KAUNAS UNIVERSITY OF TECHNOLOGY

Faculty of Mechanical Engineering and Design
School of economics and business

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Investigation of welding process of structural aluminium alloys

Bachelor Thesis

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KAUNAS, 2015

KAUNO TECHNOLOGIJOS UNIVERSITETAS

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Investigation of welding process of structural aluminium alloys

Bachelor Thesis

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Export engineering (code 612H77003)

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KAUNAS, 2015

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(Title and code of study programme)

Investigation of welding process of structural aluminium alloys

DECLARATION OF ACADEMIC HONESTY

2015 May 20
Kaunas

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Bernotaitis, E. Investigation of welding process of structural aluminium alloys**.** Title of qualification degree final project / supervisor Assoc. Dr. Prof. Saulius Baskutis; Kaunas University of Technology Faculty of Mechanical Engineering and Design, Department of Produktion engineering

Kaunas, 2015.

SUMMARY

The aim of final Bachelor's project is to conduct a welding process analysis for aluminium alloys. The main goals of said analysis are to investigate the tensile strength, micro hardness and acquire the understanding about types of welding and welding itself. The seams made for analysis of this project were welded using inert gas. In order to achieve the aim of the project, welding processes and methods were discussed, yield strength and quality of the seam were analyzed and reasons of the seam defects were found. Two tests were made: tensile and micro-hardness. Five specimens were used for tensile test, four of which were welded. Edges of welded specimens were made according to the standards. The results obtained in tensile test were compared to the material and welding wire standards. Results of the welded specimens were approved and a microstructure analysis was made. The hardness of the seam was visually compared to the base surface; also mechanical properties of different types of welding were examined. Results of the tests were analyzed and conclusions were represented.

Bernotaitis, E. Konstrukcinio aliuminio lydinių suvirinimo proceso tyrimas. Bakalauro baigiamojo projekto / vadovas Assoc. Prof. Dr. Saulius Baskutis; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas fakultetas, Gamybos inžinerijos katedra.

Kaunas, 2015.

SANTRAUKA

Bakalauro baigiamojo darbo tema yra: Konstrukcinio aliuminio lydinių suvirinimo proceso tyrimas. Tyrimo tikslas atlikti ardomąjį bei mikrokietumo tyrimą ir suprasti, kas tai yra suvirinimas, kokie būdai yra naudojami. Siūlė virinama metalo inertinių dujų suvirinimo būdu. Darbo tikslas yra : naudojami virinimo procesai ir metodai ir jų aprašymai, bandymo keliu patikrinti siūlės stiprumą bei kokybę, pateikti siūlių defektus ir jų priežastis. Darbe aptariami rezultatai, testų atlikimo metodika bei pateikiamos išvados. Buvo atlikti du bandymai: skersinio tempimo ir mikrostruktūros bandymas. Skersinio tempimo bandymui buvo panaudoti penki bandiniai, keturi iš jų buvo suvirinti. Išanalizuoti tyrimo rezultatai ir pateiktos išvados. Bandynių suvirinimo briaunos buvo padarytos pagal standartą. Gauti tempimo bandymo rezultatai buvo palyginti su medžiagos bei vielos standartiniais duomenimis. Suvirinimo bandymo rezultatams patvirtinti buvo atlikti mikrostruktūros tyrimai. Buvo vizualiai tikrinamas siūlės kietumas lyginant su baziniu paviršiumi, taip pat metalo mechaninės savybės virinant įvairiais rėžimais.

KAUNAS, 2015

KAUNO TECHNOLOGIJOS UNIVERSITETAS
MECHANIKOS INŽINERIJOS IR DIZAINO FAKULTETAS

Tvirtinu:
Gamybos inžinerijos katedros vedėjas

(parašas, data)

Kazimieras Juzėnas
(vardas, pavardė)

BAKALAURO STUDIJŲ BAIGIAMOJO DARBO UŽDUOTIS
Studijų programa: Ekcsporto inžinerija

Bakalauro studijų, kurias baigus įgyjamas magistro kvalifikacinis laipsnis, baigiamasis darbas yra mokslinio tiriamojo ar taikomojo pobūdžio darbas (projektas), kuriam atlikti ir apginti skiriama 12 kreditų. Šiuo darbu magistrantas bakalauras turi parodyti, kad yra pagilinęs ir papildęs pagrindinėse studijose įgytas žinias, įgijęs pakankamai gebėjimų formuluoti ir spręsti aktualią problemą, turėdamas ribotą ir (arba) prieštaringą informaciją, savarankiškai atlikti mokslinius ar taikomuosius tyrimus ir tinkamai interpretuoti duomenis. Baigiamuoju darbu bei jo gynimu bakalauras turi parodyti savo kūrybingumą, gebėjimą taikyti fundamentines mokslo žinias, socialinės bei komercinės aplinkos, teisės aktų ir finansinių galimybių išmanymą, informacijos šaltinių paieškos ir kvalifikuotos jų analizės įgūdžius, skaičiuojamųjų metodų ir specializuotos programinės įrangos bei bendrosios paskirties informacinių technologijų naudojimo įgūdžius, taisyklingos kalbos vartosenos įgūdžius, gebėjimą tinkamai formuluoti išvadas.

1. Darbo tema

Konstrukcinių aliuminio lydinių suvirinimo proceso tyrimas.
Investigation of welding process of structural aluminium alloys.

Patvirtinta dekano 2015 m. gegužės mėn.11 d. įsakymu Nr. ST 17-F-11-1_

2. Darbo tikslas

Bakalauro baigiamojo darbo tikslas – Ištirti sandūrinių virinimo siųlių bandynius, atliekant ardomajį tyrimą ir tiriamąjį nustatant paveiktų paviršių mikrokietumą

3. Darbo struktūra

Darbas susideda iš įvado, suvirinimo procesų apžvalgos, eksperimentinių nustatymų ir procedūrų, virinamų bandinių paruošimo suvirinimui apžvalgos , suvirinimo proceso, ruošinių paruošimo bandymams pagal standartą, skersinio tempimo bandymų, medžiagos mikrokietumo bandymų, rezultatų palyginimų bei išvadų.

