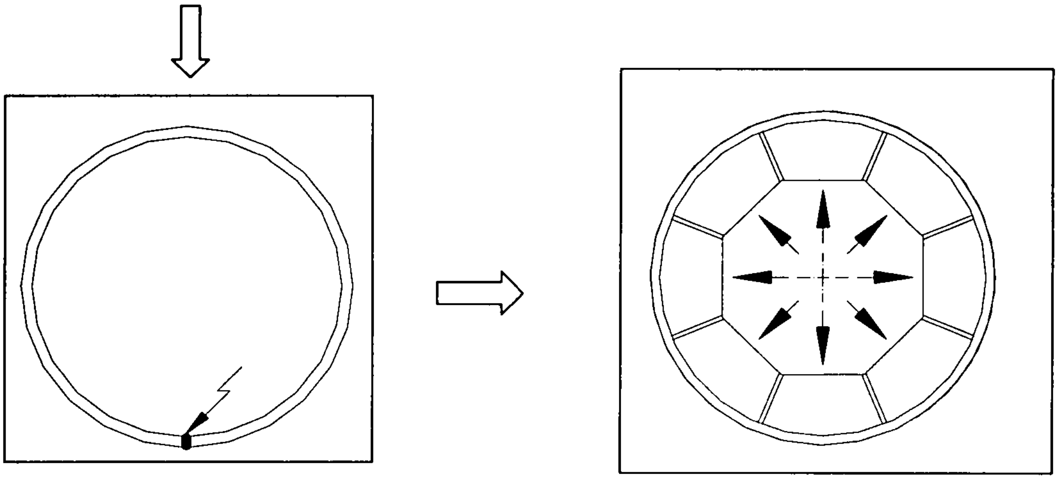
Sketches of flange manufacturing basic operations and their sequence is shown in figure 1.11.



i. Profile strip rolling ii. Profile band rounding



iv. Rotary Flash Trimming iii.. Band Flash Butt Welding



v. Weld Bead Grinding vi. Flange Expanding

Fig 1.11 : Basic Flange Production Process

Each profile type has specified shape and length in strip form and all of the profile strips have been stored at Loadstar ware houses. Depending on the flange type to produce that specific profile strip feed to the Line 05 as input material. As shown in figure vi. of Fig1.11, profile rolling operation the profile strip rolled at 4 mill roller having rolling capacity of 50 M. Ton and get a rolled profile. The both ends of rolled bands are not circular and using a rounding tool with 100 M Ton eccentric press, the both ends are rounded and prepare for welding. The next operation is profile band welding and this is done with flash butt welding. For flash butt welding line 05 has a semiautomatic flash butt machine having capacity of 500 KVA. Once the band is welded it is immediately passed to the rotary trimmer machine to trim off the excess flash occurred during the up setting. This is done at red hot state and flash at the ends of the weld and the untrimmed weld material is removed by manual grinding. At this stage of the production process it gives a circular shape flange but it does not has the dimensional accuracy and the shape accuracy. The required accuracy for the diameter is +\- 0.8 and it is achieved by stretching the flange using expanding tools.

2.0 Literature Survey

2.1 Welding as Joining Process

As joining techniques improved through the ages, so did the environment and mode of living for humans. Materials, tools, and machinery improved as civilization developed. Fastening together the parts of work implements began when an individual attached a stick to a stone to make a spear or an axe. Different types of joining methods were used to join wood and stone in ancient times. However, it was a long time before the ancients discovered a method for joining metals. Workers in the Bronze and Iron Ages began to solve the problems of forming, casting and alloying metals. Welding metal surfaces together was a problem that long puzzled metal-workers of that time period. Early metal-joining methods included such processes as forming a sand mold on top of a piece of metal and casting the desired shape directly on the base metal, so that both parts fused together, forming a single piece of metal. Another metal-joining method used in early years was to place two pieces of metal close together and pour molten metal between them. When the edges of the base metal melted, the flow of metal was then dammed and allowed to harden. [1]

The Industrial Revolution, from 1750 to 1850, introduced a method of joining pieces of iron together known as forge welding. This process involved the use of a forge to heat the metal to a soft, plastic temperature. The ends of the iron were then placed together and hammered until fusion took place. [1]

Forge welding remained as the primary welding method until Elihu Thomson, in the year 1886, developed the resistance welding technique. This technique provided a more reliable and faster way of joining metals than did previous methods. [1]

As techniques were further developed, riveting was replaced in the United States and Europe by fusion welding to repair ships at the end of World War I. At that time the welding process was considered to be vital to military security. Repairs of the ships damaged during World War I were done in great secrecy. Even today some aspects of welding are closely guarded secrets. [1]

Since the end of World War I, many welding methods have been developed for joining metals. These various welding methods are playing an important role in the expansion and production of the welding industry. Welding has become a dependable, efficient, and economical method for joining metal. [1]

A weld is defined by the American Welding Society (AWS) as "a localized coalescence (the fusion or growing together of the grain structure of the materials being welded) of metals or nonmetals produced either by heating the materials to the required welding temperatures, with or without the application of pressure, or by the application of pressure alone, and with or without the use of filler materials." Welding is defined as "a joining process that produces coalescence of materials by heating them to the welding temperature, with or without the application of pressure or by the application of pressure alone, and with or without the use of filler metal." In less technical language, a weld is made when separate pieces of materials to be joined, combined and formed one piece when heated to a temperature high enough to cause softening or melting and flow together. Pressure may or may not be used to force the pieces together. In some instances, pressure alone may be sufficient to force the separate pieces of material to combine and form one piece. Filler material is added when needed to form a completed weld in the joint. It is also important to note that the word *material* is used because today welds can be made from a growing list of materials such as plastic, glass, and ceramics. [1]

2.2 Welding Processes

The number of different welding processes has grown in recent years. These processes differ greatly in the manner in which heat, pressure, or both heat and pressure are applied and in the type of equipment used. [1]

The most popular welding processes are oxyacetylene welding (OAW), shielded metal arc welding (SMAW), often called stick welding, gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), and torch brazing (TB). [1]

Oxyacetylene is the most commonly used fuel gas mixture. It is widely used for oxy - fuel gas welding, oxy-fuel gas cutting, and oxy - fuel brazing. The oxy-fuel gas processes are the most versatile of the welding processes. The equipment shown in figure 2.1 and it is comparatively inexpensive, and the cost of operation is low. [1]

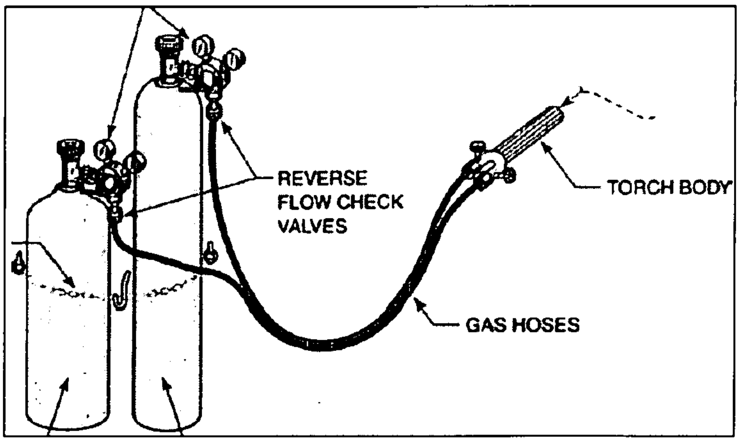


Figure 2.1 : Oxy-fuel Welding and Cutting Equipment [1]

Shielded metal arc welding (SMAW) is the most common method of joining metal. High-quality welds can be made rapidly and with excellent uniformity. A variety of metal types and metal thicknesses can be joined with one machine. [1]

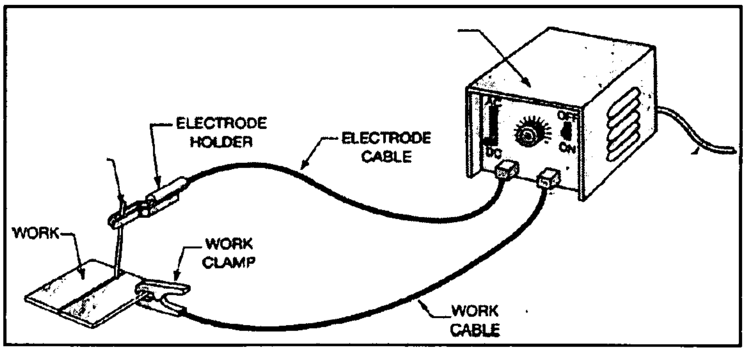


Figure 2.2 : Shielded Metal Arc Welding Equipment [1]

Gas tungsten arc welding (GTAW) is easily performed on almost any metal. Its clean, high-quality welds often require little or no post weld finishing. [1]

Gas metal arc welding (GMAW) is extremely fast and economical. This process is easily used for welding on thing gauge metal as well as on heavy plate. The high welding rate and reduced post weld clean up are making gas metal arc welding an outstanding welding process. [1]

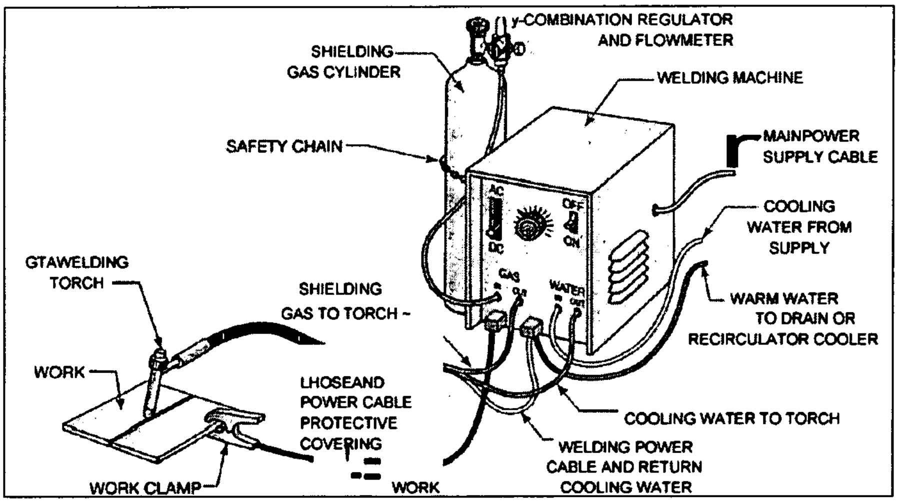


Figure 2.3 : Gas Tungsten Arc Welding Equipment. [1]

Flux cored arc welding (FCAW) uses the same type of equipment that is used for the gas metal arc welding process. A major advantage of this process is that with the addition of flux to the center of the filler wire it is often possible to make welds [1]

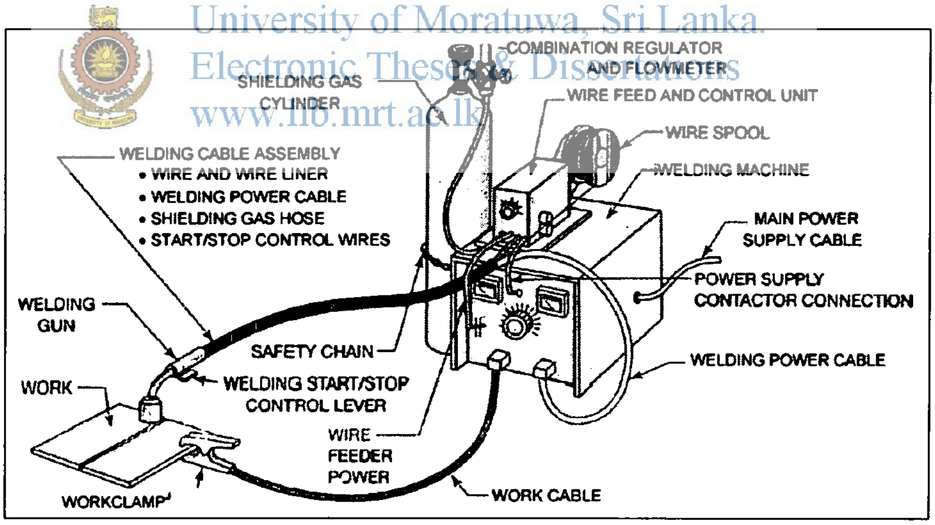


Figure 2.4 : Gas Metal Arc Welding Equipment. [1]

without the use of an external shielding gas. The introduction of smaller wire sizes and the elimination of the shielding gas from some welds has resulted in an increase in the use of FCAW process. Although slag must be cleaned from the welds after completion, the process's advantages of high quality, versatility, and welding speed offset this requirement. [1]

2.3 Flash Butt Welding

Flash-Butt welding is a process designed to produce a forge-type butt weld between two metal pieces of similar shape. It is used to join ends of rods, bars, strips, rings, tubes, forgings and fittings. [2]

The pieces to be joined are clamped in fixtures which are connected to the secondary of a welding transformer. One of the clamp fixtures is mounted on a slide which is programmed to move toward the stationary clamp at a controlled rate. [2]

During this movement the transformer is energized and as the work pieces touch, welding current flows. This flash process generates heat in the work pieces.

At the proper temperature the slide driving mechanism rapidly accelerates, forging the work pieces together to form a joint essentially as strong as parent metal without the aid of any filler material This "upsetting" action forces impurities out of the weld zone. [2]

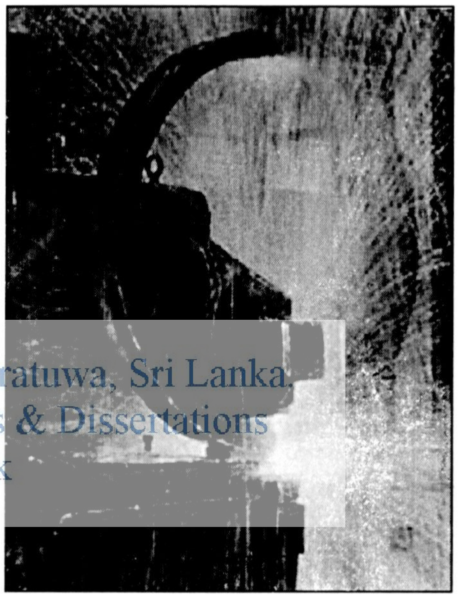


Figure 2.5 : Flash welding [3]

Thus the inner weld metal is sound and free of oxides or cast metal. The forces required for flash-butt welding are established by the forge strength of the materials being welded. The strength classifications of steel are:

- Low Forging Strength: (10,000 psi) SAE-1020, 1112, 1315, NAX9115, [2]
- Medium Forging Strength: (15,000 psi) SAE-1045, 1065, 1335, 3135, 4130, 4140, NE- 8442, 8640, 9440, 9540, 9640, etc. [2]
- High Forging Strength: (25,000 psi) SAE-4340, 4640, Stainless steel of the 400 series (13% CHROMETYPE), 300 series stainless steel (18% CHROME-8% NICKEL), high speed steel, special tool and die steels. [2]

- Extra High Forging Strength: (35,000 psi) Any special steel having extra high compressive strength at elevated temperatures. [2]

Flash Welding can be used for joining many ferrous and nonferrous alloys and combinations of dissimilar metals. Practically Flash-welding can be applied to any metal that can be forged. In addition to low-carbon steels, Flash-welding metals on a production basis include low-alloy steels, tool steels, stainless steels, heat resisting alloys, aluminum alloys, magnesium alloys, nickel alloys, and copper alloys. Cast iron (which cannot be forged) is reported as never having been successfully flash welded in production. High quality joints can be obtained consistently by Flash-welding, especially with automatic equipment including feedback controls in real time. This reliability permits to qualify Flash-welding for highly demanding applications as found in aerospace for solid and tubular sections. [2]

The selection of a standard machine or the design of a special welder will be determined by the upset forces, along with the necessary clamp forces required as a result of the sectional area of the material being welded. Fig. 2.6 shows a flash butt machine used for ban welding. [2]

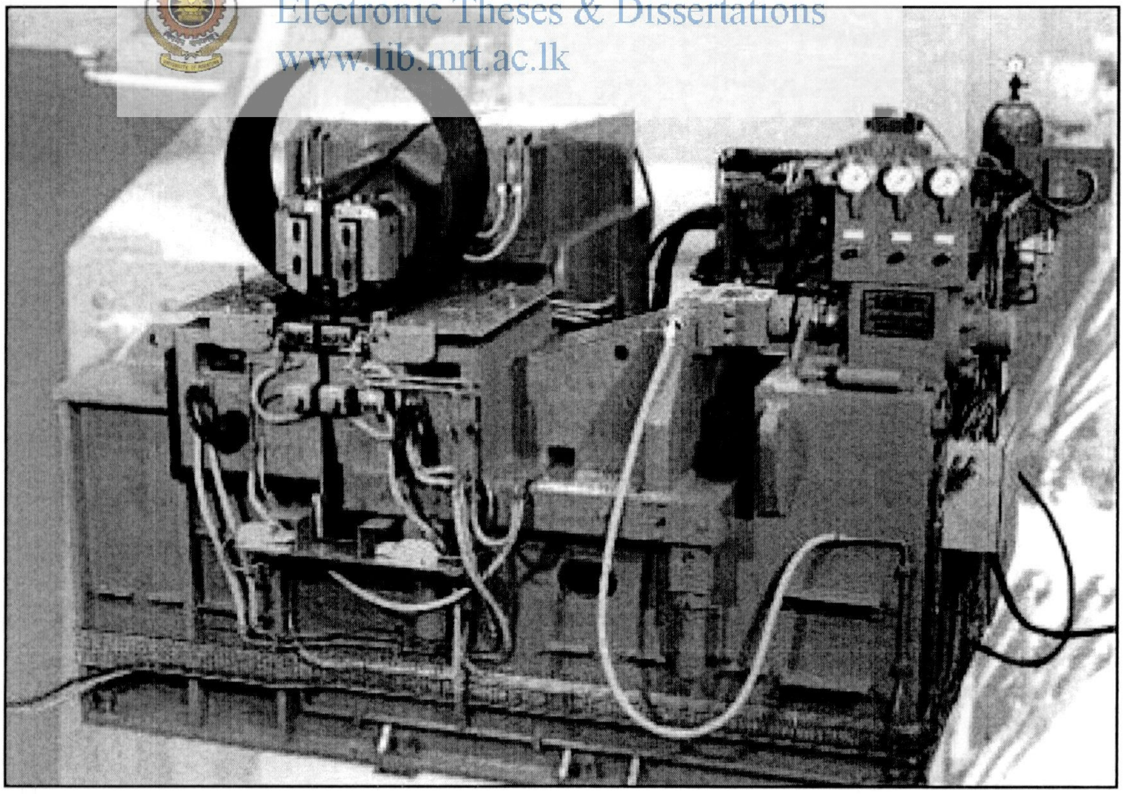


Figure 2.6 : Flash Butt Welding Machine for Band Welding [2]

2.3.1 Typical Applications of flash butt welding.

Parts of aircraft landing gears and many rings of different materials are currently manufactured by Flash-welding (rolled and welded). Many applications of Flash-welding are found in automotive production. Continuous loops of band saws are formed by Flash-welding in a special attachment to the saw itself. [3]

Sheet metal coils are welded together end to end by Flash-welding to provide the continuous supply of certain manufacturing processes. Window frames and general frames are manufactured by Flash-welding for different industries. With very large equipment, the longitudinal seam of thick pipes can be manufactured by Flash-welding. [3] Flash butt welding process has following advantages and limitations.

(a) Advantages of flash butt welding

- Economical in operation and in the use of metal.
- Suitable for mass production.
- Unskilled workforce needed.
- Strong welds obtained.
- Good fatigue properties available.
- No special symmetry requirements (different from for Friction welding). [3]

(b) Limitations of flash butt welding

- Removal of flash required (same as for Friction welding).
- Process may affect or remove any strain hardening (cold work) properties.
- Heat treatment after Flash-welding may be needed to develop full properties.
- Costly maintenance of equipment due to flashing.
- Fire hazards present.
- Electric power and upsetting force in available equipment limit the weldable size.
- Heat unbalance from different materials may cause upsetting problems.
- Shunt effect for closed rings rolled and flash welded may need attention.
- High accuracy alignment is required. [3]

2.4 The principle of flash butt welding.

As shown in the Fig. 2.7. Welding material is clamped to a fixed stand and a moveable stand, which is called a plating. When voltage is applied from a welding transformer and movable plate is taken closer slowly. Then the highest points of the contact surface will touch each other concentrating the current locally and initiate the flash and begins to disperse. Furthermore, as it is brought nearer, other portions also will in contact and a flash will be generated in the whole area. If this repeated, the whole welding edge front will be heated uniformly. Furthermore if heating progress rapidly and the plating (movable plate) moves forward faster, generation of flash will increase more and more and the pressure and the welding temperature at the welding edge front will become uniform. [4]

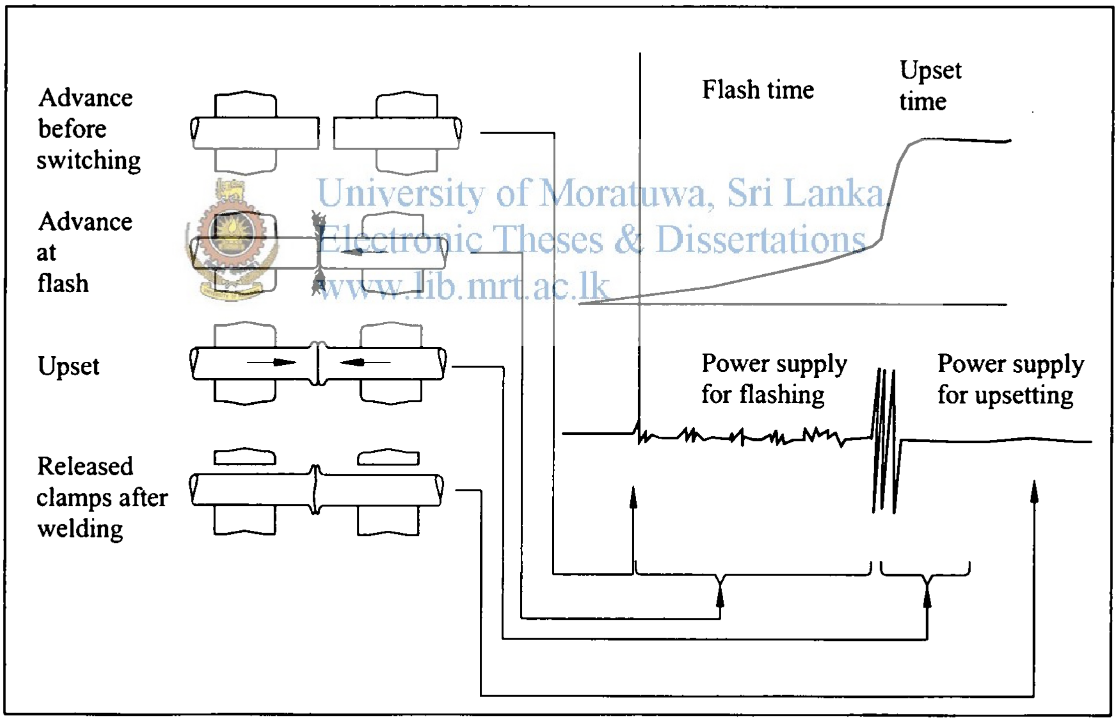


Figure 2.7 : Principle of Flash Butt Welding [4]

In upset process, the "plating" is advanced rapidly and a high uniform pressure is applied to the work piece and then welding current is intercepted. In the upset process the contacted area of the work piece gets partially melted and the oxides, impurities will be squeezed out at the interface and the joint is established. [4]

2.4.1 Preheating

During preheating, the work pieces are brought into contact under light pressure and then the welding transformer is energized. The resistance heating effect of high density current flow heats the metal between the clamps. The temperature distribution across the joint during preheating approximates a sinusoidal waveform with the peak temperature point at the interface. [4]

Three useful functions may be served by a preheating operation:

(1) It raises the temperature of the parts which, in turn, makes 'flashing easier to start and maintain.

(2) It produces a temperature distribution with a flatter gradient which persists throughout the flashing operations. This, in turn, distributes the upset over a longer length than is the case when no preheat is employed.

(3) It may extend the capacity of a machine and permit the joining of larger cross sections than when it is done without preheating. However, there is one possible drawback to preheating. Since preheating is often a manual operation, even when the machine is capable of flash welding automatically, the reproducibility of the preheating operation is largely a function of operator skill. [4]

2.5 Flash butt Machine Components

Fig. 2.8 shows the machine components of flash butt machine and basically flash welders consist of three main sections each of heavy duty construction. [2]

2.5.1 Main Frame is made of heavy duty welded construction and designed for maximum accessibility for ease of maintenance and adjustability. Mounted to the frame are the welding transformer, upsetting mechanism, upset slide/clamp, stationary clamp, four sealed main bearing boxes with precision roller bearings. [2]

2.5.2 Work Clamping Mechanisms are normally vertically operated pivoting lever-arms mounted integral with the fixed and movable platens. Each consists of steel clamping levers on heavy duty hardened and ground pivot pins and bushings. The ends of the pivot-pin bearings are sealed to protect them from weld flash. Lubrication of the bearings is through single point fittings. [2]

The clamp levers are usually operated by double acting direct cylinders, either pneumatic or hydraulically operated. The piston rods are protected by sewn leather bellows. Depending on the application, these clamp levers are designed to provide from 0.5 to 2.5 times the upset force. Other types of clamping mechanisms are available optionally as required. [2]

The Upper Electrodes are recessed in the clamping levers. They can be arranged for adjustable/fixed or self-equalizing alignment with the lower dies/work piece. The Lower Electrodes are often supplied so that the electrode on the movable platen is adjustable horizontally and the electrode on the stationary platen is adjustable vertically. This allows precision alignment of the welded parts. [2]

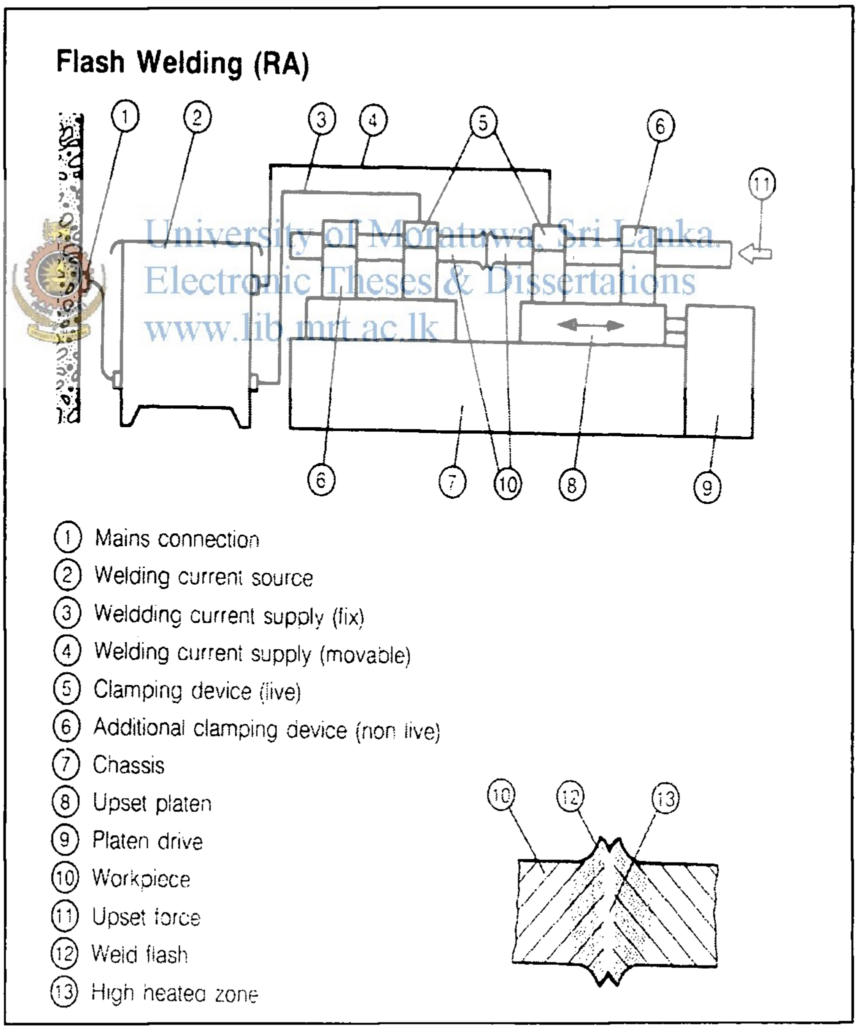


Figure 2.8 : Machine Components of Flash Butt Machine [2]

2.5.3 Upsetting Mechanism The motor operated device for controlling the flashing and upset movement of the upset slide is a gear box mounted Flashing Cam on which a steel roller runs. The cam shaft is supported by an outboard anti-friction bearing with the flash/upset cam located between the outboard bearing and the first bearing in the gear box. A variable speed 3 phase, 60 hertz, 230/460 volt motor provides a flashing time range of approximately 3 sec to 1 sec The cam shaft carries timing cam switches to turn off and on the welding power and then stop the motor after each weld cycle and upset slide is returned back to the initial position. [2]

When welding non-ferrous materials, the upsetting action may be controlled by the addition of necessary pneumatic devices between the flashing cam and the upset slide to increase the upset speed for greater control of the forging force. [2]

The flash and upsetting action may also be controlled hydraulically by the use of a double acting hydraulic cylinder in place of the motor driven gear box and flash cam. An electro-hydraulic servo control with provisions for multiple welding programs and data recovery is available. [2]

All welders are provided with control interlocking features to provide maximum safety to the operator and to prevent damage to the welder or work spoilage because of improper operator actions. [2]

2.6 Principles of operation

The basic steps in a flash welding sequence are as follows and shown in fig. 2.9

1. Position the parts in the machine and clamp the parts in the electrodes.
2. Apply the flashing voltage and start platen motion to cause flashing.
3. Flash at normal voltage.
4. Terminate flashing and upset the weld zone.
5. Unclamp the weldment and return the platen.

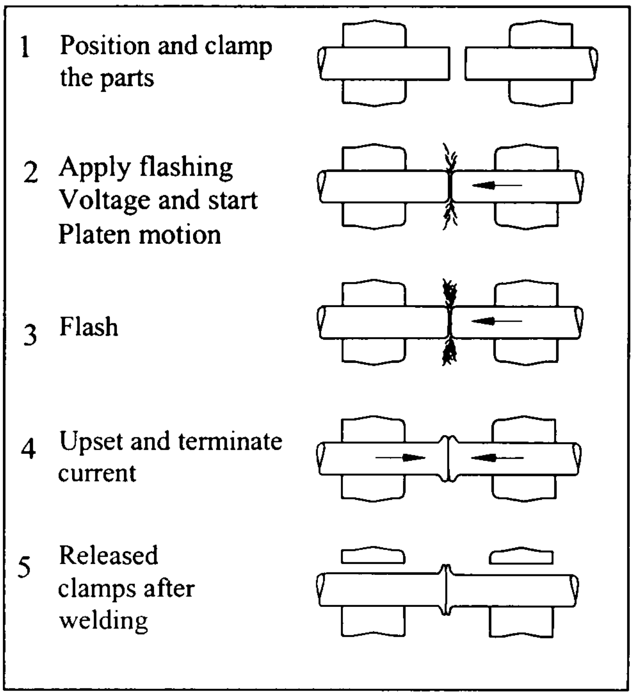


Figure 2.9 : Basic Steps in Flash Butt Welding

Figure 2.9 illustrates these basics steps. Flashing takes place between the facing surfaces as the movable part is advanced toward the stationary part. Heat is generated at the point and temperature of the parts increase with time. Flashing action (metal loss) increases with part temperature. The flashing pattern show an initial period of constant velocity motion of one part toward the other to facilitate the start of flashing. This linear motion then change into an accelerating motion which is closely approximate a parabolic curve.

To produce a strong joint with uniform upset, the temperature distribution should be uniform and average temperature of the faying surface should nearly be melting temperature of the metal. Once these conditions are reached, further flashing is not necessary. The steepness of the temperature gradient corresponding to a stable temperature distribution is a function of the part acceleration during flashing. In general the higher the rate of part acceleration the steeper is the stable temperature gradient produced. Thus the shape of the temperature distribution curve in a particular application can be controlled by appropriate choice of flashing pattern. Since the compressive yield strength of a metal is temperature sensitive the behavior of the metal during the upsetting portion of the welding cycle is markedly dependent upon the flashing pattern. [4]

The minimum flashing distance is the amount of flashing required to produce a stable temperature distribution. From practical standpoint, the flashing distance should be slightly greater than the minimum acceptable amount to ensure that the stable temperature distribution is always achieved by flashing and the two parts are brought together rapidly. The movable parts should be accelerated rapidly so that the molten metal on the flashing surfaces will be extruded before it can solidify in the joint. Motion should continue with sufficient force to upset the metal and weld the two pieces together. [4]

Upset current is sometimes applied as the joint is being upset to maintain temperature by resistance heating. This permits upset of the joint with lower force than would be required without it. Upset current is normally adjusted by electronic heat control on the basis of either experience or tests. [4]

2.6.1 Welding conditions

Flash process is related to heating and the upset process is based on pressure contact and the factors related as follows.

(a) Heating conditions

1. Materials heating quality
2. Cross sectional shape of materials
3. Condition of the clamp table
4. Secondary voltage
5. Secondary current (flash current)
6. Distance of the flash.
7. Speed of the flash.
8. Clamp distance at the beginning

(b) Pressure conditions

9. Upset pressure
10. Upset time
11. Running time of the electricity for upset
12. Upset distance
13. Interval of the clamp ending.

2.7 Process Variables

Certain parameters have to be set to have a satisfactory weld. They are flashing voltage, flashing time and parameters in upsetting process. The details and the roles of each variable described below and the behavior of the flash current and the force against time shown in fig. 2.10 [5]

2.7.1 Flashing voltage

Flashing voltage is determined by the tap setting of the welding transformer. This voltage should be kept to be as low as possible to maintain an optimum flashing action. [5]

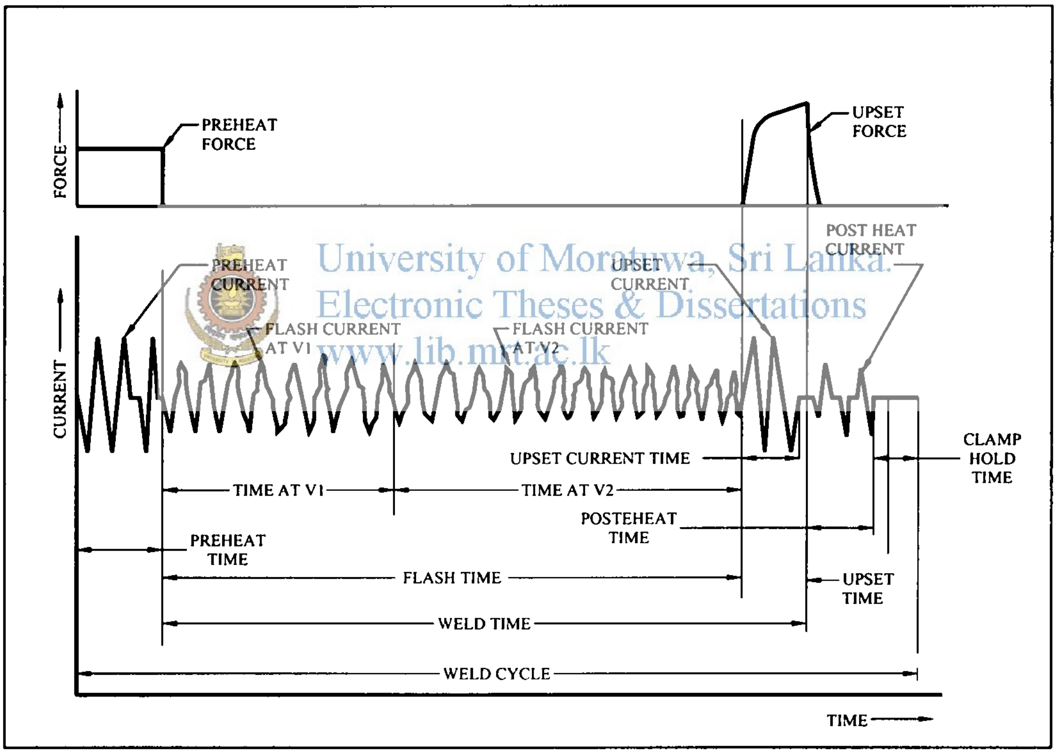


Figure 2.10 : Flash Welding, Current, Force and Time Variables [5]

One system for providing two voltage ranges uses primary contactors, each of which is connected to separate transformer taps. One contactor is energized to provide a high secondary voltage (V_1 in Figure 2.10) during the initial stages of flashing. The high voltage assists in starting the flashing action. The other contactor is energized after a predetermined time in the flashing operation to provide a normal secondary voltage (V_2 in Figure 2.10). The first contactor is de-energized at the same time. The best flashing action is achieved with this arrangement. [5]

2.7.2 Flashing time

Flashing is carried out over a particular time interval to obtain the required flash loss of metal. The time required will be related to secondary voltage and the rate of metal loss as flashing progresses. Since a flashing pattern is generally parabolic, the variables are interrelated. [5]

2.7.3 Upsetting

To produce a quality flash weld, the flash and upset variables must be considered together since they are interrelated. The parameters of the upset action are given below;

(i.) Flashing voltage cutoff

(ii.) Upset rate

(iii.) Upset distance

(iv.) Upset current magnitude and duration.

(i.) Flashing Voltage Cutoff Flashing voltage should be terminated at the moment that upset of the weld commences. Adjustments should be made during actual welding tests to ensure that the voltage termination does not take place before the mating surfaces make full contact. [5]

(ii.) Upset Rate Upset action is commenced by rapidly accelerating the contact surfaces together. In this moment the molten metal and oxides present on the surfaces are forced out of the joint. The upset rate must be sufficient to expel the molten metal before it solidifies and to produce the optimum upset while the metal has adequate plasticity during partly melted condition. [5]

The welding machine must apply a force to the movable platen to properly accelerate the part and overcome the resistance of the parts during plastic deformation. The force required depends upon the cross-sectional area of the joint, the yield strength of the hot metal, and the mass of the movable platen. [5]

(iii.) Upset Distance

The magnitude of the upset distance must be sufficient to accomplish two actions:

i. the oxides and molten metal must be expelled from the mating surfaces.

ii. The two mating surfaces must be brought into intimate metal-to-metal contact over the entire cross section to create inter atomic bonds

The amount of upset required to obtain a sound flash butt weld depends on the metal and the section thickness. Some heat-resistance alloys may require upset distances as large as 1 to 1.25 times of section thickness. Satisfactory welds are made in aluminum with upset distances about 50 present greater than those employed with steels of similar thickness [4]

(iv.) Upset current As explained under pre heating in some cases the weld zone may tend to cool rapidly after flashing is terminated. This may result inadequate upset or cold cracking of the upset metal. The joint temperature can be maintained during upset by resistance heating with current supplied by the welding transformer. The magnitude of current is commonly controlled electronically and upset current would be terminated at the end of the upset. If the flash is to be mechanically trimmed immediately after welding, upset current may be maintained for an additional period to archive the desired temperature for trimming. [4]

2.8 Flash Butt Welding Defects

The defects which can develop in flash-butt welding, can be divided into two categories.

i. Defects depend upon joint shape

ii. Defects depend upon the quality of the welded zone

The joint shape related defects are misalignment of the edges welded, flash left after its cutting-off and irregular shape of the welded joint. Such defects the dimensions of which exceed the admissible limits, can lower the strength properties of the joint. [4]

These discontinuities are easily detected by visual inspection. Misalignment of the parts is corrected by adjustment of the clamping dies and fixtures. Non uniform upset may be caused by part misalignment, insufficient clamping force, or excessive die opening at the start of upset. The latter can be corrected by decreasing the initial die opening and then adjusting the welding schedule, if necessary. [4]

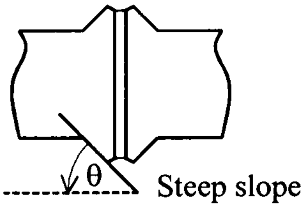
The second category includes defects located in the joint zone (in the weld), these are lack-of-fusion and non-metallic inclusions. The lack-of-fusion are sections of the joint zone which completely or partially lack the metallic bond between the parts being welded. Such sections feature the absence of crystalline fracture on the surface of samples which failed in the welded butt. The lack-of-fusion are unfilled craters which form in flashing on the end faces of the bands being welded, and can be light or dark, depending on their location in the butt. If lack-of-fusion are located at a certain distance from the surface of the items being welded, they have a light-coloured surface in the fractures in the butt. If the lack-of-penetration come to the surface of the items being welded, their surface is covered with oxides and for this reason, they are dark. [4]

Non-metallic inclusions of a relatively small area can be found in flash-butt welding A feature of non-metallic inclusions on the fracture surface, is their fine-crystalline structure. Non-metallic inclusions can contain oxides of iron and other metals present in the composition of the steel being welded. In the majority of cases, however, these are complex inclusions, incorporating iron, manganese and silicon oxides. The appearance of such inclusions located in the butt zone, is associated with the inclusions present in the steel along the rolling bands. [4]

2.8.1 Oxides Another source of metallurgical discontinuities is the entrapment of oxides at the weld interface. Such defects are rare since proper upset should expel any oxides formed during the flashing operation. [4]

2.8.2 Die burns The discontinuities produced by local overheating of the base metal at the interface between the clamping and the part surface called burns. They can usually be avoided by keeping the parts clean and mating them properly with the dies. [4]

2.8.3 Voids As a result of either insufficient upset or excessive flashing voltage voids are usually take place. Deep craters produced on the faying surfaces by excessive flashing voltage may not be completely eliminated during upset. Such discontinuities are usually discovered when the welding procedure is being qualified. They are readily avoided by decreasing the flashing voltage or increasing the upset distance. Fig. 2.11 and Fig. 2.12 show the appearance of flash welds with satisfactory and unsatisfactory upset. [4]



30° < θ < 60°

Fig 2.11 Satisfactory Heat and Upset

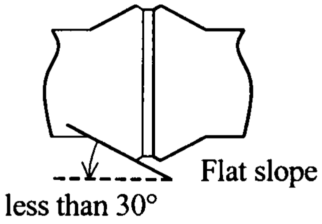


Fig 2.12 Insufficient Heat or Upset or both

2.8.4 Cracking The type of discontinuity known as a crack may be internal or external. It may be related to the metallurgical characteristics of the metal. Alloys that exhibit low ductility over some elevated temperature range may be susceptible to internal hot cracking. Such alloys, known as "hot-short" alloys, are somewhat difficult to flash weld, but usually can be successfully welded with the proper conditions. [4]

Cold cracking may occur in hardenable steels. It can usually be eliminated by welding with conditions that moderate the weld cooling rate, coupled with post-welding heat treatment as soon as possible after welding. [4]

Insufficient heating prior to or during upset is the usual cause of cracking in the external upset metal, as shown in Fig. 2.13. This can be eliminated by resistance `heating during upset. [4]

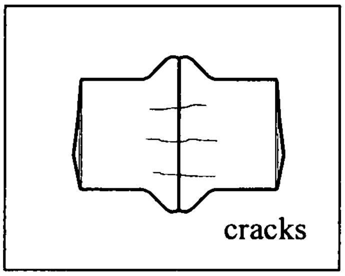


Fig. 2.13 : Cracks due to Insufficient Heat

Weld quality is significantly affected by the specific welding variables selected for the application. Table 2.1 indicates the effects of several variables on quality when they are excessive or insufficient in magnitude. Each variable is considered individually, although more than one can produce the same result. [4]

Table 2.1 : Effect of variables on Flash and Upset weld quality [4]

	Excessive	**Insufficient**
Voltage	Deep craters are formed that cause voids and oxide inclusions in the weld; cast metal in weld.	Tendency to freeze; metal not plastic enough for proper upset.
Moving Rate	Tendency to freeze	Intermittent flashing, which makes it difficult to develop sufficient heat in the metal for proper upset.
Time	Metal too plastic to upset properly.	Not plastic enough for proper upset; cracks in upset.
Current	Molten material entrapped in upset; excessive deformation.	Longitudinal cracking through weld area inclusions and voids not properly forced out of the weld.
Upsetting Distance or Upsetting Force	Tendency to upset too much plastic metal; flow lines bent perpendicular to base metal.	Failure to force molten metal and oxides from the weld; voids.

2.9 Researches done to overcome flash butt defects

Since flash butt welding is a well established welding process there are lot of researches had been carried out by professionals and institutes. Also we can see lot of patents related to flash butt machine developments to have better welding performance by improving the machine. But most of the published research papers done for high carbon rail line welding, Pipe welding and joining the high strength materials. The research papers related to low carbon profile welding or flash butt welding in rim manufacturing is very rare and this might be due to keeping those results by rim manufactures as company secrets. The welding of the profiles for construction wheels or steel bands for multi piece rims or steel bands for tubeless rims are similar to rest of the flash butt welding. The difference of the welded profiles or bands for rim manufacturing from other flash butt welding is undergoing severe deformations and lateral stretching.