4. Reikalavimai ir sąlygos

Suvirinimo siūlių kokybė turi atitikti reikalavimus nurodytus LR standartuose. Medžiagos turi atitikti LST EN standartų reikalavimus.
Kalendorinis grafikas: analizės skyrius – iki 04.20; projektinis skyrius – iki 05.03; Prietaiso konkurencingumo užtikrinimo priemonių nustatymas – iki 05.13; darbo apiforminimas – iki 06.04.

5. Darbo pateikimo terminas 2015 m. gegužės mėn. 19 d.

6. Ši užduotis yra neatskiriama baigiamojo darbo dalis

Išduota studentui: UA-1 gr. studentui Edvinui Bernotaičiui

Užduotį gavau ______________________ ______________
(studento vardas, pavardė) (parašas, data)

Vadovas ______________________ ______________
(pareigos, vardas, pavardė) (parašas, data)

Noriu padėkoti savo baigiamojo darbo vadovui Assoc. Prof. Sauliui Baskučiui už visapusišką pagalbą rašant baigiamąjį bakalaurinį darbą bei paramą viso kūrybinio proceso metu.

Taip pat dėkoju inž. Aloyzui Tvaskui, kuris geranoriškai pagelbėjo atlikti ardomąjį tyrimą bei aptarti rezultatus ir Dr. Edmundui Pupeliui už visapusišką pagalbą tiriant medžiagos kietuma laboratorijoje.

Contents

INTRODUCTION

Metal internal gas (MIG) welding continues to become one of the most popular processing method in technology. Large scale and new applications of manufacturing are increasingly looking at and adopting MIG in their processing fields. MIG nowadays is acceptable in many industries as a standard piece of equipment which causes important influence over conventional machining equipment.

This provides the possibility to minimize loss of material and enhancement of production efficiency, as well as extra productivity and capacity in manufacturing. The manufacturing sector of Lithuania does not have enough material resources, but innovative companies could solve this problem. Innovative technology as MIG welding could help raise Lithuanian companies' profits and variety of products.

Different types of welding are applied in surface treatment. MIG welding has been widely used in the aerospace, aeronautics, heavy manufacturing and automotive industries to join a variety of materials.

During the MIG welding process, the edges of joined materials are melt. High current of welding ensures high processing speed of various thickness of material plates.

The major weakness of the MIG welding process is the strict joint manufacture tolerances. The tolerances can be fulfilled when components are relatively small and parts can be produced with machine cutting. The geometry of an air gap and part mismatch variations from joints between materials are essential in welding quality.

This work investigates MIG welding butt joints with different parameters and represents experimental results of work related to the thick section butt joint welding of structural aluminium AW6082 under different welding parameters. Standard EN ISO 9296 Metal inert gas welding of aluminium and its alloy [12] requires strict preparation of edge flatness and roundness.

All experiments have been produced at the Kaunas University of Technology laboratories. The specimens were welded under 18-20 voltage with EWM Phoenix 355 Progress pulse TDM welding machine. The volt range was efficient to form seam for thick section structural aluminium butt joint. Samples were welded under different conditions of current and welding speed.

The main goal of this bachelor‘s thesis was to investigate structural aluminium alloy tensile strength and micro structure by different MIG welding parameters. The objectives of this bachelor's thesis were defined as follow:

- Analysis of experimental setup and procedures
- Hardness checking of weld zone, heat affected zone and melted zone
- Tensile testing of specimens after different welding parameters
- Evaluation of the weld ability of thick section butt joints

1. THEORETICAL BACKGROUND

In Bronze Age comes earliest examples of welding. It was small gold circular boxes were made by pressure welding lap joints together. It is estimated that these boxes were made more than 2000 years ago. During the Iron Age the Egyptians and people in the eastern Mediterranean area learned to weld pieces of iron together.

First time of welding started to develop in 1944 and is still extensively used to successfully weld aluminium alloys today. Some critical applications were used for highest quality welds, such as full penetration pipe welds on cryogenic pressure vessels, are almost exclusively made with this welding process. Alternating current (AC) is used for most applications, but direct current (DC) power is employed for some specialized applications. The GTAW process has since been replaced by the gas metal arc welding (GMAW) process for many aluminium welding applications, primarily because of the increased speed of the GMAW process to weld thicker sections. However, GTAW still has an important place in the aluminium welding industry [1].

Since that time welding equipment development was quickly increasing step by step it comes new technologies such as like t**ungsten inert gas (**TIG), gas metal arc welding **or SMAW (gas or oxy acetylene welding),** all these types are widely use in variety of manufacture ways it could belong for constructions in civil service or aeronautics, small and huge gauges manufacture**.** MIG welding is operated in semiautomatic, machine, and automatic modes. It is utilized particularly in high production welding operations. All commercially important metals such as carbon steel, stainless steel, aluminium, and copper can be welded with this process in all positions by choosing the appropriate shielding gas, electrode, and welding conditions. [2].

This developed process as aluminium welding let us go to more flexible technological way, it comes more and more popular, part's comes more lighter and stronger which are widely using in lift's or car's manufacture.

1.1 MIG PROPERTIES AND CLASSIFICATION

1.1.1 The main elements of MIG

Gas metal arc welding equipment consists of a welding gun, a power supply, a shielding gas supply, and a wire-drive system which pulls the wire electrode from a spool and pushes it through a welding gun (Fig.1.1). A source of cooling water may be required for the welding gun.

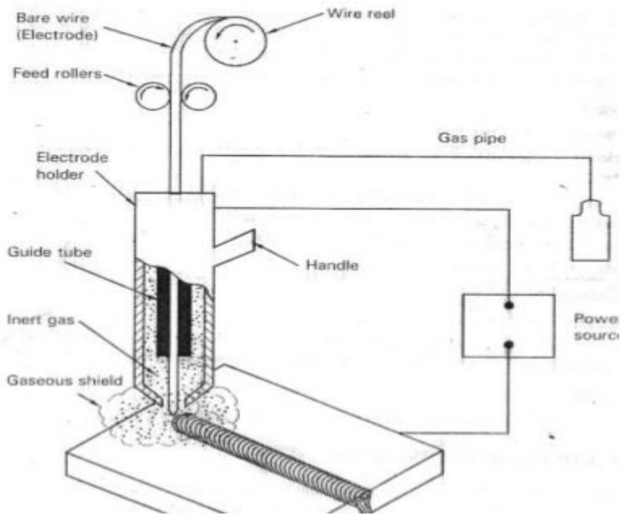


Fig.1.1 Structural scheme of MIG welding process [2].