2.9.1 Flash butt welding defects reduction by machine improvements

Professor Shuji Nakada of Osaka University done some research on the improvements of flash butt machine to eliminate welding defects in 1978 [4]. According to his research the welding machines used up to date, were performed by controlling the movable plate "plating" for the pattern decided beforehand. With that system when flashing has started, it was imagined that the flashing occurs uniformly till just before the upset takes place. However; that was not correct in fact, and it was quite discontinuous and it is also known that there are many variations. [4]

Furthermore, although it was thought that the source of generation of heat of flash welding was mainly due to resistance heat, it was understood that the fact is a repetition of a short circuit and an arc. As shown in fig. 2.14, during flashing, short Circuit and arc take place alternately, then the flash is subsequently interrupted. [4]

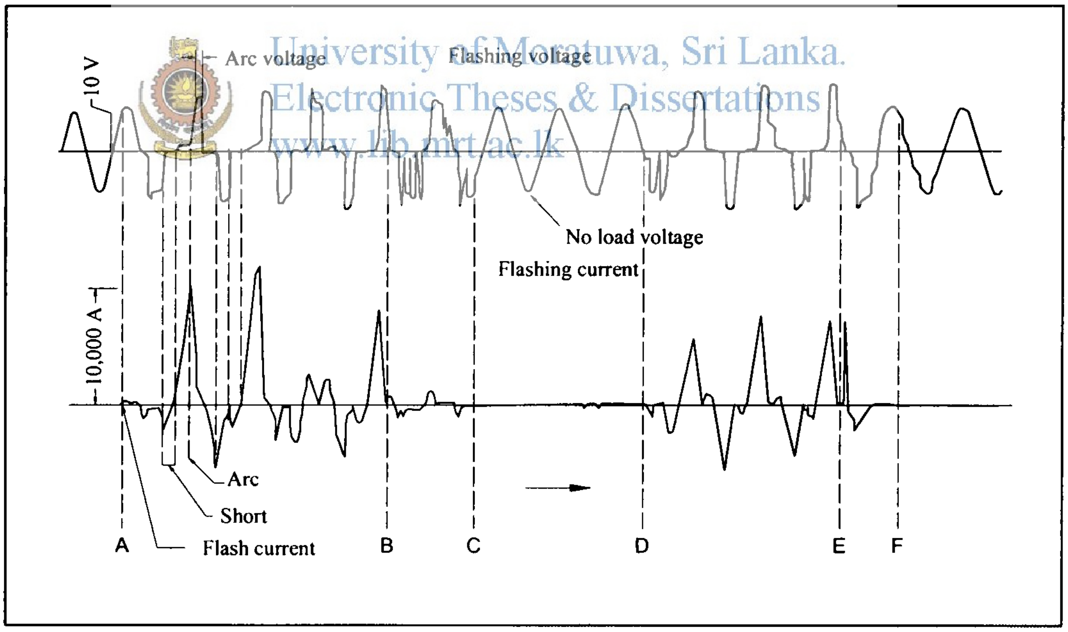
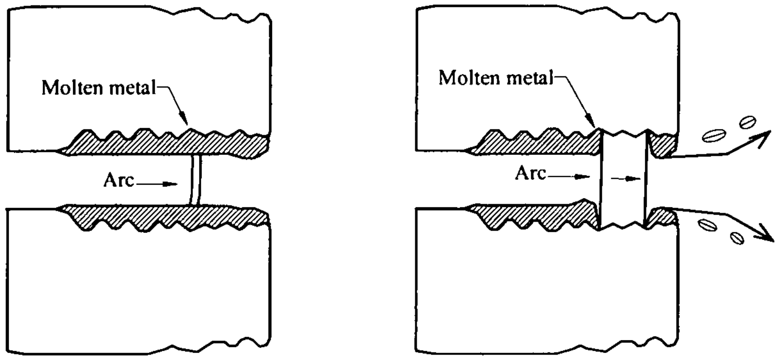


Figure 2.14 : Behavior of Flashing Voltage and Flashing Current [4]

Next, when the flash voltage is high and the arc energy is large the amount of the consumption of fusion is high, so that the applying heat for the welding material also increases. But at the real situation, because of the high heat at the affected parts, the welding material gets heat up and the molten metal get disperse as shown in Figure 2.15 [4]



Low arc energy High arc energy

Figure 2.15 : Arc Energy Difference [4]

Consequently, there is a risk in the process of upset, if the metal welds while intervened an oxide, or not been in the proper welding pressure and temperature, when the welding completes. [4]

Moreover, the welding circuit has a particular impedance. In the welding circuits, there are fixed number of circuit constants L/R, which are important elements for flash generating (flashing). When the L/R are at a small range, number of times of generating short circuit arc (frequency of short circuit arc) gets higher and the heating of advance of the metals become average. As a result the occurrence of defects decreases. After considering the facts mentioned above designing and a manufacturing of a welding machine must be required to reduce welding defects. [4]

Stability of the arc is controlled by current, voltage and the arc gap. The heat is generated from arc. Based on the professor Nakada's research findings, it is clear that in order to generate a stable flash, it is necessary to maintain supplying on heat to the welding material efficiently within short time period of welding as well as at a low electric capacity of the welding machine. To do that it is necessary to maintain low secondary voltage and that can be done with decreasing circuit impedance. [4]

However, in the case of a production machine, it does not easy to decrease the circuit impedance to keep secondary voltage low. By our experience till now, we were able to decrease the impedance 230 μΩ to 80 μΩ. If circuit impedance decreases it inevitably decrease the secondary voltage. [4]

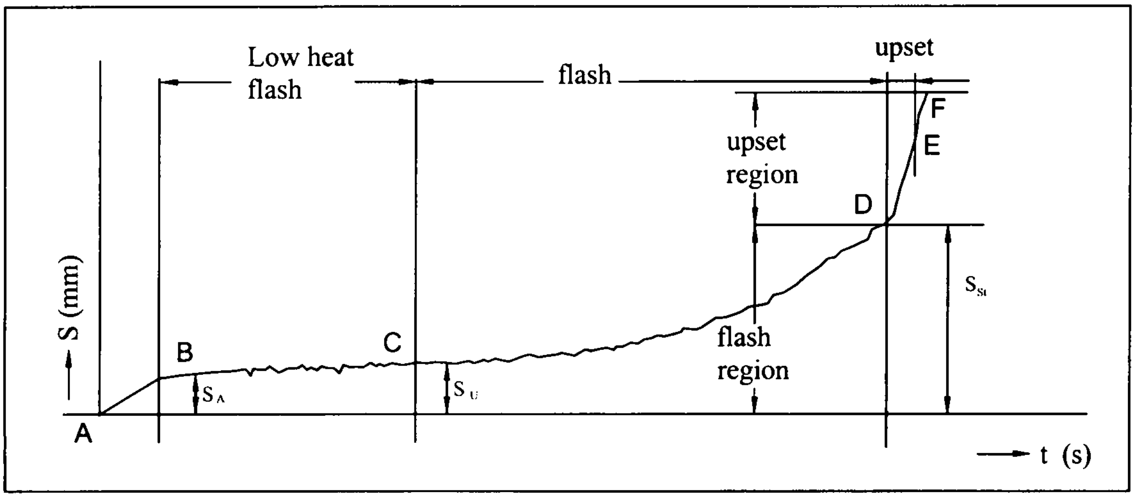


Figure 2.16 : Displacement vs Time Graph for Flash Butt Welding [4]

However molten metal of the ends freezing (petrify) is an issue with conventional upsetting operation. Then even though secondary voltage can be made low it is difficult to overcome this problem with a system like conventional "plating" control (or control of movable plate) in flashing, although. Moreover, during .flashing, although it was a short time period, the pause of flashing can be performed and occurrence of flash could be continued. [4]

Similarly, a new system for controlling movable plate is done by controlling the frequency of flashing. This is the so-called oil pressure electricity "SERVO" system. Fig. 2.16 shows the displacement vs time curve of the movable plate for the SERVO system [4]

Among the materials use for the flash butt welding recently are almost satisfactory in practical use. However reduction of the defect rats is desired more. and it can never be said that there will be no problem. The welding machine has mainly adopted the "plating" controlling method of a rotating motor cam formula, and for this machines the circuit impedance is as low as 130 μΩ and as high as 250 μΩ [4]

To increase the productivity of welding, it can be performed by shorten the time of flashing time and by increasing the upset current. It is presumed that especially the ON heat of the flashing is small. When the quality of the material (change by the lot) of a rim changes usually poor welding takes place. [4]
In this case, the defects can be minimized by changing of welding conditions. Anyhow, in most cases defects cannot be recovered by changing the welding conditions. [4]

Maximum welding current of this machine is 70000A and the circuit impedance is 90 μΩ . By experience of practical use of this machine, advantages can be reported as follows. [4]

1. It decrease an electric input
2. It reduces the rate of defects
3. It reduces the movable of defects. which occur by the difference of material
4. The movable plate is flat and it is visible through the welding machine, which is similar to the visible (bed) system of the working machines. This assures the high accuracy of the machine.

When the secondary voltage is low and the flashing speed is high, then the occurrence of flashing also gets quicker and ultimately the moving speed of the "plating" (movable plate) need to be faster. '

2.9.2 Flash butt welding defects reduction by material improvements

A research has been done by Yasutomo Ichiyama and Shinji Kodama regarding flash butt welding of high strength steels and it was published in Nippon steel technical report. According the research paper Defects which can occur in flash butt welding are similar in form to defects observed in welds of electric welded tube (penetrator, cold weld) or those observed in gas pressure welded joints (flat spot). Dispersed oxide lies beneath the fractured surface. Fig. 2.17 shows a image of fractured surface [6]

According the research paper defects which can occur in flash butt welding are similar in form to defects observed in welds of electric welded tube (penetrator, cold weld) or those observed in gas pressure welded joints (flat spot). Dispersed oxide lies beneath the fractured surface. [6]

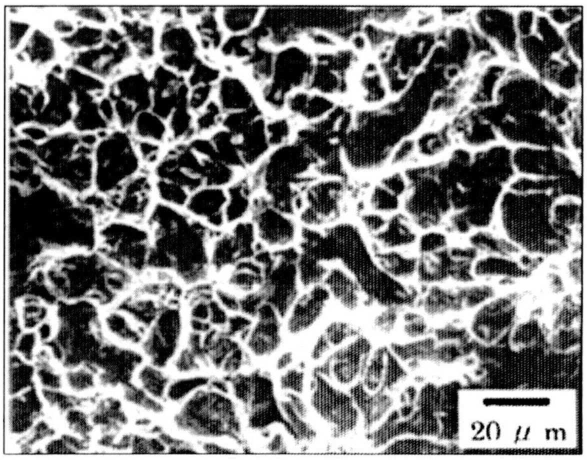


Figure 2.17 : SEM Image of Fractured Surface in Defect Area [6]

These are oxides containing Si, Mn and Al which were formed in the sheet edge in the flashing process and remained in the weld surface without being ejected in the upset force application process. The principle of heating in flash butt welding is chiefly the generation of a flash. The process involved is repetitions of three phenomena: (1) contact between convex edges, (2) resistance heating and melting, and (3) breaking of contact edges by electromagnetic pinching force and spattering of contact edges by subsequent arc discharge. If an excessively large flash occurs before upsetting, a considerably larger crater is formed at the sheet edge. This crater can cause a weld defect. [6]

Table 2.2 Chemical compositions of steels used in research (mass%) [6]

Mark	Steel	C	Si	Mn	P	S	Cr	Ni	Mo	Nb	Al	Others	Thickness (mm)
A	X80	0.082	0.25	1.84	0.011	0.001	-	0.19	0.09	0.043	0.023	Cu, Ti, V	12
B	980HT	0.07	0.23	1.9	0.015	0.008	1.8	-	-	-	0.04	Ti, V	13
C	X65	0.087	0.19	1.29	0.011	0.0007	-	-	0.22	0.034	0.033	Ca	8
		* Quenching: 920• • 15•min• WQ, Tempering: 600• • 15•min• AC											
Gr. D	Sheet steels	0.013-0.171	0.01-1.24	0.19-1.62	0.009-0.026	0.009-0.023	0.0-0.4	-	-	0.0-0.05	0.002-0.100	V	2.4-3.2

Fig. 2.18 shows an example of the influence of welding conditions (Steel A in Table 2.2). The weld surface defect is evaluated in terms of the rate that cracking occurs in a bending test. The rate is obtained as the ratio of the total sum (Σ *l*) of crack lengths (*l*) to the overall width of the test piece used in the bending test. It can be seen that increasing the upset length and applying preheating before the flashing process are effective means of reducing weld cracking. [6]

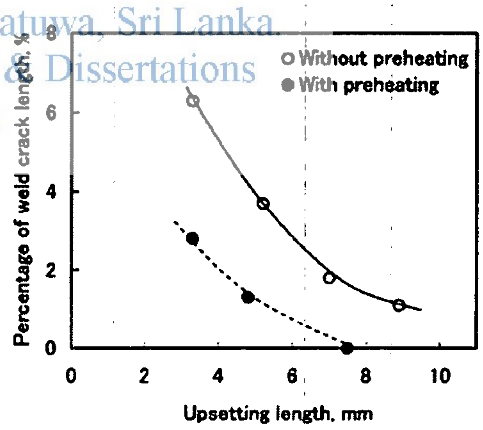


Figure 2.18 : Effect of preheating and upsetting length on weld crack length (Steel A) [6]

As shown in figure 2.19, under welding conditions that include the application of preheating, small burrs occur in the weld interface. Thus, the formation of a so-called third lip becomes conspicuous. The third lip is formed when a molten layer which has been formed on the test piece edge is removed by the upsetting force. It is considered, therefore, that the reason why the weld defect can be reduced by the application of preheating is that the increase in heat input promotes the formation of a molten layer making it easier to expel the unwanted oxides by the application of an upset force. [6]

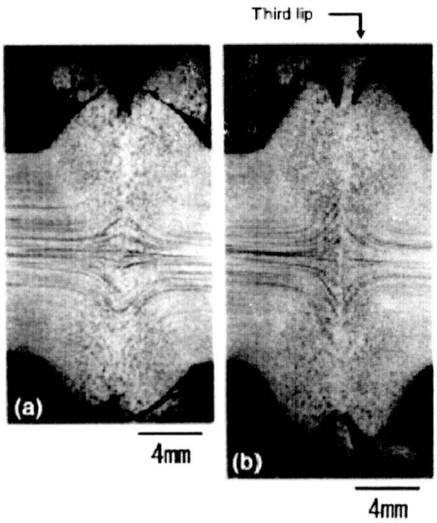


Figure. 2.19 : Cross-section of welds [6]

In principle, the chemical composition of steel largely determines the rate of occurrence of weld surface defects. In the case of mild steel sheets, the rate of occurrence of cracking generally increases as the Al content of the steel is increased. This is because mild steel contains less Si and Mn than high-strength steel and its susceptibility to cracking is determined largely by the readily oxidized Al9). On the other hand, some grades of high-strength steel are subject to marked cracking. This suggests that not only the contents of oxidizing elements, but also the ductility of the weld, are related to crack susceptibility. A study was conducted on those effects using steel sheets 2.4 mm to 3.2 mm in thickness and 323 MPa to 691 MPa in tensile strength (see Table 1, Gr. D). The test specimens used were Si-Mn-based mild steel sheets and high-strength steel sheets, including sheets containing some amounts of Cr, Nb and V. They were subjected to a bending test, with the punch diameter and bending angle being 7 mm and 180°, respectively, and the weld defects were evaluated in terms of the rate that cracking occurred. Fig. 2.20 shows the influences of C and Si contents on weld crack length, with Si content at three different levels. Both C and Si increase the weld crack length. When welded joints are softened by annealing (heating at 950° for 30 min with cooling in a furnace) after welding, the rate of cracking decreases markedly. [6]

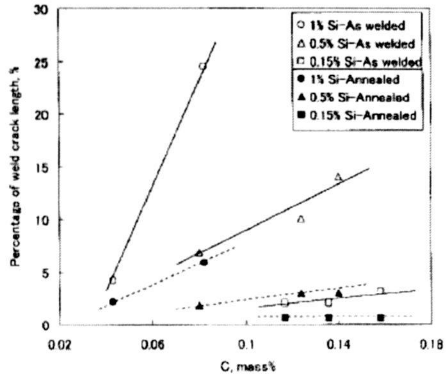


Figure. 2.20 : Effect of C and Si Contents on Weld Crack Length [6]

3.0 Problem Identification

Construction rim line produces 300 metric ton production of Construction rims monthly. But its scarp rate of the components is around 10% - 15% in weight . Basically components get scrapped at expanding stage of work in process after flash butt welding. Apart from scarps there are significant amount of reworks and repairs. This will affect to the final cost of the product as company will have to compensate their loss through completed quality passed products or simply selling product quantity. Ultimate result is product cost increasing even with very little profit margin. The company imports raw materials as steel profiles and only doing value addition to the product through the production process. The Sri Lankan electricity also at high rate and company facing lot of difficulties to compete with their competitors those who produces similar items. Presently India and specially China produces those rims at very cheap price as they have own steel suppliers in their country and also their labour cost and electricity cost relatively low than Sri Lanka. For the time being the company product quality is better than the Chinese and Indian products. But this won't be a competitive advantage in future as Chinese and Indian companies also advancing to high quality level. So it is necessary to reduce scrap rate to survive in competitive market.

When considering the tubeless production for the four months it is easy to identity the relationship between production and scrap. Based on production report created from SAP data shown in annex I, Component production summary graph for May 2008 is shown in fig. 3.1

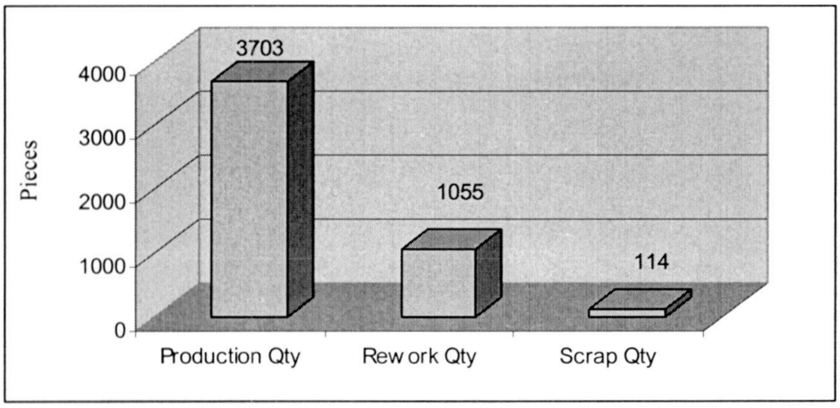


Figure. 3.1 : Comparison of Total Production, Rework and Scrap in May 2008

Table 3.1 : Segmented Scrap Summery in May 2008

Size	Production qty	Rework qty	Scrap qty	Rework Hair crack	 Over lap	 Bad trimming
BE-1	377	265	56	244	18	0
BD	280	183	5	122	61	0
BG	325	61	0	1	45	0
AE 1.7	331	45	2	38	1	6
AA	370	201	0	45	138	15
VA	369	16	1	8	8	0
U 1.7	428	46	9	17	12	12

Component production of line 05 segmented in to profile wise and the production quantity, rework quantity and scrap quantity of main profile types for May 2008 shown in table 3.1 and presented in fig. 3.2. The rework segmentation shown in fig. 3.3.

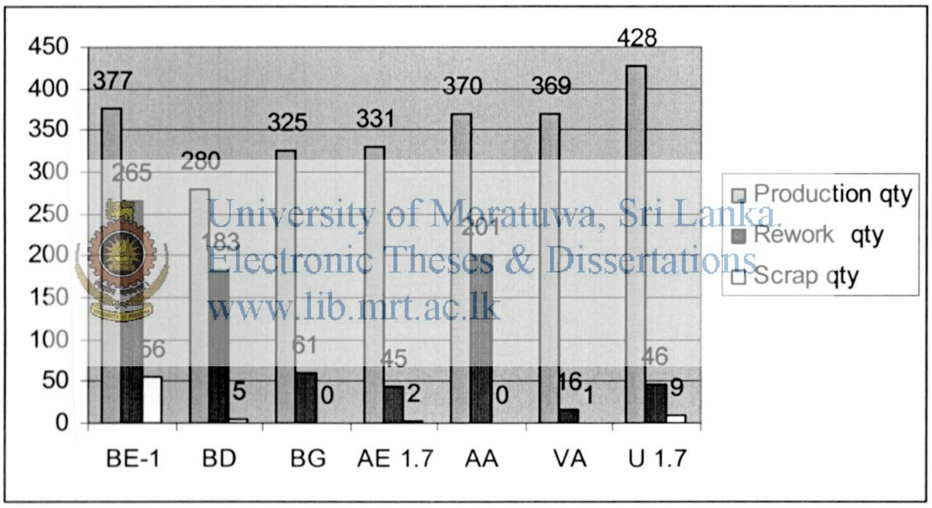


Figure 3.2 : Segmented production summery of May 2008

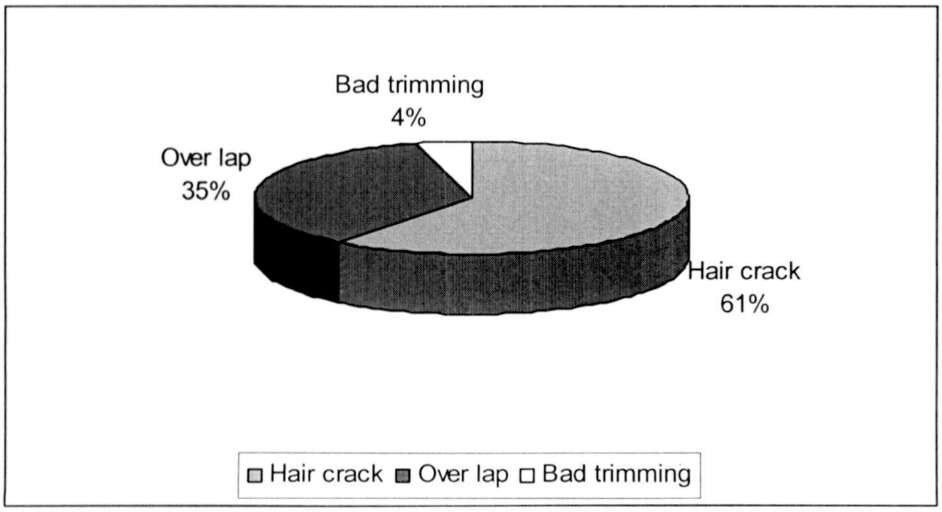


Figure 3.3 : Rework segmentation of May 2008

Based on production report created from SAP data shown in annex I , profile production summary graph for June 2008 is shown in fig. 3.4

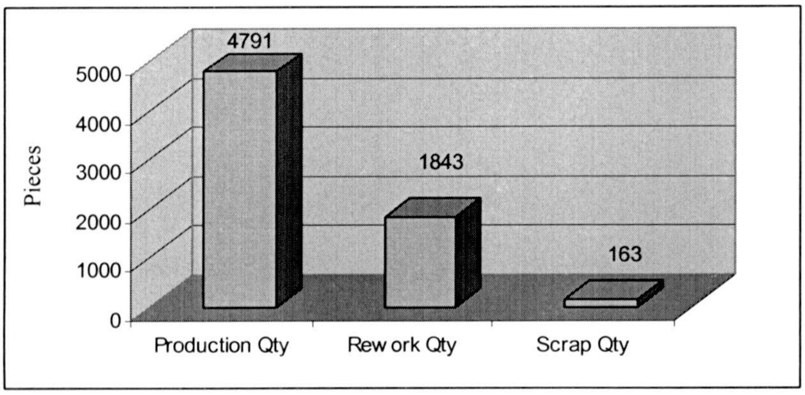


Figure. 3.4 : Comparison of Total Production, Rework and Scrap of June.

Component production of line 05 segmented in to profile wise and the production quantity, rework quantity and scrap quantity of main profile types for June 2008 shown in table 3.2 and presented in fig. 3.5. The rework segmentation shown in fig. 3.6.