In passing through the gun, the wire comes energized by contact with a copper contact tube, which transfers current from a power source to the arc. While simple in principle, a system of accurate controls is employed to initiate and terminate the shielding gas and cooling water, operate the welding contractor, and control electrode feed speed as required. The basic features of MIG welding equipment are shown in figure 10-45. The MIG process is used for semiautomatic, machine, and automatic welding. Semiautomatic MIG welding is often referred to as manual welding. [2] Semiautomatic, pistol in shape guns are usually similar to a hand-held. Sometimes they are shaped similar to an oxyacetylene torch, with electrode wire fed through the barrel or handle. In some versions of the pistol design, where the most cooling is necessary, water is directed through passages in the gun to cool both the contact tube and the metal shielding gas nozzle. The curved gun uses a curved current-carrying body at the front end, through which the shielding gas is brought to the nozzle. This type of gun is designed for small diameter wires. It is suited for welding in tight, hard to reach corners and other confined places. Guns are equipped with metal nozzles of various internal diameters to ensure adequate gas shielding. The orifice usually varies from approximately 3/8 to 7/8 in. (10 to 22 mm), depending upon welding requirements. The nozzles are usually threaded to make replacement easier. [2] The pistol holder is also used for arc spot welding applications where filler metal is required. The heavy nozzle of the holder is slotted to exhaust the gases away from the spot. The pistol grip handle permits easy manual loading of the holder against the work. The welding control is designed to regulate the flow of cooling water and the supply of shielding gas. It is also designed to prevent the wire freezing to the weld by timing the weld over a present interval. A typical semiautomatic gas-cooled gun is shown in figure 1.2 [2-3].

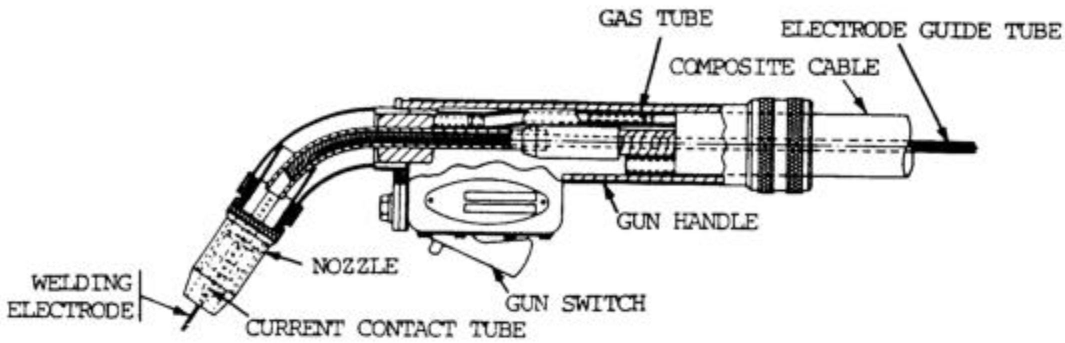


Figure 1.2. Typical semiautomatic gas-cooled, curved neck gas metal arc welding gun [2].

1.1.2. Welding types of aluminium

At the beginning of (MIG) welding analysis was searching different kinds of welding types. Some of them will be mention. Widely spread welding types are:

- Tungsten Inert Gas
- Shielded Metal Arc Welding
- Arc welding
- Flux welding
- Spot welding
- Frictional welding

TIG welding - TIG Welding is a manual welding process that requires the welder to use two hands to weld. What separates TIG welding from most other welding processes is the way the arc is created and how the filler metal is added (Fig.1.3). When TIG Welding one hand is used for holding the TIG torch that produces the arc and the other hand is to add the filler metal to the weld joint. Because two hands are required to weld; TIG welding is the most difficult of the processes to learn, but at the same time is the most versatile when it comes to different metals. This process is slow but when done right it produces the highest quality weld! TIG welding is mostly used for critical weld joints, welding metals other than common steel, and where precise, small welds are needed. TIG welding's proper name is gas tungsten arc welding or "GTAW". This is the name the American Welding Society and other welding organizations refer to this process on their welding procedures. GTAW is also the abbreviation that welding engineers use to specify the welding process that is to be used on blue prints. Tungsten is a very hard, slightly radioactive, and brittle metal. Its uses are limited compared to other metals. In TIG welding the tungsten is made into a non-consumable electrode that is used to create the arc for TIG welding. Typical other uses for tungsten are in light bulbs, heating elements, and rocket engines. Basically any place that requires a very high melting point or the need to pass electricity at a high temperature is needed. In the case of TIG welding the tungsten metal properties allows an arc to maintain a temperature up to 11,000 degrees Fahrenheit. A high melting point excellent electrical conductivity keeps the tungsten electrode from burning up. [4]

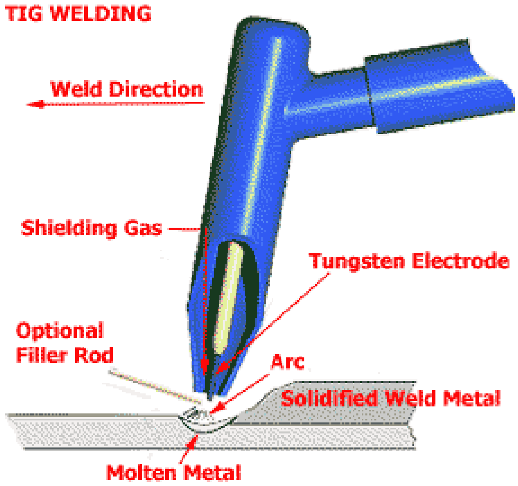
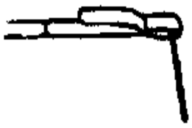


Fig.1.3 Structural scheme of TIG welding [4].

Shielded-metal-arc welding (SMAW) -evolved from carbon arc weld (CAW) when it was realized that a consumable electrode – eliminating any need for a welding rod, could replace the carbon electrode. To reduce oxidation, the electrode wire is coated with materials such as fluorides, oxides, carbonates, metal alloys, and binders to stabilize the arc, to produce gases to shield the weld from oxygen and atmospheric contaminants, and to introduce metal alloy to weld. SMAW is used principally with nickel and ferrous base metals. The electrodes are typically 2 to 6mm (3/32 to ¼ inch) in diameter and are controlled by the welder in a clamp-type electrode holder. Because of the rod shape of the electrode, SMAW is sometimes referred to as stick welding. The arc is struck by the welder when he briefly touches the electrode to the work piece and withdraws it to an optimum gap. A very experienced welder can advance the rod and maintain an optimum arc gap that produces a reasonably stable optical emission for short periods of time. But the optical radiation emitted from this type of arc when most welders hold the stick will fluctuate substantially with time (Table 1.1) [6].

Table 1.1 Data of shielded metal arc welding [6]

Welding Process	American weld society Designation	Electrode	Shielding Gases	Remarks
Shielded Metal Arc Welding (also known as "stick" welding)	SMAW 	Consumable Stick Electrode	Some shielding. Gas produced from welding rod.	Common in the field and in small shops. Produces excessive fumes.

Gas or Oxy acetylene welding- Acetylene is composed of hydrogen and carbon, as are most fuel gases. It is mainly the carbon which provides the intense heat and very high flame temperature (3100°C) when burned with oxygen. If sufficient oxygen is not provided, then the carbon is given off into the air as black, sooty smuts. Acetylene has a very high proportion of carbon in it and if the oxygen is turned down to provide a flame with excess carbon, the carbon is taken into the steel to provide a high carbon surface, used for hard surfacing operations. A neutral oxy-acetylene flame burns equal proportions of oxygen and acetylene and is reducing in nature, thereby reducing any iron oxide to iron and taking up the oxygen; consequently there is no need to use a flux when welding steel. It should be noted that iron oxide is not refractory [7].

Arc welding (Fig 1.4) is one of several fusion processes for joining metals. By applying intense heat, metal at the joint between two parts is melted and caused to intermix - directly, or more commonly, with an intermediate molten filler metal. Upon cooling and solidification, a metallurgical bond is created. Since the joining is an intermixture of metals, the final weldment potentially has the same strength properties as the metal of the parts. This is in sharp contrast to non-fusion processes of joining (i.e. soldering, brazing etc.) in which the mechanical and physical properties of the base materials cannot be duplicated at the joint. In arc welding, the intense heat needed to melt metal is produced by an electric arc. The arc is formed between the actual work and an electrode (stick or wire) that is manually or mechanically guided along the joint. The electrode can either be a rod with the purpose of simply carrying the current between the tip and the work (Fig. 1.4) [8].

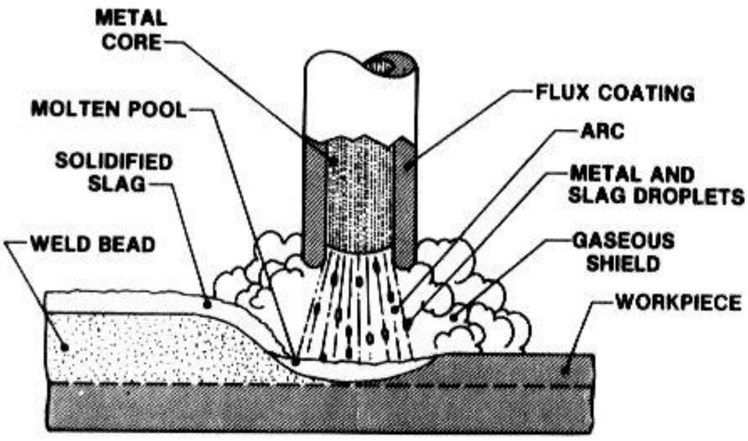


Fig. 1.4 Structural scheme of arc welding [8].

Spot welding- resistance welding (Fig. 1.5) is a process for fastening metallic objects together. The metallic objects have various electrical and thermal properties that make it possible for the resistance welding process to occur. Electrically, metallic objects have some level of resistance to the flow of electrical current. This resistance will cause heat energy as electric current passes through the specimen. The higher the capacity and duration of current, the higher the heat energy will be produced.

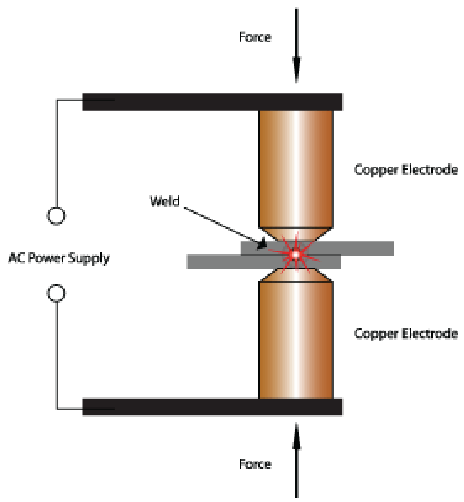


Fig 1.5 Structural scheme of spot welding [9].

This relationship can be expressed in the simple equation Resistance welding of steel is relatively easier than welding of aluminium. The characteristics that makes steel easier to resistance weld than aluminium is its higher electrical resistivity and its lower thermal conductivity as compared to the copper electrodes. The cooling of the electrodes is very important since steel requires a build-up of temperature in excess of 1300°C to melt which is well above the melting temperature of copper of 1115°C. The flow of water in the electrodes is necessary to take away heat that builds up at the electrode / specimen contact area. This will also help in maintaining the surface contact area of the copper electrodes at a proper dimension which will result in maintaining the current density to melt the steel [9-10].

1.2 MIG WELDING THEORY

One of the most important process is MIG welding is in technology processes. Main core of technological type of welding is that it uses intense power to melt the edges of material to join two metal with filling the gap. Then welding appliance moving according to the edge and melting both sides of material. In general, melting is achieved from heating source. Most of heat sources are usable on the surface of sheet, so heat transfer conduction it is very important to achieving welding penetration .The source of heat can be applied inside the sheet.