Table 3.2 : Segmented Scrap Summery of June 2008

				Rework		
Size	**Production qty**	**Rework qty**	**Scrap qty**	**Hair crack**	**Over lap**	**Bad trimming**
BE-1	314	219	24	206	10	3
BD	224	137	5	27	95	2
BG	590	281	2	136	100	23
AE 1.7	27	3	0	2	1	0
AA	549	291	0	38	182	5
VA	131	14	1	12	4	0
U 1.7	20	2	1	1	0	1

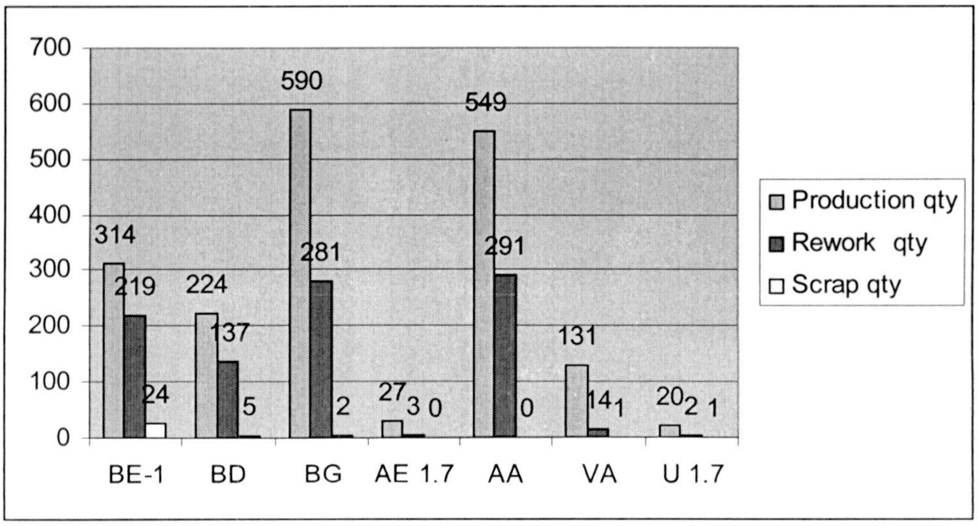


Figure. 3.5 : Segmented Production Summery of June 2008

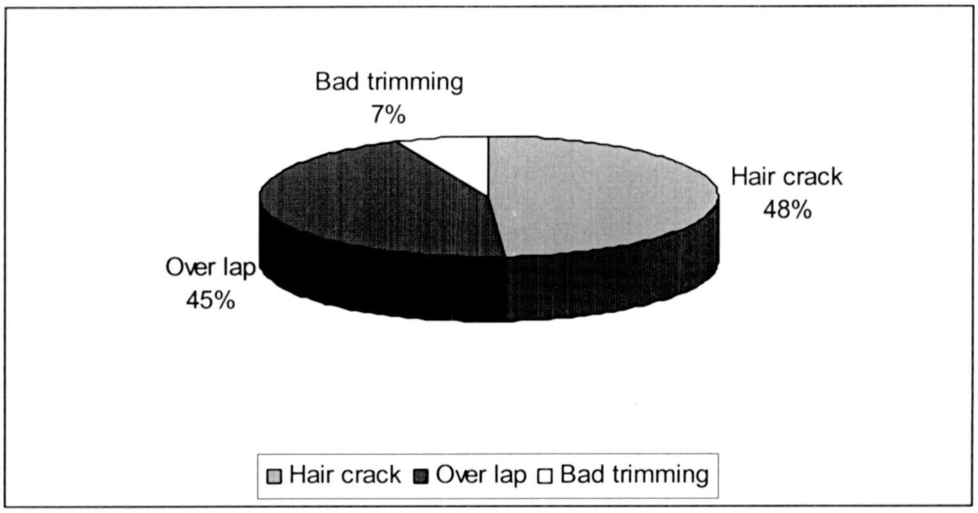


Figure. 3.6 : Rework Segmentation June 2008

Based on production report created from SAP data shown in annex I, flanges production summary graph for July 2008 is shown in fig. 3.7

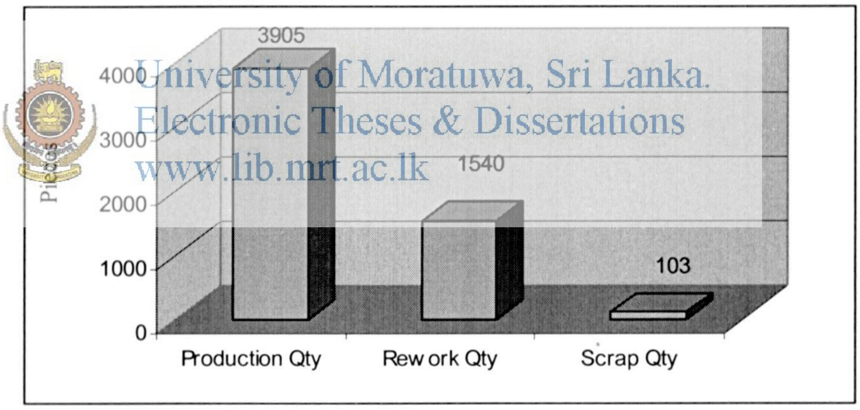


Figure 3.7 : Comparison of Total Production, Rework and Scrap in June 2008

Table 3.3 : Segmented Scrap Summery in July 2008

			Rework		
Production qty	**Rework qty**	**Scrap qty**	**Hair crack**	**Over lap**	**Bad trimming**
722	441	30	250	4	15
565	312	7	208	91	2
524	178	12	86	8	10
432	107	2	59	8	26
420	164	1	38	96	19
411	85	2	71	11	0
318	62	10	18	25	12

Component production of line 05 segmented in to profile wise and the production quantity, rework quantity and scrap quantity of main profile types for July 2008 shown in table 3.3 and presented in fig. 3.8. The rework segmentation shown in fig. 3.9.

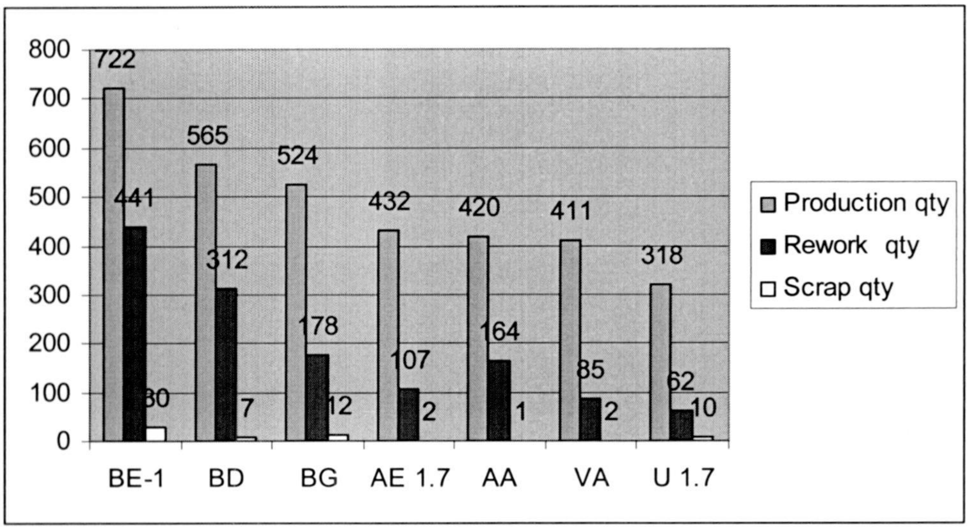


Figure. 3.8 : Segmented Production Summery July 2008

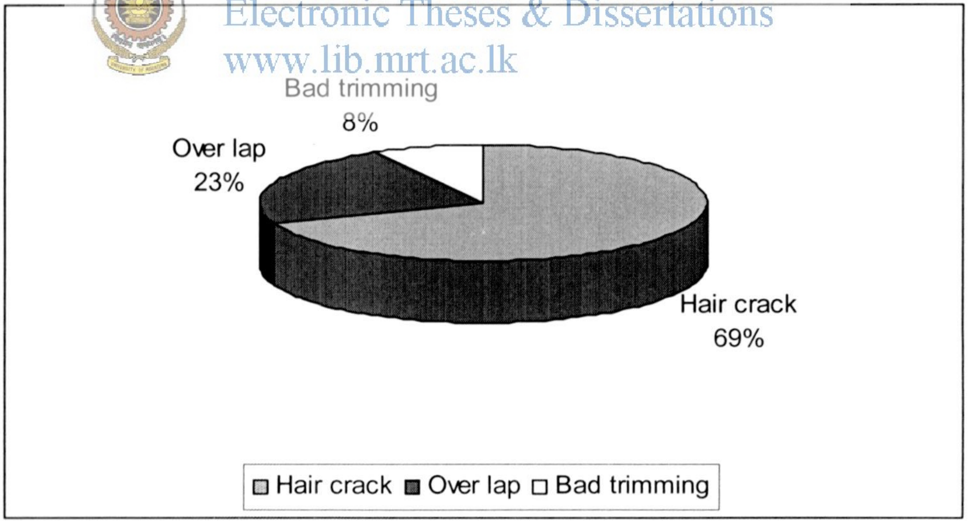


Figure. 3.9 : Rework Segmentation July 2008

According to this analysis BE-1, BD and BG profiles have higher scrap rates compared to rest of profile types. To continue the analysis further BG profile was selected as we were able to get two different types of materials from different suppliers. From this point onwards analysis is completely based on BG profile.

4.0 Experimental Procedure

4.1 Machines used

A semi automatic 320 KVA DAIDEN flash butt machine with constant displacement control facility is used to carry out the testing at Line 05. Constant displacement means the movement of the movable jaw of the flash butt machine which is constantly depending on the preset values described below and it is independent from the arc energy generated at the flashing point. Transformer of the flash butt machine has 6 tapings and depending on the required current for optimum weld the suitable position is selected. To weld any profile it is necessary to set five machine parameters. The clamping pressure and upsetting pressure parameters normally set to 120 kg/cm² and 115 kg/cm² respectively and is not adjusted frequently unless there is a significant difference in cross sectional area in the parts to be welded. For the upsetting process it is necessary to set the moving jaw starting point and ending point which are called open gap and closed gap respectively. Flashing process is done at 3 stages as explained under literature survey and those three stages of moving speed parameter denoted by VR1, VR3, & VR4 and velocity switching positions denoted as V1, V2 & V3 as shown in table 4.1. The interrelationship between V1 & VR1 is the movable jaw of the machine which moves at VR1 speed up to V1 distance (in millimeter). After the upsetting process, the whole machine is kept hold in still position until the melting is ceased and that is called holding time. Final setting is the backward motion of movable jaw and it is set under step back velocity (VR2) and Step back sensitivity (VR17). Welding parameters for BG profile are listed in table 4.1.

Table 4.1 : Welding Parameter Settings for Flash Welding Specific to BG profile

Product Type	Specific Variables Relevant to Machine											Pressure (kg/cm²)	
												Clamping	Upsetting
Profile BG-1	Platen Travel Distance (mm)		Velocity Switching Position			Advance Velocity (Rotary Indicator-Ω)			Step back Velocity (Rotary Indicator-Ω)	Step back sensitivity (Rotary Indicator-Ω)	Pressure Holding Time (s)	120	115
	Flashing	Upsetting	V1	V2	V3	VR1	VR3	VR4	VR2	VR17			
	55	25	49	45	35	195	205	230	275	900	02		

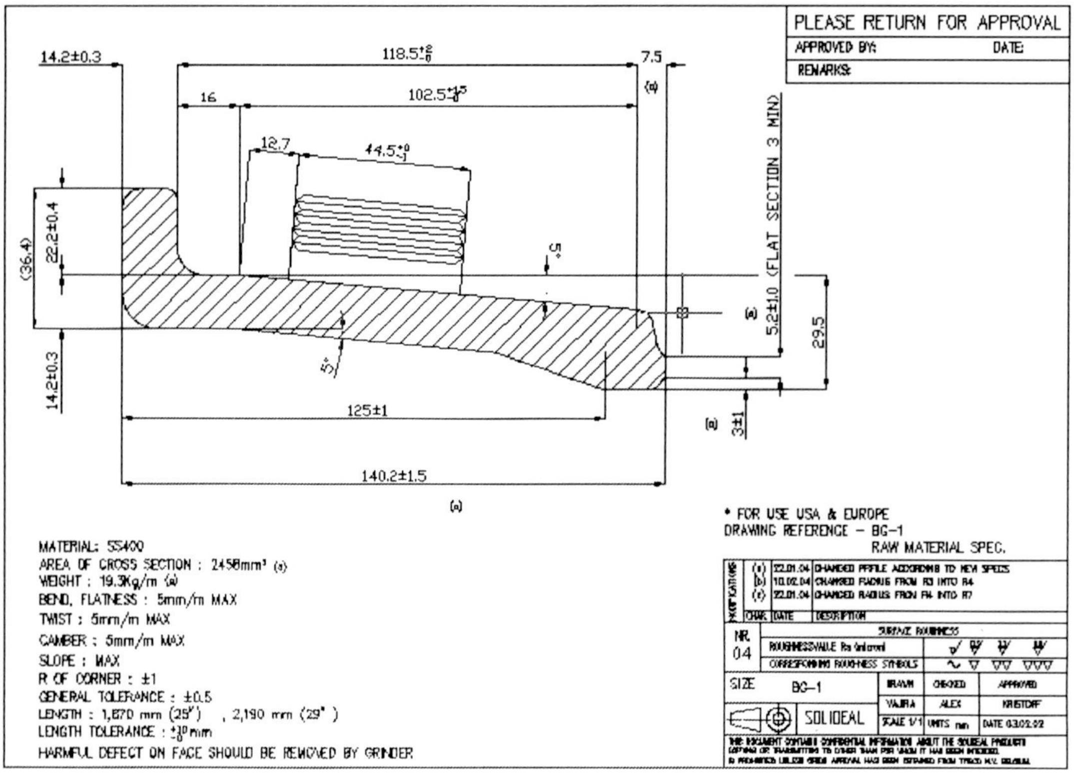
4.2 Materials used

Two types of BG profile materials are used for the testing. One profile material is Q 235B and it is from Huaiyin Steel Factory, China. The other one is SS 400 equivalent material and it is produced in PR rolling company, India. The chemical composition and the physical properties of Q 235 B and SS 400 are listed in table 4.2

Table 4.2 : Properties of Profile Materials Used.

	Chemical properties (w%)						Physical Properties		
Material Grade	C	Si	Mn	P	S	Al	Yield Strength (Nmm^{-2})	UTS (Nmm^{-2})	Elongation %
Q 235 B	0.12	0.3	0.7	0.05	0.05	0.12	235	460	25
SS 400	0.2	0.1	0	0.05	0.05	0.08	245	510	17

The cross section area of BG profile is 2450 mm² and its average length is 1860 mm. The shape of the cross section is shown in fig. 4.1. Average weight of the profile is 36 kg



MATERIAL: SS400
AREA OF CROSS SECTION : 2458mm² (a)
WEIGHT : 19.3Kg/m (a)
BEND, FLATNESS : 5mm/m MAX
TWIST : 5mm/m MAX
CAMBER : 5mm/m MAX
SLOPE : MAX
R OF CORNER : ±1
GENERAL TOLERANCE : ±0.5
LENGTH : 1,870 mm (25') , 2,190 mm (29')
LENGTH TOLERANCE : $^{+10}_{-0}$ mm
HARMFUL DEFECT ON FACE SHOULD BE REMOVED BY GRINDER

* FOR USE USA & EUROPE
DRAWING REFERENCE – BG-1
RAW MATERIAL SPEC.

CHAR.	DATE	DESCRIPTION
(a)	22.01.04	CHANGED PROFILE ACCORDING TO NEW SPECS
(b)	10.02.04	CHANGED RADIUS FROM R3 INTO R4
(c)	22.01.04	CHANGED RADIUS FROM R4 INTO R7

NR. 04
SIZE BG-1
DRAWN VAJIRA
CHECKED ALEX
APPROVED KRISTOFF
SOLIDEAL
SCALE 1/1
UNITS mm
DATE 03.02.02

Figure 4.1 : Section Drawing of BG Profile

4.3 Experimental setup

All issues related to the flash butt welding defects are identified using an issue tree shown in figure 4.2. Material issues, machine related issues, human related issues and operational issues are mainly identified.

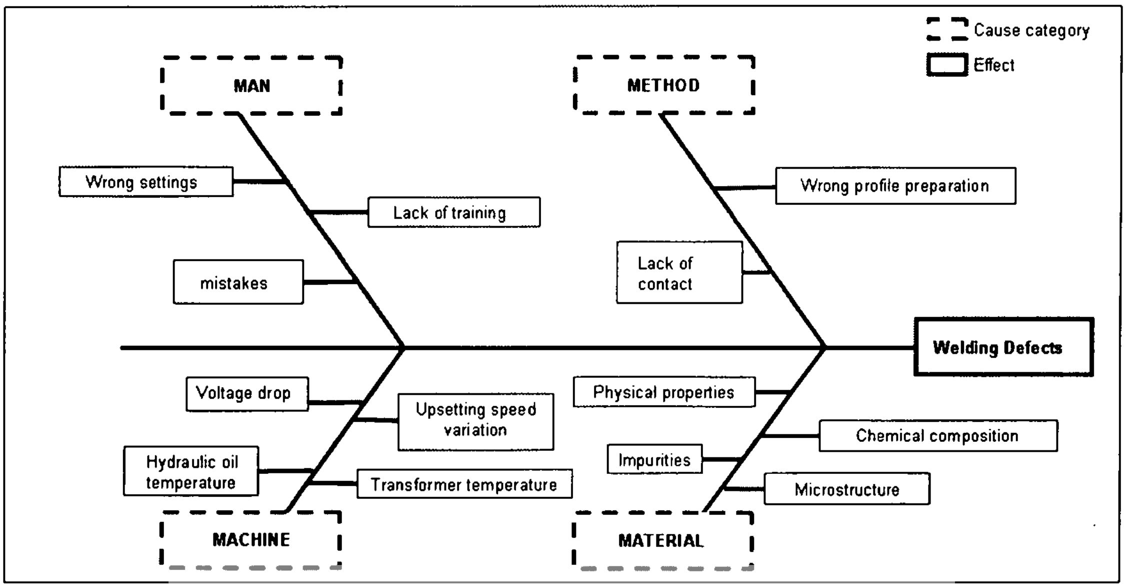
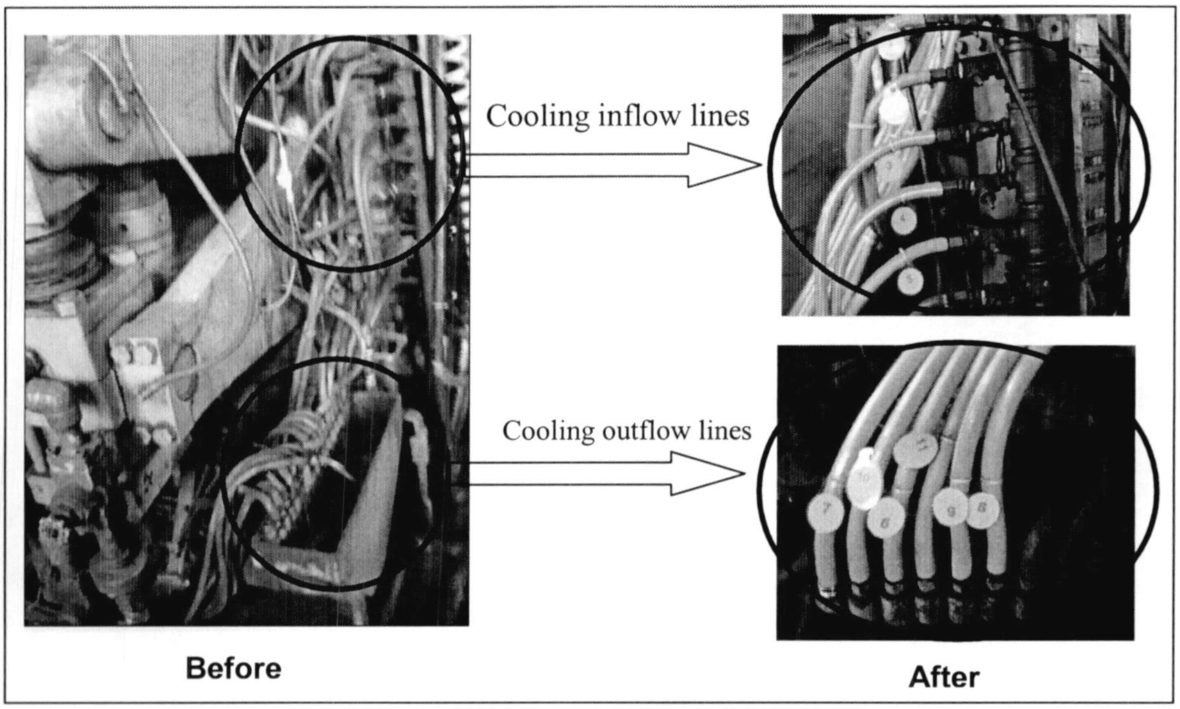


Figure 4.2 : Cause and Effect Analysis for Flash Butt Defects

It was noticed that the temperature of hydraulic oil of the machine, temperature of the welding electrodes and welding transformer getting higher while the machine is operated. When the temperature of transformer is more than 40 °C, the performance is going down and when the given secondary current less than the rating current it affects the flash. [7] When hydraulic temperature exceeds 55 °C it reduces the force related to the preset hydraulic pressure significantly and due to that, the clamping force and upsetting force of the flash butt machine get reduced than the expected values which affects the quality of welding.

The current conductivity through the flash butt electrodes is drastically reduced if electrode temperature is more than 45 °C which also affects the flash [7]. To remove temperature increasing effect of electrodes, all cooling lines are cleaned and scales and other clogged impurities are removed by using a high pressure air and active cleaning agents. A separate refrigerant cooler is used for transformer cooling lines to eliminate temperature rising effect of the transformer. Fig. 4.3 shows the cooling system improvements and fig 4.4 shows the temperature readings after the improvements.



Before

After

Figure 4.3 : Cooling System Improvements

Quality of the weld also depend on the upsetting process and clamping as explained under literature survey. There was no proper system to investigate the behavior of moving jaw while upsetting and clamping pressure behavior during upsetting. Earlier when there was a failure in the system there was no any method to identify the errors. A special monitoring system is installed to monitor performance of critical parameters including movement of the movable jaw and claming pressure.

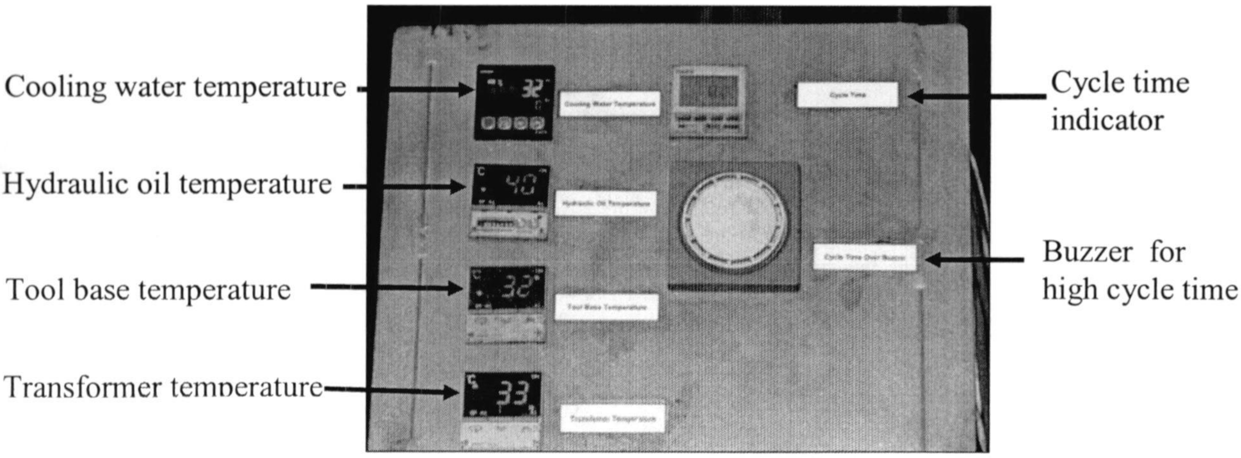


Figure 4.4 : Temperature Readings After Cooling System Improvements

With the installed system it was identified that the hydraulic pressure behavior of the movable jaw and clamping pressure behavior was not uniform. Maintenance team investigated the machine and identified that there was an internal leakage in the servo valve of the hydraulic system and some function errors in servo control card. The defective servo valve and the servo control card was replaced and rest of the moving parts of the machine was fully serviced including sliders of the moving jaw and replaced the bladders of hydraulic accumulators. After the whole overhauling the machine it was able to terminate the issues related with the movable jaw and clamping process. Fig. 4.5 shows the behavior of machine performance after all repairs mentioned.

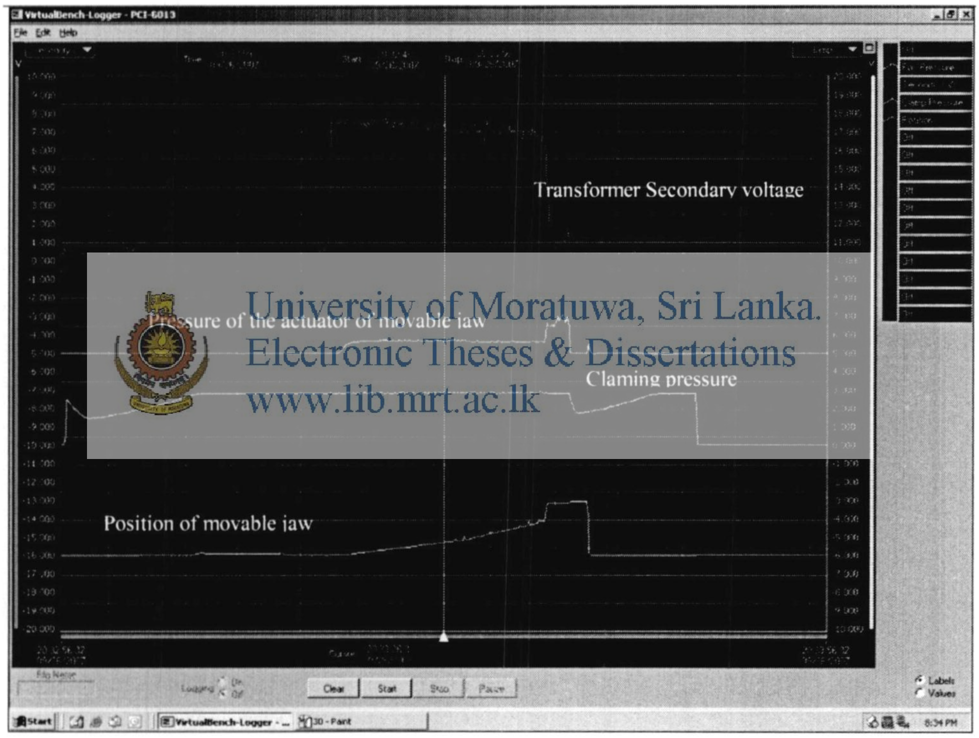


Figure 4.5 : Monitoring the Behavior of Machine Performance

The voltage at the secondary end of the transformer was 8 volts and when it measured at electrode end, it was 6 volts. This preliminary observation highlighted the 25% voltage drop in the electrode path and while dismantling the electrode path it was found that there were some spark eroded cavities in the mating surfaces of the tool path as shown fig 4.6. Components of the electrode path machined and removed all cavities at mating surfaces to assure 100% touching each other of tool parts to have higher conductivity. After the electrode repair the voltage drop at the electrode end was 0.5 volts and also revised the maintenance activity plan asking to clean the electrode path in every preventive maintenance.

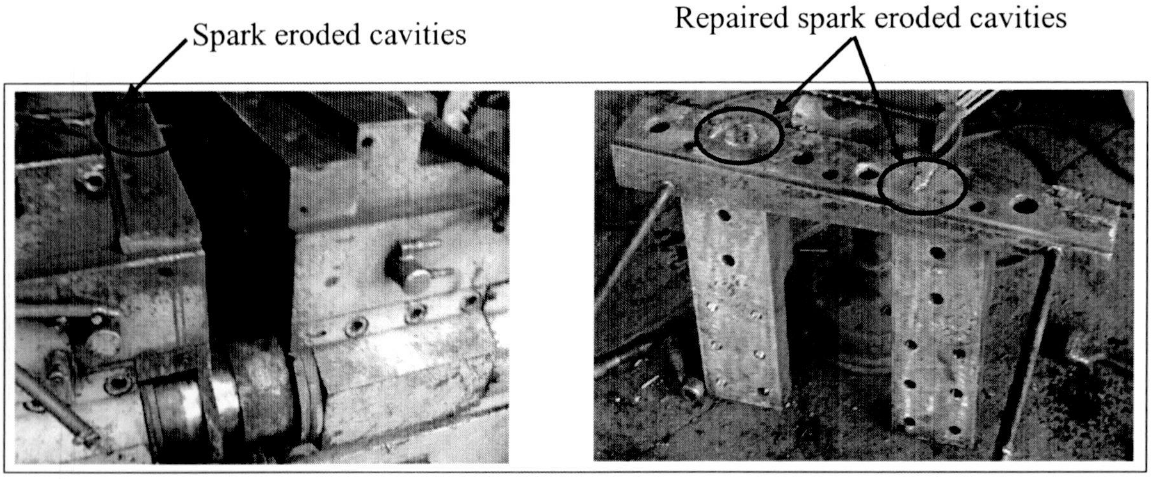
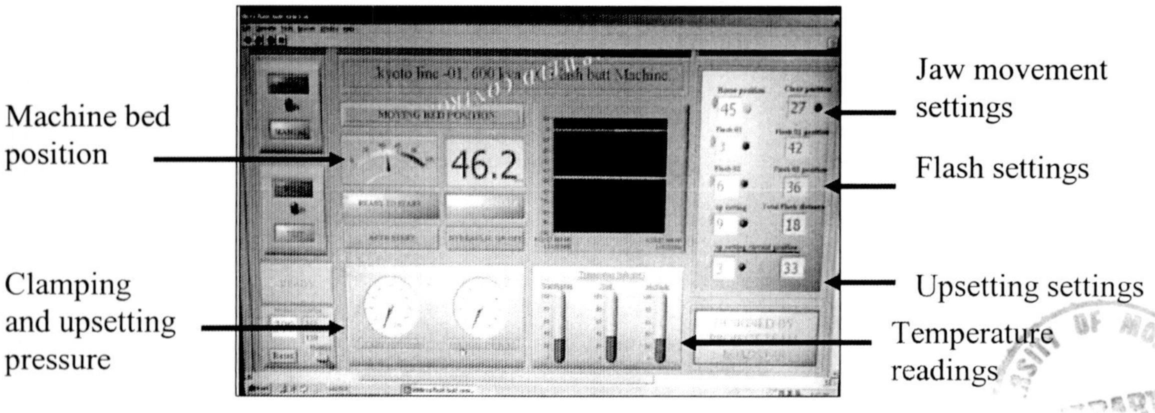


Figure 4.6 : Spark Eroded Cavities in Electrode Path

During the preliminary investigation it was noticed that a lot of defects occurred due to wrong machine settings. The skill level of the machine operators was improved to eliminate this issue. But the issue continued further and even high skill operators made mistakes during machine setting since it had to be set 13 parameters. To overcome this problem a mistake proof parameter setting system was introduced by maintenance engineers using linear encoders incorporated with lab view software. After introducing this system the operator has to just select the profile type and the critical parameters related to the selected profile type set by machine itself. Fig. 4.7 shows the computer screen of the Labview system and the different parameter settings.



Home position 45
Clear position 27
Flash 01 3
Flash 01 position 42
Flash 02 6
Flash 02 position 36
Up setting 9
Total Flash distance 18
Up setting current position 3 33

Figure 4.7 : Labview System for Parameter Setting

The third category related to defects is method related and basically it was identified two major levers. The first one is degree of profile clamping. To have a better welding it is necessary to have a good contact between flash butt welding electrodes and the profile. The electrodes dressed using CNC milling machine to match exactly with the profile shape and revised the standard operating procedure (SOP) instructing to check the profile clamping with paper pressing and should be assured more than 80% impression on the paper after clamping with the profile.

The rounding process of rolled profile is done manually and quality of rounding solely depend on machine operators. Also the roundness of the profiles might change from one to another. The profiles being heavy it won't deform severely and take the electrode curvature even under heavy clamping force and if it is not rounded correctly. Then, due to incorrect curvature there might be less contact with electrode even electrode being adjusted correctly at the beginning. Also insufficiently rounded profiles, which not carrying the electrode curvature are subjected to severe stress while clamping and even though got welded due to sufficient clamping will be cracked due to stress released while unclamping. So a perfect rounded profile which carry the electrode curvature is necessary to have a better weld.

The gauges have been introduced for each profile type to overcome the roundness problem and operators will check the roundness of the profile while setting of rounding machine and also check time to time during production.

Failure mode and effect analysis had been carried out in the whole process starting from rolling to expanding and identified all possible causes for the failures and solutions. The identified solutions included as actions or quality control gates and displayed those points in quality network focus point (QNFP). The prepared QNFP for rounding machine and flash butt machine is shown in annex II. Operator of each work station, petrol quality controller, supervisor, and final quality controller must check those points while performing their duties.

The final category of defects is related to profile materials. The company is not a large construction wheel manufacturer compared to Titan, the world largest, GKN or Topy wheels who also leading. So the company is a small customer for world profile manufactures and minimum order quantity exceeds annual production capacity. Also the price of the profiles is also very expensive. Profile materials required manufacturing are bought from China, India and Germany. A lot of chemical variations, physical property variations and inclusions can be seen with those materials specially from Chinese and Indian materials. There are significant chemical composition variation in same batch of the profiles.

This material related issue controlling is beyond out of the company reach and the company will have to find the solution with those available materials. The material issue is considered for the area for the research. Basically paid attention on the behavior of chemical composition and microstructure with different parameter settings for welding defects.

BG profile is considered for the research as it has the 2nd highest defects rate and it is and was able to get different types of materials as explained under 4.2

4.4 Welding conditions

The welding conditions to prepare the test material will be with different combinations of flashing voltage settings, upsetting rates, upset times and upsetting distances.

The testing and test piece preparations are done according to Specifications and Qualifications of welding procedures for metallic materials –Welding procedure test part 13: Resistance butt and flash welding [ISO 15614-13:2005(E)] [8]

Testing done with several advance velocity values which control the moving speed of the moving jaw of flash butt machine while keeping other setting parameters constant.

4.4.1 Shape and dimensions of test specimens

The specimens or the test pieces would be of sufficient number and/or size to allow all required tests to be carried out. They would correspond to the test procedure and the component to be welded. Additional test pieces/specimens, which are larger than the minimum allowed, manufactured for subsequent tests and for back-up tests. The type and number of tests are shown in Table 4.3. [8]

Table 4.3 : Testing and examination of the test specimens according to ISO 15614-13:2005(E) [8]

Test specimen	Test type	Extent of test	Footnote
Bars/rods	Visual examination	every weld	
	Penetrant test	every weld	
	Tensile test	3 specimens	a
	Bend test	6 specimens	a
	Macro section	1 weld	b, g
	Hardness test	1 meas. row	b, g

a When the used test pieces are large enough, more than one specimen can be taken from one weld joint.

b Not required for steels in group 1 in accordance with ISO/TR 15608:2000 under static loading except for low temperature applications.

g Measuring row in a macrosection transverse to the weld.

4.4.2 Test specimen for Appearance test piece

Burrs or swellings which were generated in the welding would not be removed form the surface of the test piece except those which were automatically removed during the welding

4.4.3 Test specimen for the tensile test

Burrs and swellings will be removed until they become flat with the surface of the tensile test piece. As the test piece is too large for the tensile test to be carried out, a tensile piece of appropriate dimensions will be cut out. The test specimen will be prepared in accordance with EN 10002-1, while also taking into account ISO 4136, [8]

4.4.4 Test specimen for the bend test

Burrs and swellings of the bending test piece will be removed until they become approximately flush with the surface of the bending test piece. As the test piece is too large for the bending test to be carried out, a bending piece of appropriate dimensions will be cut out. The test specimen will be prepared in accordance with ISO 5173. [8]

4.4.5 Test specimen for the hardness test

The section hardness test piece would be cut approximately along the center line in the axial direction of the test material and ground. The test specimen would be prepared in accordance with ISO 9015-1 and ISO 9015-2.

4.4.6 Test specimen for the macro section

A macro section transverse to the weld would be prepared and etched in order to show clearly the weld zone, the heat-affected zones and the unaffected parent material clearly.

Two materials of BG profile were selected for the testing as mention in the 4.2. But the Chinese material (Q235 B) was not considered since it had a lot of inclusions in the raw materials. All testings were done for only SS 400 material type.

4.5 Sample preparation.

Samples prepared across the welding as shown in figure 4.8 with consideration of the requirements discussed in 4.4.1 to 4.4.6. All test samples were prepared with band saw and surface grinder with excess coolant fluid.

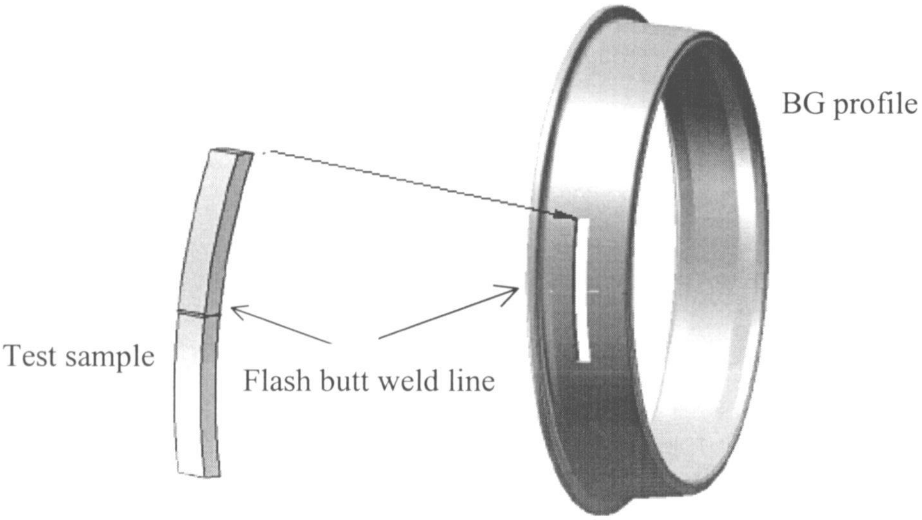


Figure. 4.8 : Test Sample Preparation

4.6 Testing and examination

As discussed in section 4.4 the testing was done for BG profiles manufactured using SS 400 with several advance velocity settings. The considered value range is listed in table 4.4. For each advance velocity settings, testing was continued while maintaining similar operating conditions like secondary voltage of the transformer, temperature of cooling water and hydraulic temperature were maintained at the same range throughout all testings.

Table 4.4 : Advance Velocity Settings Used for BG Profile

Advance Velocity (Rotary Indicator-Ω)		
VR1	VR2	VR3
185	195	225
190	200	230
195	205	235
200	210	240
205	215	245
215	225	255
220	230	260

The tool setting is done with good clamping and it is checked with a paper. The profile is clamped to the tool by placing a piece of paper in between tool and profile and the impression of the clamping marked on the paper is checked. The impression mark that has more than 80% of total clamping area is benched marked for rest of the tool settings in order to have similar clamping conditions through out the tests. The machine is run twice with out loading the profile (dry run condition) for every test level to have a smooth and conditioned operational level. The flash butt machine is kept idle for a little time period until it reaches to normal temperature settings shown in figure 4.4. in between the flash butt welding.

4.6.1 Extent of testing

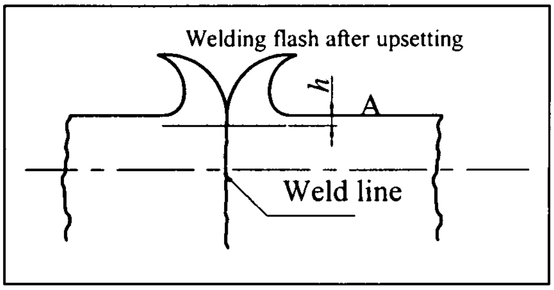
The testing includes both non-destructive and destructive testing. It also will correspond with the quality requirements of the component to be welded, as well as the requirements stated in Table 4.3. The size of the test specimens would include the zone which is liable to failure, even outside the heat affected zone (HAZ). [9]

4.6.2 Visual examination

Visual examination was carried out in accordance with ISO 17637. A magnifying glass was used to inspect the welds for visible imperfections, such as surface cracks. Metal expulsion and weld burr would also be taken into consideration if they had not been removed directly after the welding process. [9] All test samples closely inspected for visible imperfections through naked eye and with a magnifying glass. The excess materials at weld zone and other burrs at the weld removed carefully with a grinder in order to have uniform cross section across the weld. The weld samples that had cavities, surface cracks or any other imperfections were not considered for further analysis discussed in later paragraphs since it would mislead the test results. Also the metal flow of the weld was inspected and the samples that had insufficient welding depth that were discussed under section 4.5.3 were not considered for further analysis.

4.6.3 Macro section

In the macroscopic test, cracks blowholes or remaining non metallic foreign substances were examined. The condition of the metal flow and insufficient welding as indicated in figure 4.9 were examined. [9]



h : Insufficient welding depth

Figure 4.9 : measuring position insufficient welding from A

Also test specimen was prepared as a cross-section cut through the weld and it was then etched to show the weld, the heat-affected zone (HAZ) and the unaffected parent material. The test was carried out in accordance with ISO 17639.

4.6.4 Tensile test

Tensile testing was carried out in accordance with EN 10002-1.

4.6.5 Bend test

Bend testing was carried out in accordance with ISO 5173.

4.6.6 Microstructure Examination

Microstructure examination was done for each profile types for different advance velocity settings. For each advance velocity settings the samples for microstructure examination were selected as shown in Fig. 4.10.

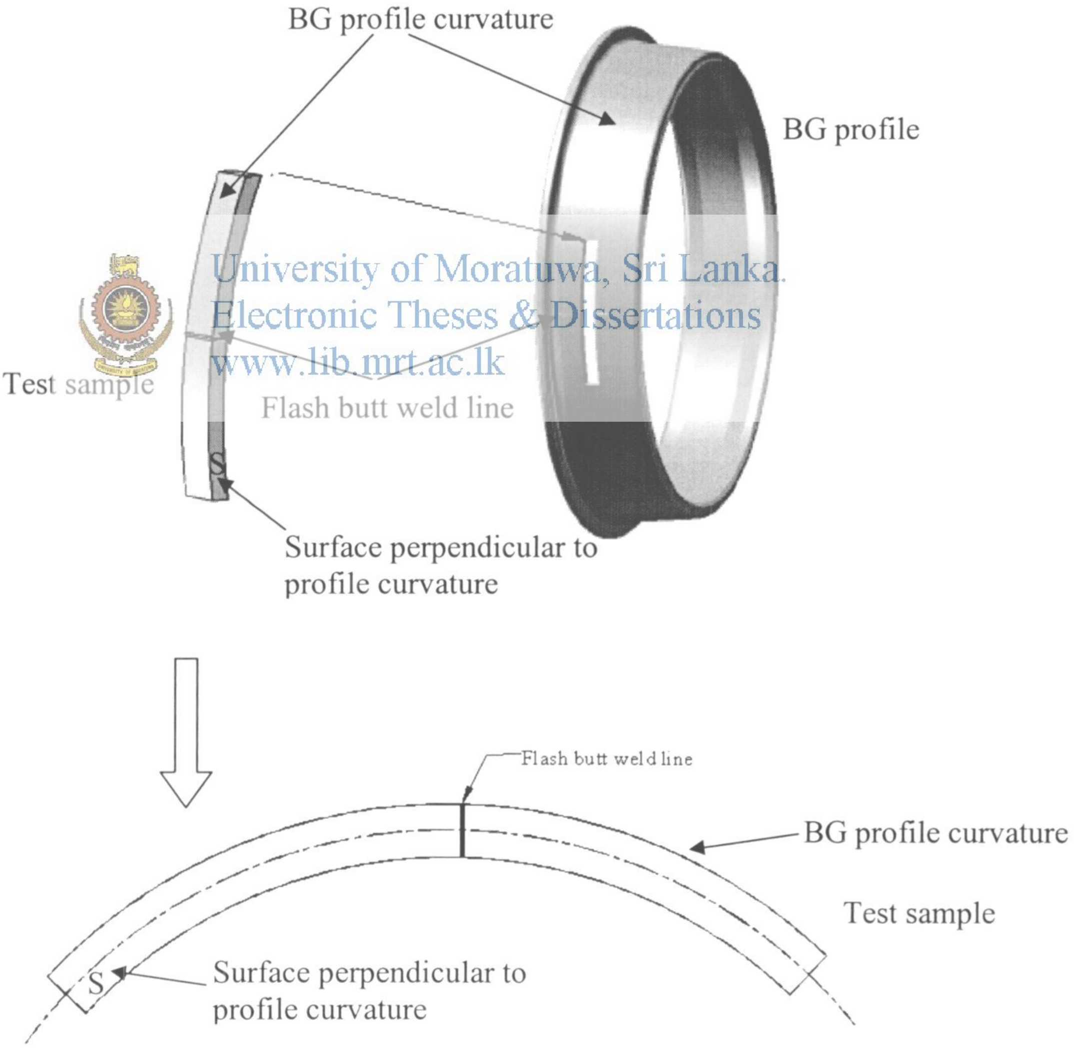


Figure 4.10 : Sample Selection For Microstructure Examination

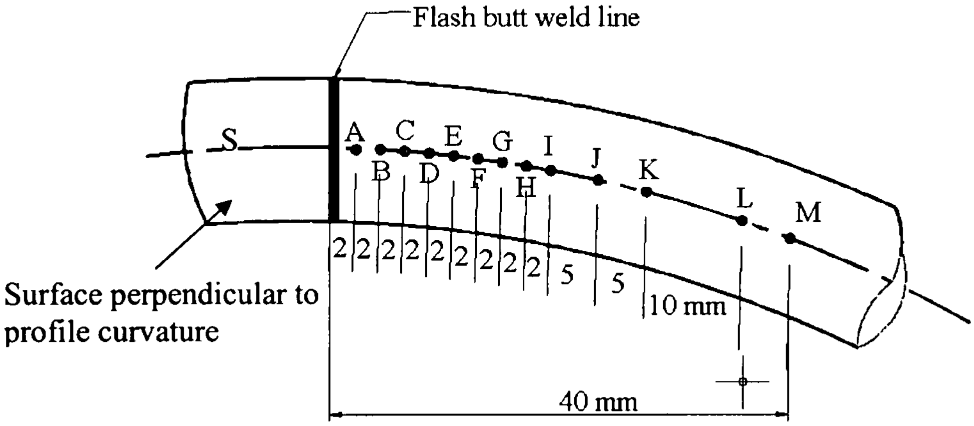


Figure 4.11 : Microstructure Examination Locations of Selected sample

One half of the sample starting from the weld line was considered to examine microstructures of the weld and adjacent zone. Thirteen points were considered to examine the microstructure as shown in figure 4.11. The first point ‘A’ was selected just 2 mm from the flash butt weld line. Another 8 points having 2 mm gap starting from ‘B’ to ‘I’ were selected and another four points were also selected as shown in figure 4.11 and the gap is indicated in the figure 4.11 is in millimeters. The length of the sample is 200 mm and all samples had to be cut into small pieces with the width of 45 mm since maximum length that could be inserted to the microscope is 45 mm . To make 45 mm width test pieces the sample cut across the weld and then the two halves were sized into 45 mm. So two test pieces of each and every sample were used to examine the microstructures. It was difficult to cut the samples across the weld exactly due to both reasons that the parting line is not clearly visible and parting is done manually using a hacksaw. After investigating the microstructures of two halves of same profile one series of microstructures of one piece is selected based on the distribution to over come above issue.

4.6.7 Hardness distribution

The surface of the cross-section to be tested was properly prepared and preferably etched, so that accurate measurements of the diagonal of the indentations can be obtained in different zones of the welded joint. The hardness can be determined in one or more traces. A trace consists of a row of hardness indentations, whereby all individual indentations are in a straight line. In the case of a circular cross-section, if only one trace has been defined in the design specification, the trace shall be arranged as a parallel at 0,6 times the radius to the centre axis. With a steel sheet section, the trace shall be of 0,6 times the sheet thickness and positioned parallel to the sheet surface as shown in Fig. 4.12. The hardness measurement is carried out in accordance with ISO 14271.