1. The welding procedures for MIG welding are similar to those for other arc welding processes. Adequate clamping of the work are required with adequate accessibility for the welding gun. Clampers must hold the work rigid to minimize distortion from welding. It should be designed for easy loading and unloading. Good connection of the work lead (ground) to the specimen, clamping is required. Location of the connection is important, particularly when welding ferromagnetic materials such as steel. The best direction of welding is away from the work lead connection. The position of the electrode with respect to the weld joint is important in order to obtain the desired joint penetration, fusion, and weld bead geometry. Electrode positions for automatic MIG welding are similar to those used with submerged arc welding.
2. When complete joint penetration is required, some method of weld backing will help to control it. A backing strip, backing weld, or copper backing bar can be used. Backing strips and backing welds usually are left in place. Copper backing bars are removable.
3. The assembly of the welding equipment should be done according to the manufacturer's directions. All gas and water connections should be tight; there should be no leaks. Aspiration of water or air into the shielding gas in arc operation and contamination of the weld. Porosity may also occur.
4. The gun nozzle size and the shielding gas flow rate should be set according to the recommended welding procedure for the material and joint design to be welded. Joint designs that require long nozzle-to-work distances will need higher gas flow rates than those used with normal nozzle-to-work distances. The gas nozzle should be of adequate size to provide good gas coverage of the weld area. When welding is done in confined areas or in the root of thick weld joints, small size nozzles are used.

5. The gun contact tube and electrode feed drive rolls are selected for the particular electrode composition and diameter, as specified by the equipment manufacturer. The contact tube will wear with usage, and must be replaced periodically if good electrical contact with electrode is to be maintained and heating of the gun is to be minimized.

6. Electrode extension is set by the distance between the tip of the contact tube and the gas nozzle opening. The extension used is related to the type of MIG welding, short circuiting or spray type transfer. It is important to keep the electrode extension (nozzle-to-work distance) as uniform as possible during welding. Therefore, depending on the application, the contact tube may be inside, flush with, or extending beyond the gas nozzle.

7. The electrode feed rate and welding voltage are set to the recommended values for the electrode size and material. With a constant voltage power source, the welding current will be establish by the electrode feed rate. A trial bead weld should be made to establish proper voltage (arc length) and feed rate values. Other variables, such as slope control, inductance, or both, should be adjusted to give good arc starting and smooth arc operation with minimum spatter. The optimum settings will depend on the equipment design and controls, electrode material and size, shielding gas, weld joint design, base metal composition and thickness, welding position, and welding speed [2].

1.2.1 Joint fitting before welding

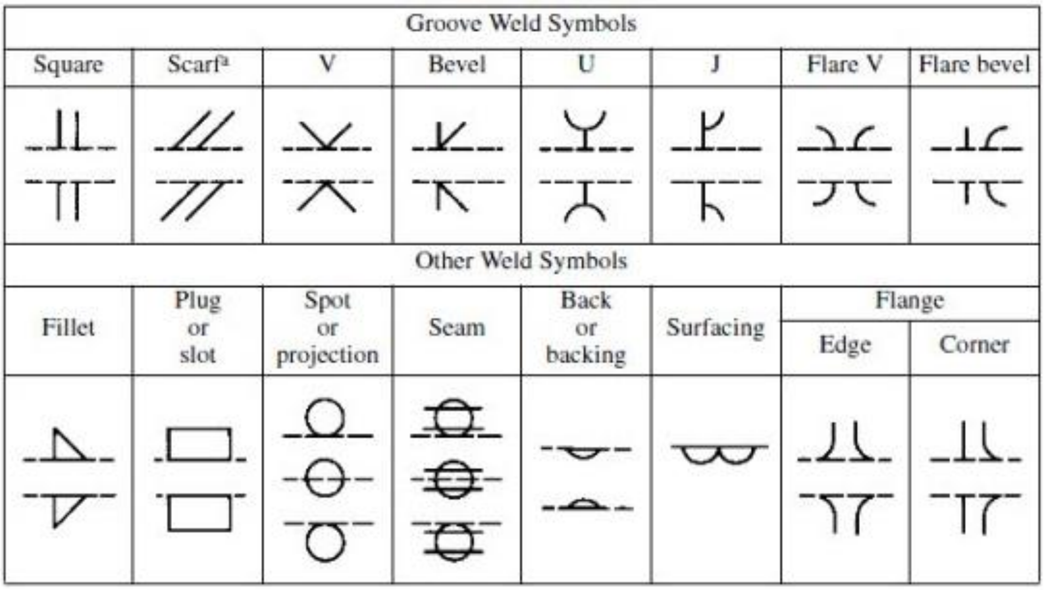
Joint arrangements. Gas metal arc welding, commonly called MIG, it creates an arc between a continuous wire filler metal (consumable electrode) and the sheet metal specimen. Shielding gas protects both the molten metal and the arc from the atmosphere .This process is suitable for most metals and alloys. Among the most readily welded materials are: carbon steels, low-alloy steels, stainless steel; 3000, 5000, and 6000-series aluminium alloys; and magnesium alloys. Other alloys that can also be MIG-welded via special methods include 2000 and 7000-series aluminium alloys; high-zinc-content copper alloys, and high-strength steels. [13] In our case we have 6000-series of structural aluminium.

Basic Weld Symbols: These designate the type of welding to be performed. The basic symbols which are shown in the table Basic Weld Symbols are placed approximately in the canter of the reference line, either above or below it or on both sides of it as shown in above figure. Welds on the arrow side of the joint are shown by placing the weld symbols on the side of the reference line towards the reader (lower side). Welds on the other side of the joint are shown by placing the weld symbols on the side of the reference line away from the reader (Table 1.2) [13].

Effective gap in welding metal such like aluminium or other alloy metals are very important to guaranty properly welding seam and it is not related with welding equipment. The usability of air gap depends on welding speed, material thickness, and material structure. It can affect metal melting speed and fluidity.

Benefits of air gaps is that, that it porosity which depends on air gap larger gap increasing possibilities properly weld metal.

Table 1.2 Basic Weld Symbols [13]



In all solid metals plastic flow in the individual crystals of the material occurs along specific slip planes. These slip planes offer the lowest resistance to internal shear stresses and at the atomic level shear movement occurs along these planes without any separation of the material. If a metal is strained over its elastic limit it begins to flow and permanent plastic deformation occurs. When subjected to loads above the material's elastic limit tensile test specimens become longer and thinner. In the material many of such shear planes appear. Since the commercial alloys, when considered macroscopically, are generally fine grained and relatively isotropic, the shear planes are inclined at approx. ±45° corresponding to the plane with the highest shear stress. For the engineer, thinking in mechanical terms, it is easy to appreciate that an improvement of the shear strength should also improve the general mechanical strength of the metal. The idea that this can be achieved by use of structures which act like shear dowels is not so very wrong and is a help in understanding the various differing methods of hardening aluminium. The basic principle is that all types of lattice imperfection can cause an increase in shear strength. [14] Welding of structural AW6082 aluminium is able to reach high welding speed for different thickness of material. Edge roughness all the time has influence for penetration depth. Each case of welding requires proper selection of all these parameters because quality of welding depends on it.

2 EXPERIMENTAL SETUP AND PROCEDURES

In this section featured of experimental procedure, mechanical properties and visual properties investigation are presented. The main goal of work is to figure out the best combination of MIG welding parameters and ensure the highest quality of welding with minimum defects in the thick section. Research project was accomplished in Kaunas University of Technology laboratories.

2.1 Experimental procedure

The tensile mechanical tests were performed using 50 kN "Universal mechanical" testing machine and HBM TYP U5 testing equipment. The hardness tests were performed using Vickers hardness testing equipment "UHL VMHT" with Leica Plan objectives. All tests were conducted in the laboratory environment (at 20±2 ^{0}C and 50±5 % relative humidity).

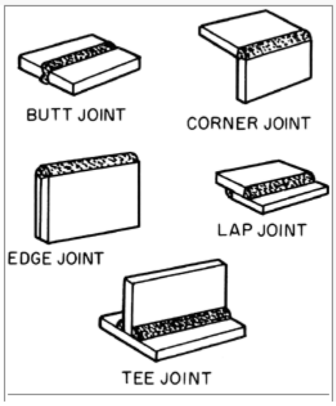


Fig 2.1 Types of welded joints

Classification of joints and welds. The relative positions of the joined components are the basis for the various categories of joints: butt joints, T-joints, lap joints, and corner joints. Each type of joint has specific characteristics that depend on the welding method chosen, whether arc welding butt weld, electro slag welding fillet weld, resistance welding (weld for corner joint), or some other method. The segment of the welded joint directly connecting the components being welded is called the weld. All types of welds can be classified according to the metal-deposition technique used as single pass welds, welds formed from the centre toward the ends, and welds formed by back step welding. Welds can be also distinguished by the spatial positioning during welding as vertical, horizontal and overhead welds. Welds can also be classified according to the method by which their cross sections are formed as single-layer and multilayer welds. State and industry standards specify the basic types of welded joints, the structural components of edges and welds, and the tolerances and feasible ranges for the thicknesses of the components being joined. These data apply to all types of welds. [16]

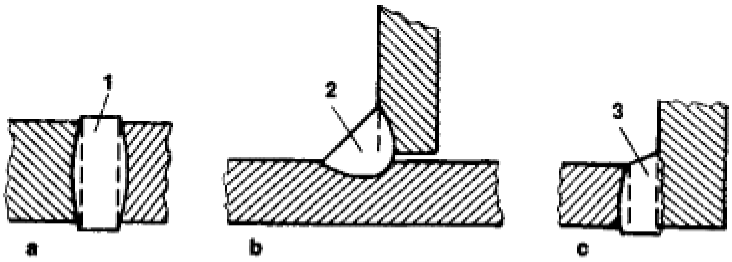
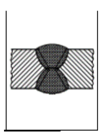
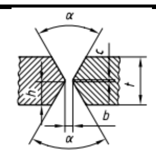


Figure 2.2 Types of welded joints and welds used in electro slag welding: (a) butt joint, (b) T-joint, (c) corner joint; (1) butt weld, (2) fillet weld, (3) weld for corner joint.[16]

2.2 Joint preparation

Joint preparation: all specimens were prepared according to EN ISO 9692-3:2001, „Welding and allied processes — Recommendations for joint preparation —Part 3: Metal inert gas welding and tungsten inert gas welding of aluminium and its alloys“. The recommendations given in this part of ISO 9692 have been compiled on the basis of experience and contain dimensions for types of joint preparation that are generally found to provide suitable welding conditions. However, the extended field of application makes it necessary to give a range of dimensions. The dimension ranges specified represent design limits and are not tolerances for manufacturing purposes.

Table 2.1 — Joint preparation for butt welds, welded from both side

Ref.No[a]	Workpiece thickness, t	Deignation	Symbol [b]	Illustration	Cross section	Angle α,β	Gap, b	Thickness of root face, c	Other dimensions	Recomended welding process [c]
2.3.3.	6≤t≤15	Double-V butt weld	X			60^0≤α	b≤3	c≤2	-	141
	15≤t					70^0≤α		c≤2	-	131

Manufacturing limits depend, for instance, on welding process, parent metal, welding position, quality level, etc. Due to the common character of this part of ISO 9692, the examples given cannot be regarded as the only solution for the selection of a joint type. [12]. Therefore, it was guided according to it. It was prepared aluminium plates with dimensions 170x340 mm and thickness 10 mm. All plates were cut by end milling tool and it also required additional machining. Each edge of plates was prepared by 30 degree angle which was required in a standard (Table 2.1). In reality the edges of specimens looks as shown in figure 2.2.