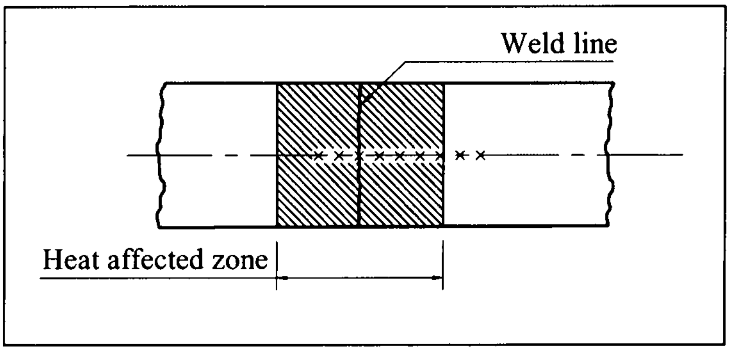


Figure 4.12 : Example of Measuring Position of Section Hardness

5.0 Results and Discussion

The main observation was when increasing the advance velocity, the flashing speed was increased and the weld cycle time was reduced drastically as shown in Fig. 5.1. The cycle times for each advance velocity settings were shown in Table 5.1. Also the arc generating speed was proportional to the advance velocity and it was increased with the advance velocity. The colour of the arc was light yellowish red when advance velocity is low (VR1 = 185) and during increasing the advance velocity the colour change from red heat range to white heat range. Since available infrared thermometer in the factory has capability to measure maximum 300 °C degree it was unable to measure exact arc temperature. Otherwise it would have been a very good measurement to interpret microstructure behavior discussed under section 5.4 Also the temperature distribution across the profile was measured and it was notice that the temperature at 200 mm from the weld fusion line after one minute is 55 °C for VR1 = 185 and 37 °C for VR1 = 220 while ambient temperature was 31 °C.

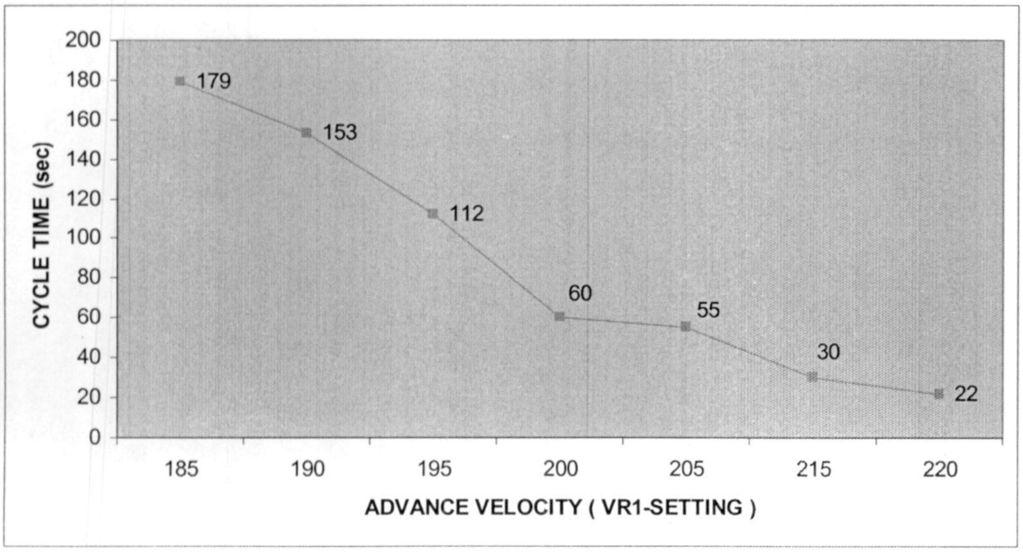


Figure 5.1 : Behavior of Weld Cycle Time Against Advanced Velocity

5.1 Tensile Test Results

Tensile test results against different velocity switching positions and other variable parameters are tabulated in Table 5.1. As explained in experimental procedure by increasing the advance velocity movement of the moving jaw of the flash butt machine increased. Since three Advance welding settings are increased by similar values during the testing, the graphs are plotted against one advance velocity. (eg. VR1) Fig. 5.2 shows the behavior of tensile strength, yield strength and elongation for different advance velocity settings. Sample tensile testing graphs for VR1 = 195 and VR1 = 200 are shown in annex III.

Table 5.1 : Behavior of Weld Strength Against Advance Velocity Settings

Advance Velocity (Rotary Indicator-Ω)			Ultimate Tensile strength N/mm^2	Yield Strength N/mm^2	Elongation (%)	Secondary Voltage (V)	Cycle time (s)
VR1	VR2	VR3					
185	195	225	416	279	30	8.5	179
190	200	230	438	254	31	8.5	153
195	205	235	449	334	31	8.4	112
200	210	240	453	309	34	8.6	60
205	215	245	478	253	37	8.5	55
215	225	255	510	368	38	8.3	30
220	230	260	486	324	35	8.5	22

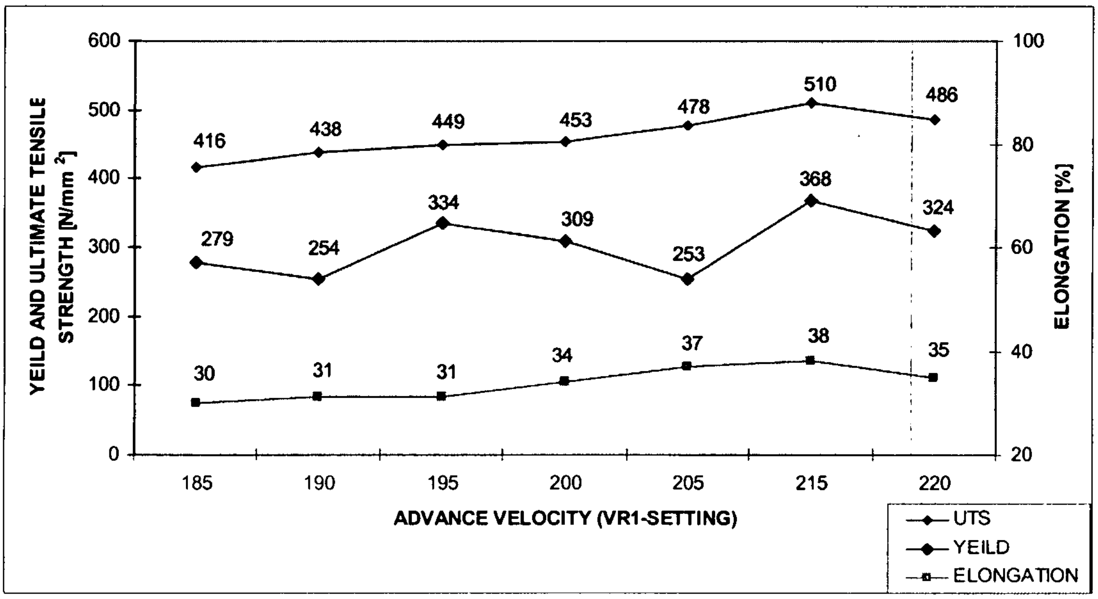


Figure 5.2 : Behavior of Weld Strength and Elongation Against Advanced Velocity

To carry out tensile testing it was unable to get the straight welded samples as explained under EN 10002-2 which is the ISO standard tensile test piece preparation method. The welding done with rolled profiles (as explained under section 1.6.1) and samples had a curvature of 600 in diameter. Therefore for the tensile samples prepared with curvature, an assumption was taken and that the length of the tensile samples (200 mm) compared to the curvature of the test piece it is almost straight. Also tensile samples were accepted since during the tensile testing, the first phase of stretching took place to straighten the curved profile which was common for all tested samples as the objective of tensile testing was to compare weld strength against the different advance velocities.

5.2 Results of Bending Test

Results of bending test against different advance velocity switching positions are tabulated in table 5.2

Table 5.2 : Behavior of bending strength against Advance Velocity settings

Advance velocity VR1	Bend stress N/mm^2	Bending Results
185	980	Cracked
190	1000	Cracked
195	1120	Cracked
195	1080	Cracked
200	1020	Bend
205	1140	Cracked
210	1012	Cracked
215	1180	Cracked
220	1120	Cracked

Bend testing was done as shown in Fig. 5.3 A for the first set of testing to achieve worst bending and it was difficult to keep the profile samples in the direction shown in the Figure 5.3 A. So later on all bending tests done as shown in figure 5.3 B. the bending results were not satisfactory and almost all test samples failed 180 bending test irrespective to the value of advance velocity. The main objective of the bending test in this experiment was to compare the weld strength of the test samples with different advance velocities. Therefore those bending results were not considered for the final conclusions as all most all test pieces failed.

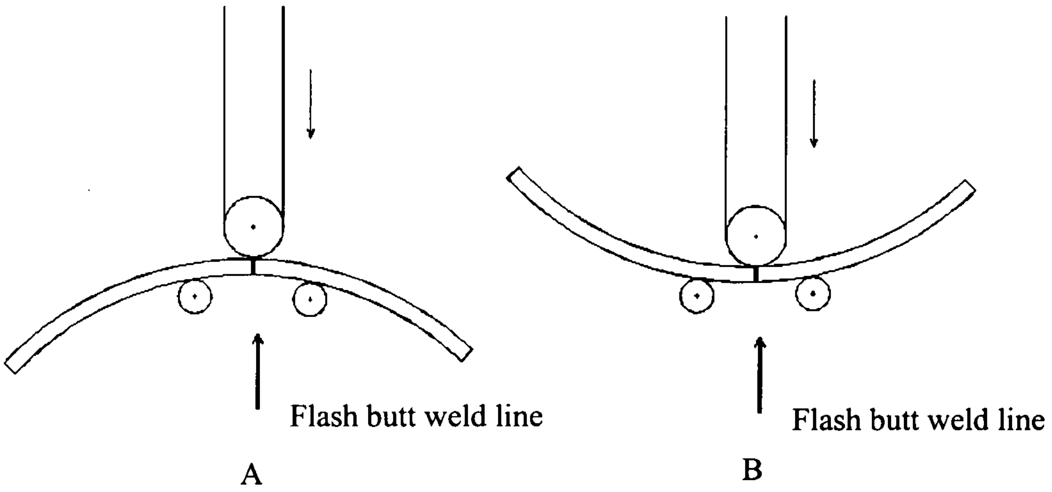


Figure 5.3 : Bend Testing

5.3 Microstructure Examination

Figure 5.4 shows the comparison of microstructures of different locations against the different advance velocity settings. The magnification of the microstructures are X 200.

Microstructures of different locations of two advance velocities which were VR1= 195 and VR1 = 215 shown in figure 5.5 are considered for further discussion. Microstructure of both velocities contains combine of Ferrite and pearlite structure. For the velocity 195 setting, microstructures at the point 2 mm away from weld line and the point 4 mm away from the weld line contains bainite structure and it was converted to fine microstructure at 8 mm away from the weld. So the weld line was relatively brittle for velocity 195 setting sample. The reason for this transformation was high amount of heat input to the material. The weld cycle time for VR1 195 setting was 112 sec. (Table 5.1) and huge amount of heat was transferred to profile material and after the upsetting process adjacent area of weld line which was at elevated temperature leads to create bainate structure. The failure occurs across the weld fusion line at low stress when it was subjected to a tensile load. (Table 5.1)

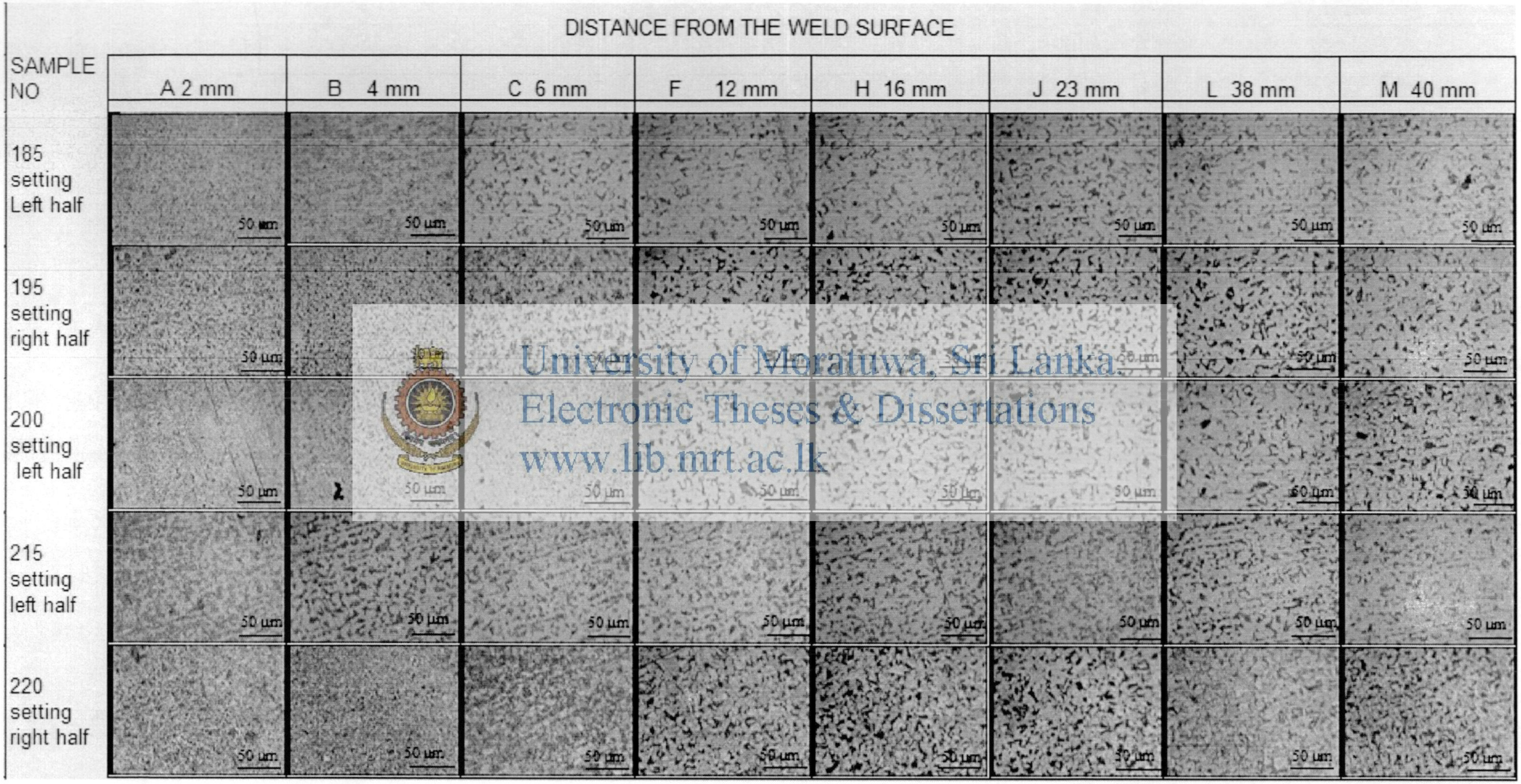
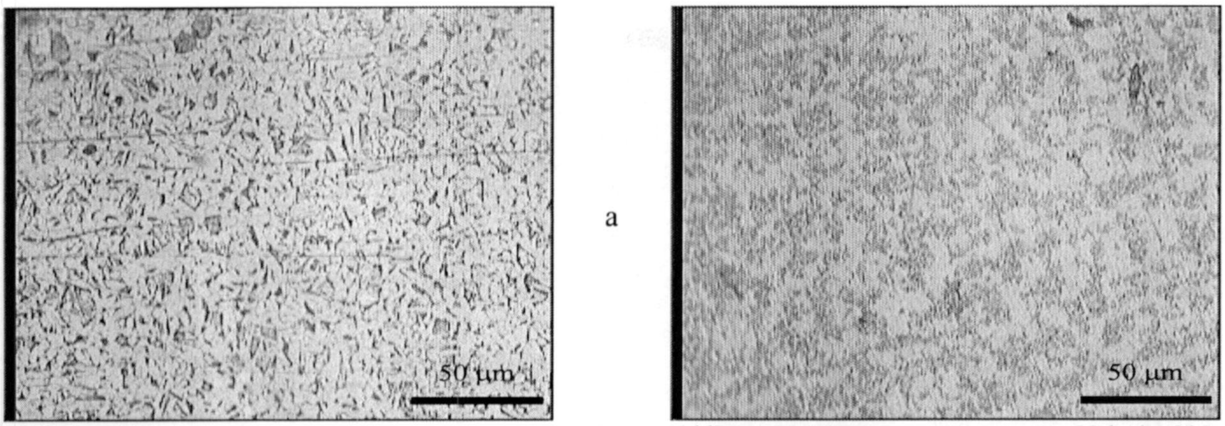
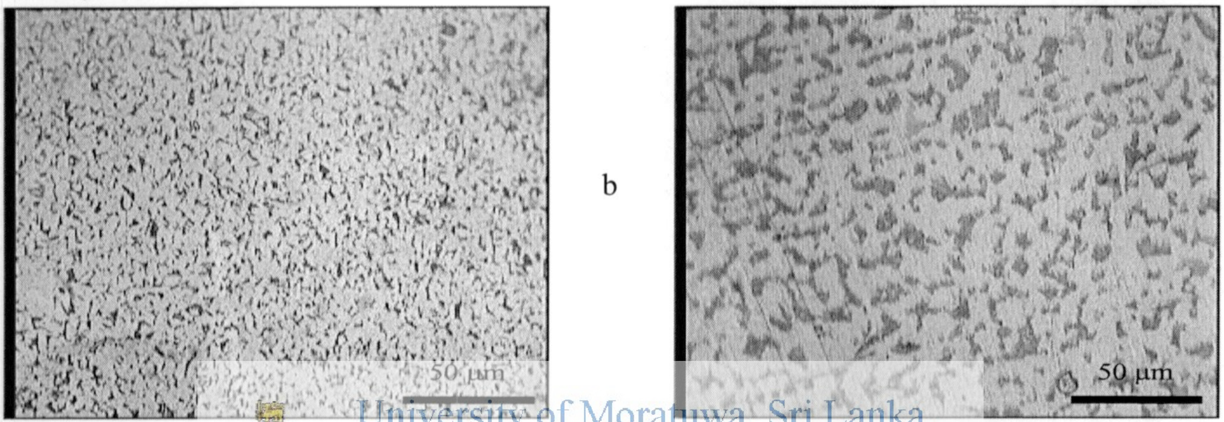


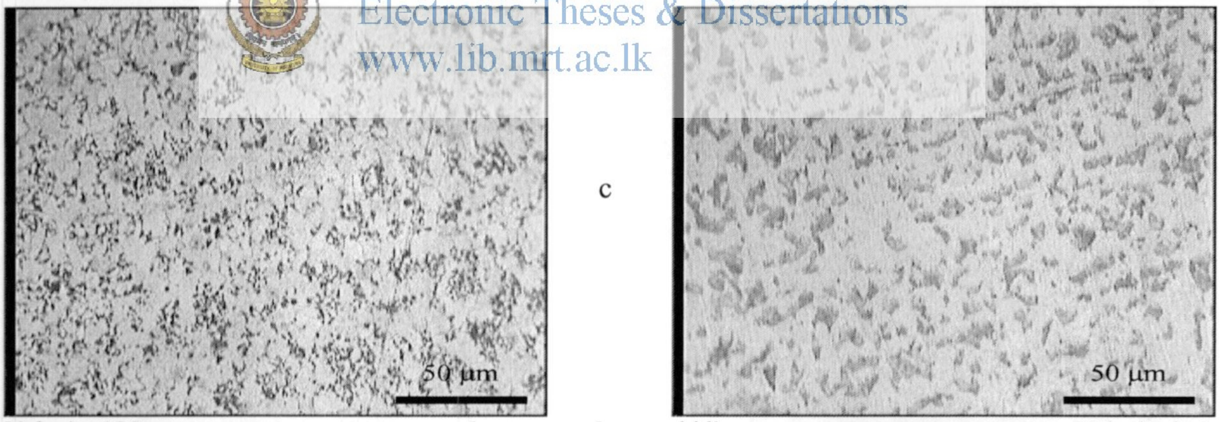
Fig 5.4 Microstructures at different location of the samples with different advance velocities



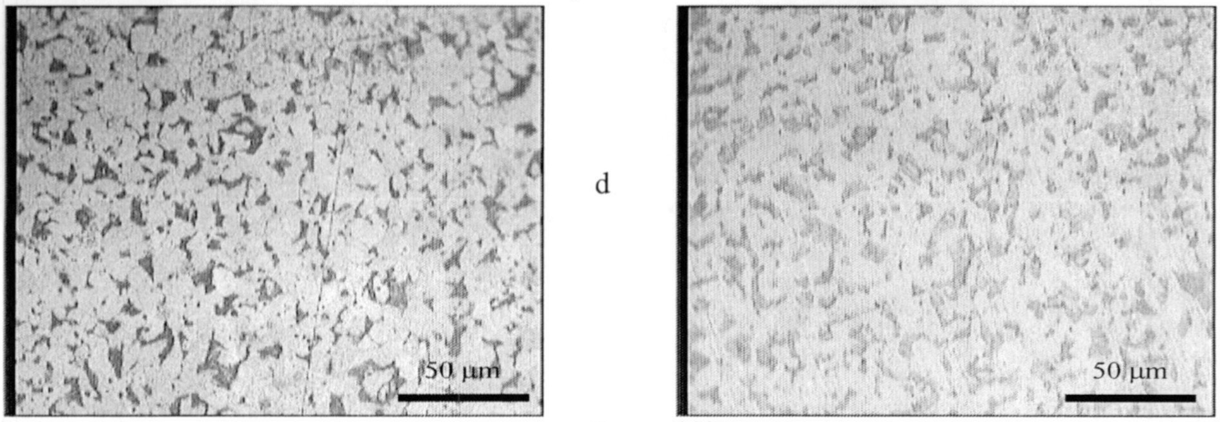
Velocity 195 2 mm away from weld line Velocity 215



Velocity 195 4 mm away from weld line Velocity 215



Velocity 195 6 mm away from weld line Velocity 215



Velocity 195 8 mm away from weld line Velocity 215

Fig 5.5 Microstructures of two advance velocities at different locations

`For the velocity 215 setting, microstructures at the point 2 mm away from weld line and the point 4 mm away from the weld line contain refined ferrite-perlite structure. Also it has higher perlite composition compared to the microstructures at points 6 mm & 8 mm away from the weld line and all microstructures contain refined structure. So the weld face is harder and due to refined structure it has more ability to bear loads than the velocity setting 195. The reason for this transformation is low amount of heat input to the material. The weld cycle time for VR1 215 setting is 30 sec. (Table 5.2) and huge amount of heat was given to upsetting region and there is little time to transfer the heat to the profile material since materials in upsetting region was expelled due to upsetting process.

Increasing advance velocity to improve weld quality has limitations. At one stage when the arc gap too was narrow the most of heated materials converted to flash due to high arc energy and removed from the material which makes it difficult to develop sufficient heat in the metal for proper upsetting. If the advance velocity continuously increased then at one stage the two ends get stuck and become red hot (freeze).

6.0 Conclusion

1. Although flash welding is a simple and efficient welding technique, it has limited applications because of the difficulties involved in ensuring the required weld quality. Increasing the advance velocity of the movable jaw of flash butt machine while keeping at the same voltage will give better results in weld joints.

2. The reduction of welding time contributes to the refinement of the weld microstructure.

3. Also weld cycle time reduction leads it to become more economical and efficient since the production can be increased with low weld cycle time

4. The joint of flash butt welding for SS 400 (low carbon steel) show good strength with optimum advance velocity of the movable jaw of flash butt machine.

5. To reduce scrap rate of profiles in line 05 discussed in chapter 3 it is necessary to redefine the machine parameters based on microstructures by achieving refined structure which has higher elongation.

6. The effect of advance velocity increment is applicable only for the flash butt machines that has constant current control feature. The flash butt machines that has constant displacement control machines will change its current with the displacement increment.

7. Optimizing the advance velocity is not the only way to achieve refined structure. Further testing need to be carried out with different upsetting length and with different voltages.

7.0 References

1. Larry, J : Welding principals and applications, fifth edition

2. http://www.taylorwinfield.com/ Resistance_Welding/FlashButt/flashbutt.html

3. http://www.welding - advisers.com / Flash-welding.html/solutions with effective, practical advice.

4. Nakada, Pro. S. : Flash butt welding phenomenon of steel, Paper presentation 10th September 1978 Osaka University.

5. Hudson, R. S. : ASME International, P 319 (1986)

6. Ichiyama, Y. Kodama, S. : Flash butt welding of high strength steels, Nippon steel technical report No. 95 January 2007

7. JIS Handbook, Welding, Japanese Standard Association (2001)

8. International Standard ISO 15614-13, Specifications and qualification of welding procedures for metallic materials-Welding procedure test; Part 13: Resistance butt and flash welding .

Appendices

Annex I

SAP production reports

Production Report May 2008 (1 of 2)

Date	Profile	JOB NO	Total	Daily Total Production	Scrap Total	SCRAP Percentage	Daily Total Scrap	Daily Total Scrap %	Defect Qty&Reason						Total	Re/W Percentage	Daily Rework %
									W/C	H/C	O/L	B/T	D/S	Other			
1-May-2008	BE-1	AA117	58	58	5	8.6	5	8.6		39	9				48	82.8	82.8
2-May-2008	BE-1	AA177	64	111	11	17.2	11	9.9	0	38	5				43	67.2	81.1
2-May-2008	AA	Z459	47		0	0.0				5	42				47	100.0	
3-May-2008	BG	AA177	162	162	0	0.0	0	0.0		5	30	1			36	22.2	22.2.
6-May-2008	BD	AA177	120	160	1	0.8	2	1.3		73	21				94	78.3	75.6
6-May-2008	BD	AA178	30		1	3.3				16	6				22	73.3	
6-May-2008	BD	AA174	10		0	0.0				3	2				5	50.0	
7-May-2008	BD	AA174	45	86	1	2.2	2	2.3		21	12				33	73.3	43.0
7-May-2008	VA 25	Z882	21		1	4.8					2				2	9.5	
7-May-2008	U 1.7	Z882	20		0	0.0				1		1			2	10.0	
8-May-2008	AT	Z810	16	107	0	0.0	0	0.0		1	2				3	18.8	21.5
8-May-2008	AT	Z977	30		0	0.0				0	3				3	10.0	
8-May-2008	BC-2	Z977	17		0	0.0				0	4				4	23.5	
8-May-2008	BC-2	Z810	16		0	0.0				0	1				1	6.3	
8-May-2008	AA	T2891	4		0	0.0				0	1				1	25.0	
8-May-2008	AA	AA180	20		0	0.0				1	8				9	45.0	
8-May-2008	AA	AA347	4		0	0.0				0	2				2	50.0	
9-May-2008	BA-1	AA186	30	90	2	6.7	17	18.9		1	9	2			12	40.0	47.8
9-May-2008	BA-1	Z422	12		2	16.7				0	7	0			7	58.3	
9-May-2008	BB	AA186	18		11	61.1				3	1	0			4	22.2	
9-May-2008	BB	AA168	30		2	6.7				11	7	2			20	66.7	
11-May-2008	KALMAR	600061379	103	103	6	5.8	6	5.8		16		3			19	18.4	18.4
12-May-2008	AA	AA183	20	183	0	0.0	0	0.0		1	8				9	45.0	34.4
12-May-2008	AA	Z900	40		0	0.0				1	21				22	55.0	
12-May-2008	AA		30		0	0.0				1	20				21	70.0	
12-May-2008	BG		93		0	0.0				0	11				11	11.8	
13-May-2008	BD	Z819	51	110	1	2.0	11	10.0		3	18				21	41.2	48.2
13-May-2008	BB	Z422	12		0	0.0				4	1				5	41.7	
13-May-2008	BB	AA123	21		1	4.8				13	0				13	61.9	
13-May-2008	BE-1	Z-900	26		9	34.6				14					14	53.8	
14-May-2008	AB-12	Z900	82	217	15	18.3	37	17.1		35					35	42.7	40.1
14-May-2008	BE-1	Z819	26		2	7.7				14	1				15	57.7	
14-May-2008	VA 25	AA181	21		1	4.8				4		0			4	19.0	
14-May-2008	AA	AA182	58		0	0.0				17		11			28	48.3	
14-May-2008	AF		30		19	63.3				5					5	16.7	
15-May-2008	AA	AA080	74	204	0	0.0	0	0.0		7	32	3			42	56.8	27.0
15-May-2008	VA 25	AA394	100		0	0.0				3	5	0			8	8.0	
15-May-2008	AE		30		0	0.0				3	2	0			5	16.7	
17-May-2008	KALMAR		180	180	0	0.0	0	0.0		5	0	7			12	6.7	6.7
18-May-2008	KALMAR		212	312	2	0.9	3	1.0		5	0	2			7	3.3	5.13
18-May-2008	U1.7	AA394	100		1	1.0				2	0	7			9	9.0	
19-May-2008	VA 25	AA394	97	97	0	0.0	0	0.0		0	0	0			0	0.0	0
20-May-2008	U1.7		33	112	0	0.0	0	0.0		4	0	0			4	12.1	17.0
20-May-2008	AE1.7		79		0	0.0				14	1	0			15	19.0	
21-May-2008	U1.7		67	122	2	3.0	2	1.6		2	0	4			6	9.0	14.8
21-May-2008	BG		55		0	0.0				5	4	3			12	21.8	

Production Report May 2008 (2 of 2)

Date	Profile	JOB NO	Total	Daily Total	Scrap Total	SCRAP Percentage	Daily Total	Daily Total	Defect Qty&Reason						Total	Re/w Percentage	Daily Rework
									W/C	H/C	O/L	B/T	D/S	Other			
22-May-2008	KALMAR		150	150	5	3.3	5	3.3		4	0	0			4	2.7	2.7
24-May-2008	KALMAR		20	219	0	0.0	0	0.0		0	0				0	0.0	8.7
24-May-2008	AA		54		0	0.0				10	3			3	16	29.6	
24-May-2008	VA 25		130		0	0.0				1	1	0			2	1.5	
24-May-2008	AE1.7	AA394	15		0	0.0				1	0	0			1	6.7	
25-May-2008	AE1.7	AA394	55	275	1	1.8	6	2.2		1	0	2			3	5.5	3.3
25-May-2008	AE1.7	AA395	80		0	0.0				1	0	1			2	2.5	
25-May-2008	U1.7	AA395	90		4	4.4				0	1	0			1	1.1	
25-May-2008	U1.7	AA394	50		1	2.0				0	2	1			3	6.0	
27-May-2008	AA		19	100	0	0.0	0	0.0		2	1	1			4	21.1	32.0
27-May-2008	AB-7		30		0	0.0				2	3	2			7	23.3	
27-May-2008	KALMAR		21		0	0.0				0	2	4			6	28.6	
27-May-2008	AB-3		30		0	0.0				13	2				15	50.0	
29-May-2008	BD		24	141	1	4.2	2	1.4		6	2	0			8	33.3	24.1
29-May-2008	BG		15		0	0.0				2	0	0			2	13.3	
29-May-2008	AE1.7		102		1	1.0				21	0	3			24	23.5	
30-May-2008	U1.5	AA979	10	185	2	20.0	4	2.2			3				3	30.0	36.8
30-May-2008	U1.5	AA959	20		1	5.0					2				2	10.0	
30-May-2008	U1.5	AA942	2		0	0.0									0	0.0	
30-May-2008	U1.5	AA978	10		0	0.0					1			1	2	20.0	
30-May-2008	U1.3	AA606	12		0	0.0				2	1				3	25.0	
30-May-2008	U1.7	AA733	68		1	1.5				9	9			5	23	33.8	
30-May-2008	VA	AA606	20		0	0.0				7					7	35.0	
30-May-2008	VA	AA733	43		0	0.0				26				2	28	65.1	
31-May-2008	BE-1	AA356	26	219	2	7.7	29			20				2	22	84.6	68.0
31-May-2008	U-24	AA732	16		0	0.0			4						4	25.0	
31-May-2008	BE-1	AA961	12		4	33.3				9					9	75.0	
31-May-2008	BE-1	AA548	25		5	20.0				18					18	72.0	
31-May-2008	BE-1	AA960	25		5	20.0				14					14	56.0	
31-May-2008	BE-1	AA742	27		2	7.4				24					24	88.9	
31-May-2008	BE-1	AA547	21		0	0.0				16					16	76.2	
31-May-2008	BE-1	AA693	67		11	16.4				38	3			1	42	62.7	
TOTAL			**3703**		**142**		**142**		**4**	**##**	**334**	**60**	**0**	**14**	**###**	**28.5**	

Production Report June 2008 (1 of 3)

Date	Profile	JOB NO	Total	Daily Total Production	Scrap Total	SCRAP Percentage	Daily Total Scrap	Daily Total Scrap %	Defect Qty&Reason						Total	Re/W Percentage	Daliy Total	Daily Rework %
									W/C	H/C	O/L	B/T	D/S	Other				
01-Jun-08	BE-1	AA747	17		0	0.0				5	1				6	35.3		
01-Jun-08	BG-1	AA548	86		1	1.2				18					18	20.9		
01-Jun-08	BD-1	AA693	86		1	1.2				47	4				51	59.3		
01-Jun-08	BD-1	AA548	30		0	0.0				16	4				20	66.7		
01-Jun-08	BG-1	AA677	23		0	0.0				8				1	9	39.1		
01-Jun-08	BD-1	AA948	60	302	1	1.7	3	1.0		35	9				44	73.3	148	49.0
04-Jun-08	BG	AA607	37		0	0.0				10				1	11	29.7		
04-Jun-08	BG	AA961	30		0	0.0				2					2	6.7		
04-Jun-08	BG	AA995	30		0	0.0				7					7	23.3		
04-Jun-08	BG	AA739	30		0	0.0				6				1	7	23.3		
04-Jun-08	BG	AA547	30		0	0.0				5					5	16.7		
04-Jun-08	BD	T2916	10	167	0	0.0	0	0.0		4	5				9	90.0	41	24.6
05-Jun-08	BE-1	AA742	30		1	3.3				16	4				20	66.7		
05-Jun-08	BE-1		48		4	8.3				31	3				34	70.8		
05-Jun-08	BE-1	AA547	20		3	15.0				9	3				12	60.0		
05-Jun-08	BD	AA995	54		0	0.0				13	25				38	70.4		
05-Jun-08	BD	AA547	17		0	0.0				7	2				9	52.9		
05-Jun-08	KALMAR	6E+07	212	381	9	4.2	17	4.5		9				21	30	14.2	143	37.5
06-Jun-08	BE-1	AA607	58		14	24.1				24	15				39	67.2		
06-Jun-08	AB-12	AA836	36		11	30.6				6	16			1	23	63.9		
06-Jun-08	BE-1	AA836	37		1	2.7				21	5				26	70.3		
06-Jun-08	AA	AA834	30	161	0	0.0	26	###		2					2	6.7	90	55.9
07-Jun-08	AA		20		0	0.0									0	0.0		
07-Jun-08	AA	AA835	24		0	0.0				4	4			2	10	41.7		
07-Jun-08	AA	AA740	17		0	0.0				3	2			4	9	52.9		
07-Jun-08	BD	AA742	25		0	0.0				13	2				15	60.0		
07-Jun-08	BD	AA608	90	176	1	1.1	1	0.6		18	27			2	47	52.2	81	46.0
10-Jun-08	BC-2	AA589	13		1	7.7				2				10	12	92.3		
10-Jun-08	BB	AA839	38		7	18.4				18		2			20	52.6		
10-Jun-08	BB	AA841	60		7	11.7				33					33	55.0		
10-Jun-08	BB	AA842	77		6	7.8				31	3				34	44.2		
10-Jun-08	BA-1	AA842	30		0	0.0				1	13				14	46.7		
10-Jun-08	BA-1	AA840	18		0	0.0					3				3	16.7		
10-Jun-08	BA-1	AA841	54	290	1	1.9	22	7.6		4	13				17	31.5	133	45.9
11-Jun-08	BG	AA844	52		0	0.0				5	38			1	44	84.6		
11-Jun-08	BB	AA842	14		0	0.0				6				1	7	50.0		
11-Jun-08	BG	AA608	50		0	0.0				17	14				31	62.0		
11-Jun-08	BG	AA396	10		0	0.0					5				5	50.0		
11-Jun-08	BG	AB043	14		1	7.1					3			1	4	28.6		
11-Jun-08	AA	AA998	30		0	0.0				6	10			3	19	63.3		
11-Jun-08	AA	AA781	10		0	0.0				9					9	90.0		
11-Jun-08	AA	AA838	8		0	0.0				4	1			1	6	75.0		
11-Jun-08	AA	AA845	40	228	0	0.0	1	0.4		7	24				31	77.5	156	68.4

Production Report June 2008 (2 of 3)

Date	Profile	JOB NO	Total	Daily Total Production	Scrap Total	SCRAP Percentage	Daily Total Scrap	Daily Total Scrap %	Defect Qty&Reason						Total	Re/W Percentage	Daily Total	Daily Rework %
									W/C	H/C	O/L	B/T	D/S	Other				
12-Jun-08	AA	AA846	30		0	0.0				1	18			6	25	83.3		
12-Jun-08	BE-1	AA608	32		1	3.1				18	1				19	59.4		
12-Jun-08	BE-1	AA043	12		0	0.0				8		1			9	75.0		
12-Jun-08	BE-1	AA844	48		0	0.0				33					33	68.8		
12-Jun-08	AB-24	AA835	25		1	4.0				18					18	72.0		
12-Jun-08	BE-1	AA396	10		0	0.0				7					7	70.0		
12-Jun-08	BE-1	T2427	12		1	8.3				11					11	91.7		
12-Jun-08	KALMAF	6E+08	71		0	0.0				2					2	2.8		
12-Jun-08	KALMAF	6E+08	191	431	12	6.3	15	3.5		5					5	2.6	129	29.9
13-Jun-08	KALMAF	6E+08	175		10	5.7			7	17		8			32	18.3		
13-Jun-08	AB-3	AA080	6		0	0.0				1	4				5	83.3		
13-Jun-08	AB-3	AA817	3		0	0.0				1	1				2	66.7		
13-Jun-08	AB-3	AA781	10		0	0.0				3	1				4	40.0		
13-Jun-08	AA	AA837	28		0	0.0					20				20	71.4		
13-Jun-08	AA	AA843	50		0	0.0				2	26			3	31	62.0		
13-Jun-08	BD-1	AA844	52		2	3.8				16	8				24	46.2		
13-Jun-08	BD-1	AB43	8		0	0.0					4				4	50.0		
13-Jun-08	AJ	T2907	3	335	0	0.0	12	3.6							0	0.0	122	36.4
16-Jun-08	AF	AA181	18		3	16.7				3	1				4	22.2		
16-Jun-08	AB-3	AB011	67		7	10.4				31					31	46.3		
16-Jun-08	AB-3	AA817	88	173	12	13.6	22	###		34					34	38.6	69	39.9
17-Jun-08	BG	AA730	24		0	0.0				3					3	12.5		
17-Jun-08	BG	AB043	37		0	0.0						2			2	5.4		
17-Jun-08	BE-1	AA693	34		11	32.4				19		2			21	61.8		
17-Jun-08	BD-29	AA730	6		0	0.0					2	1			3	50.0		
17-Jun-08	BD-1	AA844	30	131	0	0.0	11	8.4		2	10	2		1	15	50.0	44	33.6
18-Jun-08	AA	AA836	30		0	0.0					10	3			13	43.3		
18-Jun-08	AA	AB011	24		0	0.0					5	1			6	25.0		
18-Jun-08	KALMAF	6E+08	145		0	0.0				8	5			19	32	22.1		
18-Jun-08	KALMAF	6E+08	166	365	0	0.0	0	0.0		4	4	24			32	19.3	83	22.7
19-Jun-08	AB-12	AB646	20		0	0.0				12	5				17	85.0		
19-Jun-08	AE-1.7	AA395	7		0	0.0									0	0.0		
19-Jun-08	BE-1	AB011	20		1	5.0				8	8				16	80.0		
19-Jun-08	AA	AB011	39		0	0.0					18				18	46.2		
19-Jun-08	AA	AA817	49	135	0	0.0	1	0.7			28				28	57.1	79	58.5
22-Jun-08	BE-1	AB565	20		1	5.0				11	1				12	60.0		
22-Jun-08	BE-1	AB437	8		0	0.0				4					4	50.0		
22-Jun-08	BE-1	AB432	7		0	0.0				6					6	85.7		
22-Jun-08	AJ	AA730	19		0	0.0				3		5		2	10	52.6		
22-Jun-08	BB	AA841	6		0	0.0					6				6	###		
22-Jun-08	VA	AB193	15		0	0.0				2					2	13.3		
22-Jun-08	VA	AB192	40		0	0.0				4					4	10.0		
22-Jun-08	VA	AB642	20		0	0.0									0	0.0		
22-Jun-08	BE-1	AB441	111	246	9	8.1	10	4.1		81					81	73.0	125	50.8

Production Report June 2008

(3 of 3)

Date	Profile	JOB NO	Total	Daily Total Production	Scrap Total	SCRAP Percentage	Daily Total Scrap	Daily Total Scrap %	Defect Qty&Reason						Total	Re/W Percentage	Daliy Total	Daily Rework %
									W/C	H/C	O/L	B/T	D/S	Other				
23-Jun-08	AE-1.5	AB192	40		0	0.0				12	2				14	35.0		
23-Jun-08	AE-1.5	AB439	8		0	0.0				3					3	37.5		
23-Jun-08	AE-1.3	AB193	23		0	0.0				6				3	9	39.1		
23-Jun-08	AE-1.7	AB642	20		0	0.0				2	1				3	15.0		
23-Jun-08	VA-24	AA606	11		0	0.0									0	0.0		
23-Jun-08	VA-25	AB642	23		0	0.0				2					2	8.7		
23-Jun-08	VA-25	AB193	33	158	1	3.0	1	0.6		2	4				6	18.2	37	23.4
24-Jun-08	AE-24	AB643	30		1	3.3				5		2			7	23.3		
24-Jun-08	AE-1.3	AB434	20		0	0.0				3	2				5	25.0		
24-Jun-08	AE-1.3	AB193	40		0	0.0				10	9				19	47.5		
24-Jun-08	U-1.7	AB642	20		1	5.0				1		1			2	10.0		
24-Jun-08	U-24	AB643	32		2	6.3				8	3				11	34.4		
24-Jun-08	U-1.5	AB049	22		2	9.1					1				1	4.5		
24-Jun-08	U-1.5	AB192	43		3	7.0									0	0.0		
24-Jun-08	U-12	AB439	9		1	11.1						1			1	11.1		
24-Jun-08	U-1.3	AB434	5		0	0.0									0	0.0		
24-Jun-08	U-1.3	AB193	41	262	1	2.4	11	4.2		1					1	2.4	47	17.9
25-Jun-08	BG		38		0	0.0					3	16			19	50.0		
25-Jun-08	BG	AB565	20		0	0.0					1	1			2	10.0		
25-Jun-08	BG	AB437	8		0	0.0			1			4			5	62.5		
25-Jun-08	BD-25	AB437	8		0	0.0					1	1			2	25.0		
25-Jun-08	BD-25	AB565	22	96	1	4.5	1	1.0		4	4	1			9	40.9	37	38.5
28-Jun-08	BG	AB441	70		0	0.0				14	12			5	31	44.3		
28-Jun-08	BG	AB441	109	179	0	0.0	0	0.0		16	15			11	42	38.5	73	40.8
29-Jun-08	AA	AB441	60		0	0.0					16	1		12	29	48.3		
29-Jun-08	BG	AA441	49		0	0.0				25	9				34	69.4		
29-Jun-08	KALMAF	6E+08	176	285	3	1.7	3	1.1		1	3			12	16	9.1	79	27.7
30-Jun-08	BD	AB441	89		3	3.4				4	67				71	79.8		
30-Jun-08	KALMAF	6E+08	126		3	2.4			7						7	5.6		
30-Jun-08	BD	AB441	15		0	0.0			10	1	1				12	80.0		
30-Jun-08	AA	AB449	20		0	0.0			14						14	70.0		
30-Jun-08	AA	AA817	40	290	0	0.0	6	2.1	21						21	52.5	125	43.1
TOTAL			**4791**	**4791**	**163**		163		**60**	**##**	**##**	**79**	**0**	**##**	**###**	**38.4**		

Production Report July 2008 (1 of 3)

Date	Profile	JOB NO	Total	Daily Total Production	Scrap Total	SCRAP Percentage	Daily Total Scrap	Daily Total Scrap %	Defect Qty&Reason						Total	Re/W Percentage	Daily Tota	Daily Rework %
									W/C	H/C	O/L	B/T	D/S	Other				
01-Jul-08	BE-1		99		5	5.1				56	4	1		1	62	62.6		
01-Jul-08	BG	AB282	68		1	1.5				4	21	1		5	31	45.6		
01-Jul-08	BG	AB441	28		2	7.1					2	2			4	14.3		
01-Jul-08	BG	AB435	10	205	0	0.0	8	3.9		1		1			2	20.0	99	48.3
04-Jul-08	BD	AB282	17		1	5.9				1		1		6	8	47.1		
04-Jul-08	AF	AB606	32		21	65.6				7					7	21.9		
04-Jul-08	BG	AB282	49		0	0.0				20				9	29	59.2		
04-Jul-08	BE-1	AB436	12		0	0.0				10					10	83.3		
04-Jul-08	BE-1	AB648	20		0	0.0				16					16	80.0		
04-Jul-08	BD	AB282	17		0	0.0				10	3				13	76.5		
04-Jul-08	BD	AB441	67		1	1.5				31	4				35	52.2		
04-Jul-08	BD	AB195	51	265	1	2.0	24	9.1		23	11				34	66.7	152	57.4
05-Jul-08	BE-1	AB433	80		2	2.5				45				12	57	71.3		
05-Jul-08	BE-1	AB646	12		0	0.0				7					7	58.3		
05-Jul-08	BE-1	AB195	18		0	0.0				11					11	61.1		
05-Jul-08	BE-1	AB433	60		1	1.7				16		1			17	28.3		
05-Jul-08	BE-1	AB283	23		0	0.0				19		1			20	87.0		
05-Jul-08	BG	AB433	22		1	4.5				5		1			6	27.3		
05-Jul-08	BG	AB195	50		0	0.0				15					15	30.0		
05-Jul-08	BG	AB648	23		1	4.3				3		1			4	17.4		
05-Jul-08	BG	600067768	25	313	0	0.0	5	1.6		11	1	1			13	52.0	150	47.9
06-Jul-08	AA	AB189	58		0	0.0				1	12			1	14	24.1		
06-Jul-08	VA	AA181	5		0	0.0				1	2				3	60.0		
06-Jul-08	BE-1	AAB433	38		1	2.6				23					23	60.5		
06-Jul-08	BE-1	AB343	24		1	4.2				13	5	1			19	79.2		
06-Jul-08	BD	AB436	13		1	7.7				6	2				8	61.5		
06-Jul-08	BD	AB433	83	221	3	3.6	6	2.7		26	18				44	53.0	111	50.2
07-Jul-08	BE-1	AB433	51		1	2.0				19				4	23	45.1		
07-Jul-08	BE-1	AB440	60		2	3.3				31		5		4	40	66.7		
07-Jul-08	BE-1	AB443	17		5	29.4				11					11	64.7		
07-Jul-08	BE-1	AB563	17		1	5.9			10	5					15	88.2		
07-Jul-08	AB	AA817	12		3	25.0				5		2			7	58.3		
07-Jul-08	BG	AB438	18		1	5.6				4	1				5	27.8		
07-Jul-08	BG	AB443	25		1	4.0				8		2			10	40.0		
07-Jul-08	BG	AB563	12		0	0.0				4					4	33.3		
07-Jul-08	BG	AB433	53	265	2	3.8	16	6.0		13		5			18	34.0	133	50.2
10-Jul-08	BD	AB443	24		0	0.0				13	2				15	62.5		
10-Jul-08	BD	AB438	23		0	0.0				8	2				10	43.5		
10-Jul-08	BD	AB433	76		0	0.0				21	1				22	28.9		
10-Jul-08	BD	AB563	3		0	0.0				2					2	66.7		
10-Jul-08	BG	AB563	19		1	5.3				3					3	15.8		
10-Jul-08	AA	AB646	30		0	0.0				8				5	13	43.3		
10-Jul-08	AA	AB189	30		0	0.0					12			2	14	46.7		
10-Jul-08	AA	AB628	6		1	16.7					2				2	33.3		
10-Jul-08	BG	AB440	53	264	1	1.9	3	1.1		9	6			8	23	43.4	104	39.4