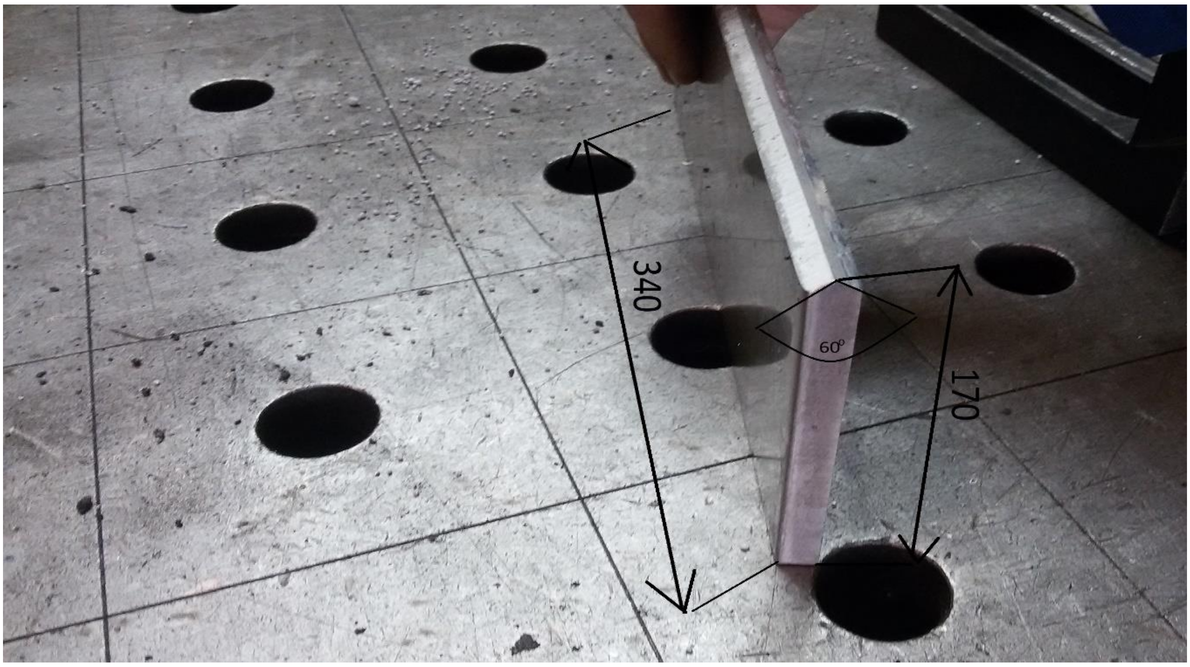


Fig. 2.2 Prepared edges of the specimens for welding procedure

Before the welding process, edges of both plates was cleaning by wire brush to ensure welding quality and stability, all the time if we want to weld properly aluminium, we must to remove thin safety layer from aluminium surface. Oxide (Al_2O_3) which is protecting aluminium on welding process it is very bad conductor because it is melting temperature are triple times bigger than aluminium. Aluminium melting temperature ~ 660 C. This oxide creates when aluminium reacting with oxygen. To weld properly according the standard we clamped specimens on the table with properly air gap which was given in the standard specification (Table 2.1).

After welding it becomes as one plate which dimensions of 343x340 mm, because before the welding the air gap was taken 3 mm for required specimen. There is no EN ISO standard guidance for an over butting or length, but is 3.4 times more than the plate thick.

Tolerances of lap joint groves are not strict as butt joint and flatness of a specimen was taken to account. The aluminium plates were clamped rigidly for positioning on a table. Mostly butt joint requires tight clamping and high tolerances of flatness. The air gap between the plates ensures that the aluminium edges welds properly according to the standard ISO 9692. Specimen are shown in (Fig. 2.4).

Fig. 2.4 Specimen for MIG welding

Figure 2.5 shows how the plate's looks like before welding with taken root. Root were taken for sprays which were melted on the welding surface, it could make influence for experiment accuracy.

Fig.2.5 Prepared aluminium plates before welding

2.3 MIG welding parameters

In this case of study, welding has been doing using „Phoenix 355 Progress Pulls TDM", welding machine. Welding length of all experiment of plates were 1360 mm because the plates were welded from both sides by 340 mm length. In the beginning of the welding process we have used impulses welding.

It means that when welder push gun switcher wire firstly heats the surface and then start welding. Before other side of welding we can see fluidity of melted wire and aluminium alloy. This alloy must be taken out for properly welding process of this calls take out the root. By this process welder must remove all the sprays which was made after welding, it affects results of welding, because each aluminium plate was welded with different parameters of current when voltage is 18-20 V. The welding machine system parameters are shown in the table 2.2.

Table 2.2 Welding machine "Phoenix 355 TDM" parameters [18]

	TIG	MIG/MAG	MMA
Setting range for welding current	5A-350A		
Setting range for welding voltage	10,2V-24V	14,3V-31,5V	20,2V-34V
Duty cycle	40^0C		
60%	350A		
100%	300A		
Load alternation	10min. (60%DC-6min welding, 4min welding, pause)		
Open circuit voltage	79V		
Mains voltage tolerance	3x400 V (-25% to +25%)		
Frequency	50/60Hz		
Mains fuse(safety fuse, slow blow)	3x25A		
Mains connection lead	H07RN-F4G4		
Max. Connection load	10,6kVA	13,9kVA	15kVA
Recomended generator rating	20kVA		
cos (fi)	0,99		
Insulation class/protection clasification	H/IP 23		
Ambient temperature		20˚Cto+40˚C	
Machine/torch cooling	Fan/gas		
workpiece lead	$70mm^2$		
Dimensions (LxWxH)	625mmx300mmx535mm		
Weight	41Kg		
EMC	A		
Constructed to standards	IEC 60974-1,-10		

As we can see from (Table. 2.2) welding machine "EWM Phoenix 355" Progress pulse has a wide range of options to maximize applications flexibility. Specimens were welded with argon shielding gas air temperature were 17 C^0, maximum wire flow could be 7.2 m/min. In our experiment case next to 120A flow was 2.9m/min, 135 A - 3.2 m/min, 150 A - 3.4-3.5 m/min and 165 A - 3.8 m/min, the voltage for all specimens was 16-18V.

2.4 Material of specimens

Aluminium and it's alloys have become increasingly used in production special in automobiles and trucks, food packaging of and beverages, construction of buildings, transmission of electricity, development of transportation infrastructures, production of defence and aerospace equipment, machinery manufacture and tools and structures of marines with its unique properties such as resistance of corrosion , electrical conductivity and thermal conductivity high strength, energy absorption fracture toughness, workability, ease of joining (welding (both solid state), riveting, brazing, bolting, soldering) and recyclability. 6082 aluminium–magnesium–silicon alloys have high corrosion resistance and are heat treatable and moderate strength. With this high moderate strength and corrosion resistance, this alloy 6082 alloys are widely used in shipbuilding industry both separately and together. Aluminium is different metal as other metals. It's 3 times lighter as steel, because it's density are lower 2.7 g/cm^3 if we compare with steel which density are 7.85 g/cm^3 as well aluminium are better conductor of heat, it also are easier to manufacture (cut, bend, make milling operations or stamping processes), this material cannot have rusts. Welding of this material are special, because it's melting temperature are quite low, but oxide which is protecting aluminium surface are higher it reaches 2000 C. Normal aluminium melting temperature 660 C. If we will compare with steel melting, the temperature is approximately 1500 C.