Production Report July 2008 (2 of 3)

Date	Profile	JOB NO	Total	Daily Total Production	Scrap Total	SCRAP Percentage	Daily Total Scrap	Daily Total Scrap %	Defect Qty&Reason						Total	Re/W Percentage		
									W/C	H/C	O/L	B/T	D/S	Other			Daily Total	Daily Rework %
11-Jul-08	BD		60		0	0.0				25	1	1			27	45.0		
11-Jul-08	BC-2	AB614	7		3	42.9					1				1	14.3		
11-Jul-08	BG	AB440	69		1	1.4				11					11	15.9		
11-Jul-08	AT	AB614	20		0	0.0				1	8				9	45.0		
11-Jul-08	Kalmar	610008538	7	163	0	0.0	4	2.5							0	0.0	48	29.4
12-Jul-08	BE-1		20	20	3	15.0	3	15.0		13	2				15	75.0	15	75.0
13-Jul-08	AA	AB450	100	100	0	0.0	1	1.0		5	51	8			64	64.0	64	64.0
16-Jul-08	Kalmar	610008538	30		1	3.3				1		9		1	11	36.7		
16-Jul-08	BE-1	610008562	49		2	4.1				28				1	29	59.2		
16-Jul-08	Kalmar	610008538	170	249	3	1.8	6	2.4		2	1	36		1	40	23.5	80	32.1
17-Jul-08	VA	AB943	10		0	0.0				1					1	10.0		
17-Jul-08	VA	AB823	20		0	0.0				14					14	70.0		
17-Jul-08	VA	AB715	51		1	2.0				19					19	37.3		
17-Jul-08	AE	AB943	10		0	0.0				3					3	30.0		
17-Jul-08	AE	AB823	20		0	0.0				14					14	70.0		
17-Jul-08	AE	AB715	24	135	0	0.0	1	0.7		5					5	20.8	56	41.5
18-Jul-08	AE	AB715	25		0	0.0				3		2			5	20.0		
18-Jul-08	VA	AB939	20		0	0.0				4					4	20.0		
18-Jul-08	U	AB715	51		1	2.0						2		2	4	7.8		
18-Jul-08	U	AB813	10		0	0.0					3				3	30.0		
18-Jul-08	U	AB943	12		2	16.7						1		1	2	16.7		
18-Jul-08	U	AB823	20		1	5.0				1					1	5.0		
18-Jul-08	VA	AB939	81		0	0.0			2	21					23	28.4		
18-Jul-08	AE	AB939	109		1	0.9				17					17	15.6		
18-Jul-08	U	AB939	40	368	1	2.5	6	1.6			1				1	2.5	60	16.3
19-Jul-08	U	AB939	65		4	6.2				6	1	2		3	12	18.5		
19-Jul-08	VA	AB939	100		0	0.0					7			1	8	8.0		
19-Jul-08	U	AB9390	41		1	2.4				5	7				12	29.3		
19-Jul-08	AE	AB939	150	356	0	0.0	5	1.4		13	6			9	28	18.7	60	16.9
20-Jul-08	U	AB939	58		0	0.0			1	4	7	7			19	32.8		
20-Jul-08	U	AB732	15	73	0	0.0	0	0.0		2	6				8	53.3	27	37.0
22-Jul-08	VA	AB939	70		0	0.0				8	1				9	12.9		
22-Jul-08	VA		54		1	1.9				3	1				4	7.4		
22-Jul-08	AE	AB939	69	193	1	1.4	2	1.0		2		24			26	37.7	39	20.2
23-Jul-08	AE	AC050	23		0	0.0				2	2			5	9	39.1		
23-Jul-08	AE	Y744/R	2		0	0.0									0	0.0		
23-Jul-08	BE-1	AB770	19		4	21.1				11					11	57.9		
23-Jul-08	AB	AB826	9		0	0.0									0	0.0		
23-Jul-08	AB	AB096	10		0	0.0									0	0.0		
23-Jul-08	AB	AB028	4		0	0.0				1					1	25.0		
23-Jul-08	AB	Z133	10		0	0.0									0	0.0		
23-Jul-08	AB	AB097	49		2	4.1				36					36	73.5		
23-Jul-08	BE-1	AB775	37		1	2.7				13		4		1	18	48.6		
23-Jul-08	BE-1	AB614	10		0	0.0				4					4	40.0		
23-Jul-08	BE-1	AB770	5		0	0.0				4					4	80.0		
23-Jul-08	BE-1	AB716	20		0	0.0				7	1	3		2	13	65.0		
23-Jul-08	BE-1	AB615	15		1	6.7				3	1				4	26.7		
23-Jul-08	BE-1	AC108	4		0	0.0				4					4			
23-Jul-08	BE-1	AB824	12	229	0	0.0	8	3.5		8					8	66.7	112	48.9

Production Report July 2008 (3 of 3)

Date	Profile	JOB NO	Total	Daily Total Production	Scrap Total	SCRAP Percentage	Daily Total Scrap	Daily Total Scrap %	Defect Qty&Reason						Total	Re/W Percentage		
									W/C	H/C	O/L	B/T	D/S	Other			Daily Total	Daily Rework %
24-Jul-08	BD	B648(AB28	13		0	0.0				2	3				5	38.5		
24-Jul-08	BD	AB775	36		0	0.0				3	16				19	52.8		
24-Jul-08	U	AC050	6		0	0.0									0	0.0		
24-Jul-08	BD	AB775	10		0	0.0				6	1				7	70.0		
24-Jul-08	BD	AB744	40		0	0.0				10	13			5	28	70.0		
24-Jul-08	BD	AB770	20		0	0.0				9	4				13	65.0		
24-Jul-08	BD	AB716	20		0	0.0				6	8				14	70.0		
24-Jul-08	BD	AB715	9		0	0.0				6	2				8	88.9		
24-Jul-08	BC-2	AB824	14		0	0.0				6	2				8	57.1		
24-Jul-08	AT	AB824	11	179	1	9.1	1	0.6		4				2	6	54.5	108	60.3
25-Jul-08	BA	AB925	17		0	0.0				4	4			2	10	58.8		
25-Jul-08	AA	AC097	22		0	0.0					6	3			9	40.9		
25-Jul-08	AA	AC096	12		0	0.0					4				4	33.3		
25-Jul-08	AT	AB814	21		0	0.0				1	6				7	33.3		
25-Jul-08	AA	AC099	4		0	0.0				1					1	25.0		
25-Jul-08	AA	AC097	50		0	0.0				11		5		3	19	38.0		
25-Jul-08	AA	AC111	30		0	0.0				2	2				4	13.3		
25-Jul-08	AA	AC112	30		0	0.0				5					5	16.7		
25-Jul-08	AA	AC100	9		0	0.0					1				1	11.1		
25-Jul-08	AA	AC103	18	213	0	0.0	0	0.0		4		2			6	33.3	66	31.0
30-Jul-08	AB	AC099	4		0	0.0				3	1				4			
30-Jul-08	AB	AC100	9		0	0.0				4	2				6	66.7		
30-Jul-08	AB	AC103	21		2	9.5				7	4				11	52.4		
30-Jul-08	AB	AC112	31		3	9.7				14	6				20	64.5		
30-Jul-08	AB	Z133/R	8		0	0.0				4	3				7	87.5		
30-Jul-08	AA	Z133	10		0	0.0					3				3	30.0		
30-Jul-08	AA	B030(T149/	6		0	0.0					2				2	33.3		
30-Jul-08	AA	B031(T153/	1		0	0.0									0	0.0		
30-Jul-08	AA	B028(S752/	4	94	0	0.0	5	5.3		1	1	1			3	75.0	56	59.6
TOTAL			[illegible]	[illegible]			104		13				0	96	[illegible]	[illegible]	[illegible]	[illegible]

Annex II

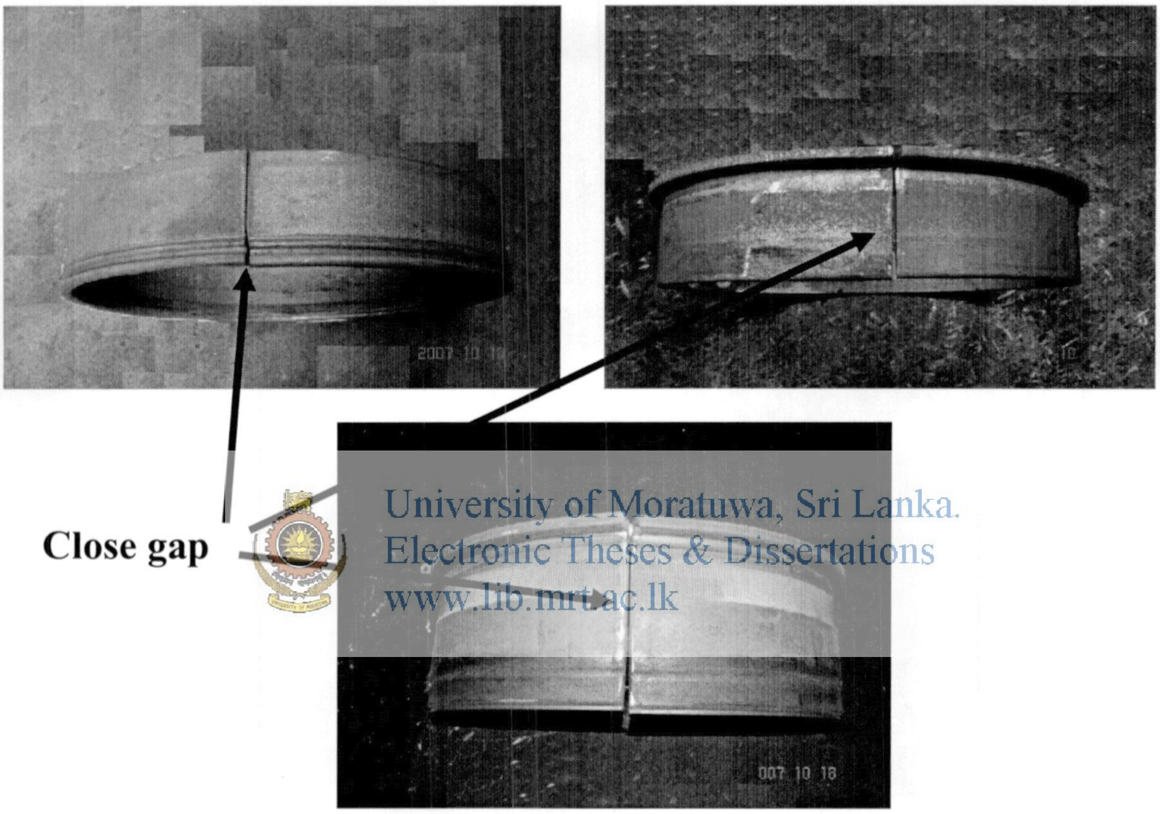
Quality Network Focus Points

	2	QUALITY ASSURANCE NETWORK FOCUS POINT	ISSUE NO: 01

1	**2**	3	4	5	6	7	8	9	10	11	12	13	14	15

ක්‍රියාවලිය	ROUNDING
ක්‍රියාකාරකම්	PROFILE එක ROUNDING කිරිම
පරික්ෂා කල යුතු තත්ත්ව පරාමිතින්	**CLOSE GAP, END CURVATURE**

Photo -ඡායාරූපය	ස්ථානය



උපරිම (Close gap) 10 mm විය යුතු අතර දෙකෙලවර එකිනෙක නොගැටි තිබිය යුතුය දෙකෙලවර එකිනෙක හොදින් Align වී තිබිය යුතුය

2 - ROUNDING

N-TRIAL - 11-01 ADJUSTMENT TABLE

3	**QUALITY ASSURANCE NETWORK FOCUS POINT**	ISSUE NO: 01

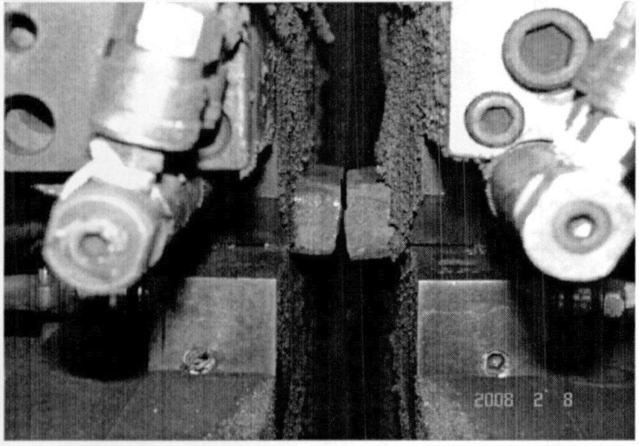
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

ක්‍රියාවලිය	FLASH BUTT WELDING
ක්‍රියාකාරකම්	Profile එක WELDING කිරීම
පරික්ෂා කල යුතු තත්ත්ව පරාමිතින්	**PARAMETER SETTING , VISUAL**

Photo -ඡායාරූපය

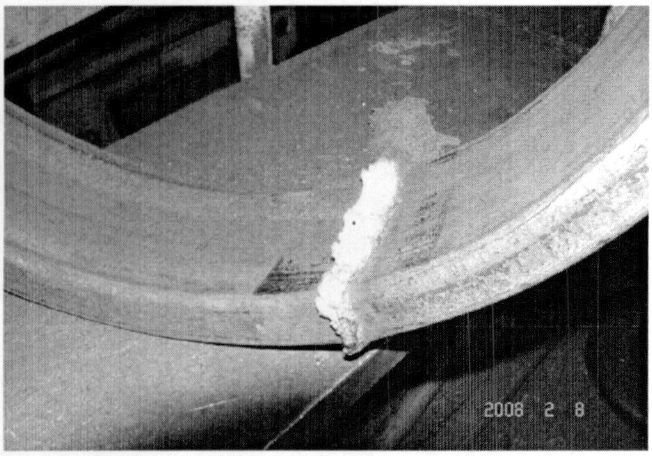
ස්ථානය

3 - FLASH BUTT WELDING



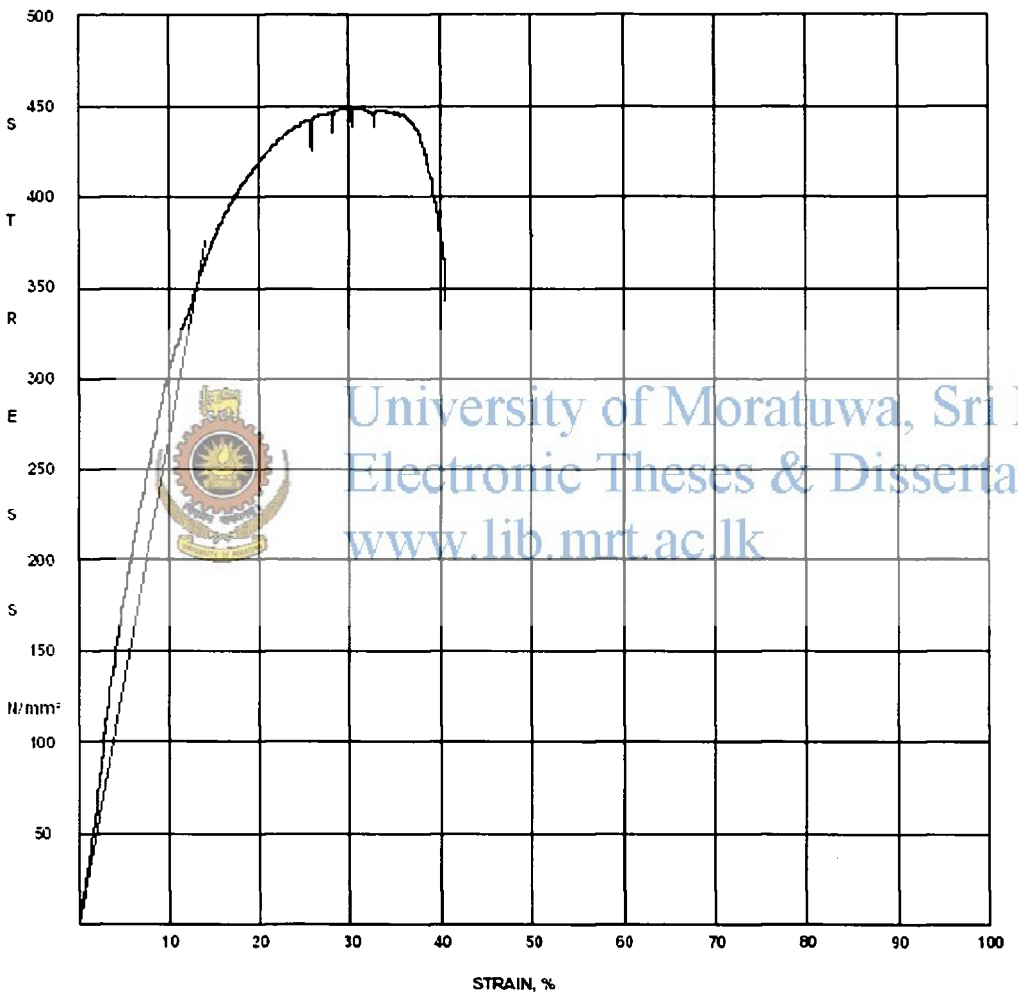
ජොබ් එක පටන් ගැනීමේ දී
Clamping Pressure පරීක්ෂා කල යුතුය

Profile එකෙහි දෙකෙළවර එකිනෙක
නොගැටි තිබිය යුතු අතර ළංවීම 10
mm ක් පමන ගැප් එකක් තිබිය
යුතුය



Annex III

Sample Tensile Test Graphs

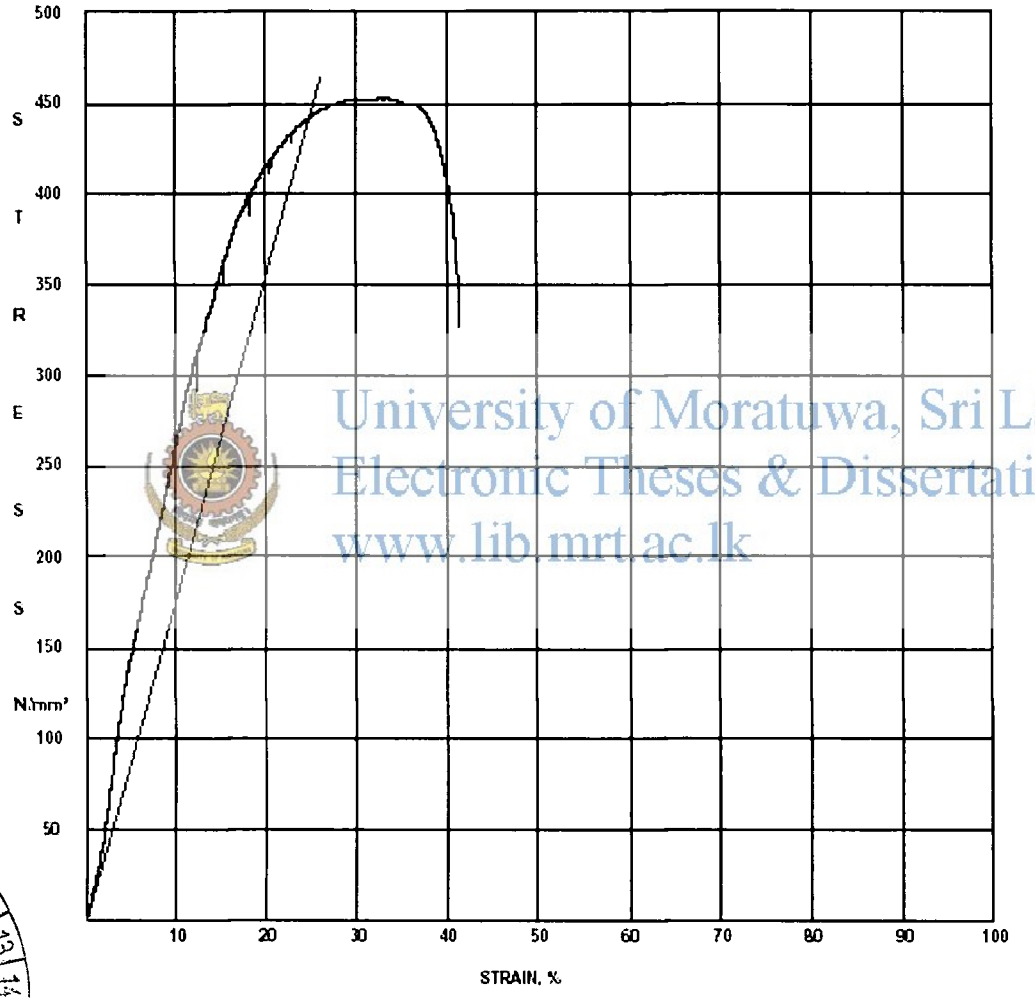


Loadstar (Private) Limited
No 4, Hunupitiva Road
Colombo 2
Sri Lanka

Tensile Test for Metals

Product Name	20081218TS21
Product Code	BG PROFILE
Batch Details	I-1.3
Test Date	12/18/2008
Operator	INDIKA
Remarks	PR ROLLING MILLS
Ultimate, N/mm^2:	449
Yield, N/mm^2:	334
OS @ .2, N/mm^2:	351
TE, %:	40.6
Elongation, %:	30.7
Yield, %:	12
Area, mm^2:	135.8
Initial Gage, mm:	100
Final Gage, mm:	140.6
Test Speed:	20
Specimen:	Flat

Dec 18, 2008 2:41:56 PM
SN: 211024-R0 V7.02.02



Loadstar (Private) Limited
No 4, Hunupitiva Road
Colombo 2
Sri Lanka

Tensile Test for Metals

Product Name	20081218TS24
Product Code	BG PROFILE
Batch Details	I-3.2
Test Date	12/18/2008
Operator	INDIKA
Remarks	PR ROLLING MILLS
Ultimate, N/mm²:	453
Yield, N/mm²:	309
OS @ .2, N/mm²:	439
TE, %:	41.5
Elongation, %:	33.5
Yield, %:	12.21
Area, mm²:	127.8
Initial Gage, mm:	100
Final Gage, mm:	141.5
Test Speed:	20
Specimen:	Flat

Dec 18, 2008 3:28:51 PM
SN 211024-R0 V7.02.02