Table 2.3 Mechanical characteristic of structural aluminium properties AW-6082 were used in experiment

Temper	Proof Stress 0.20% (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Elongation A5 (%)	Elongation A50 (%)	Hardness Brinell HB	Hardness Vickers HV	Fatigue Endure. Limit (MPa)
AW6082 T6	310	340	210	11	11	95	100	210

Table 2.4 Physical properties for structural aluminium alloy AW-6082[19].

Property	Value
Density	2700 kg/m^3
Melting Point	555°C
Modulus of Elasticity	70 GPa
Electrical Resistivity	0.038x10^{-6} Ω.m
Thermal Conductivity	180 W/m.K
Thermal Expansion	24x10^{-6} /K

Table 2.5 Chemical composition of structural aluminium alloy AW- 6082 [19]

EN AW-6082	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
Spec. min.	-	-	-	0,4	**4**	0,05	-	-
Spec. Max.	0,4	0,4	0,1	1	4,9	0,25	0,25	0,15
Actual	0,27	0,38	0,07	0,6	4,8	0,11	0,09	0,03

2.5 Weldment wire standard and specification

Table 2.6 Mechanical composition of structural aluminium wire 6082 were used in experiment [31].

Protective gas of welding processes in test temperature	The values of welding by DIN 1732-3
0,2%-Yied stress($Rp_{0,2}$)	110[MPa]
Tensile strength R_m	250[MPa]
Stretching A (L_0=5d_0)%	18[%]
Electrical conductivity	15-19[S*m/mm^2]
Thermal conductivity	110-150[W/(m*K)]
Thermal expansion coefficient	23,7*-10^{-6}[1/K]

Table 2.7 Chemical composition of structural aluminium wire AW- 6082 [31].

Al	Mg	Mn	Cr	Ti
Basis	5	0,35	0,1	0,15

2.6 Specimen preparation

The specimens were cuts by saw using cooling fluid. Butt joint had misalignment for welded supports of a plates. The butt joint were in the middle of the plate because it were not made any process on the seam it was not damaged. After sawing operation we make a program on CNC milling machine (Leadwell 102A) with end mill toll we milled off the specimen.

3. TESTS OF A SPECIMEN

3.1 Hardness test

The welded samples were tested for micro-hardness and measurements were taken on the cross-sections perpendicular to the welding direction. The location of individual measurement points in the test specimens is schematically presented in fig. 3.1.

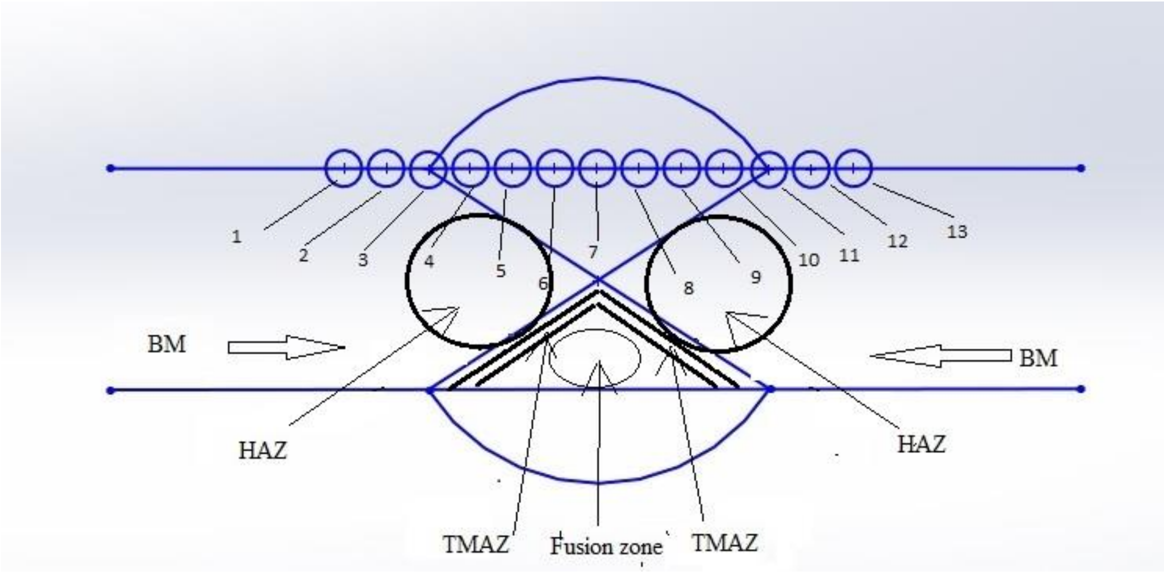


Fig. 3.1 Location of hardness testing points on the cross section of welded joint.

Polished parts was putted to Micro Hardness Testing machine UHL VMTH which can suggest 12 different ways for testing force : 1, 5, 10, 15, 25, 50, 100, 200, 300, 500, 1000 and 2000 g all these forces were checked by EN ISO 6507 and EN ISO 4545 standard for properly work. Forces could be automatically changed by clicking the button on a screen. The velocity can be selected from 25 till 60 μm/s during testing process. Optics of this machine could be x10 or x50 times bigger it depends on structure type of the specimen. In this test we have used Vickers indenter (fig.3.1). The Vickers indenter is also is used for instrumented indentation to test mechanical properties of measurement on the nanoscale. The Vickers indenter, mostly use for softer metals, is a four-sided pyramid. The Vickers indenter tip is for a traceable pyramid standard. In our case all specimens were tested with 1000 g load perpendicular to the welding direction. The loading time was 25 s. The type of the instrument used for the experiments is shown in the (fig3.2) .The micro hardness of the weld (fusion zone) and zone which was affected by heat, i.e. the hardness of the heat affected zone (HAZ) also was measured for the specimens.

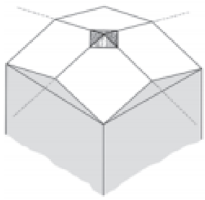


Fig 3.2 Vickers hardness test pyramid. [29].

Each specimen was testing more than 10 times to ensure and get appropriate results. The gap between measurements places was 1.5 mm. The gap by this distance we check wide area of our polished parts. In our case the load was taken 1 kG. It means that if we getting a bigger area, the HV number should be weaker. Each number of the test takes 25 s until machine shows one area results.

$$HV = \frac{F}{A} \quad (1)$$

Where, F-load, A-area of indention, HV- Vickers pyramid number.

First specimen was welded with the current of 120 A. The hardness of testing result is shown in (figure 3.1.2)

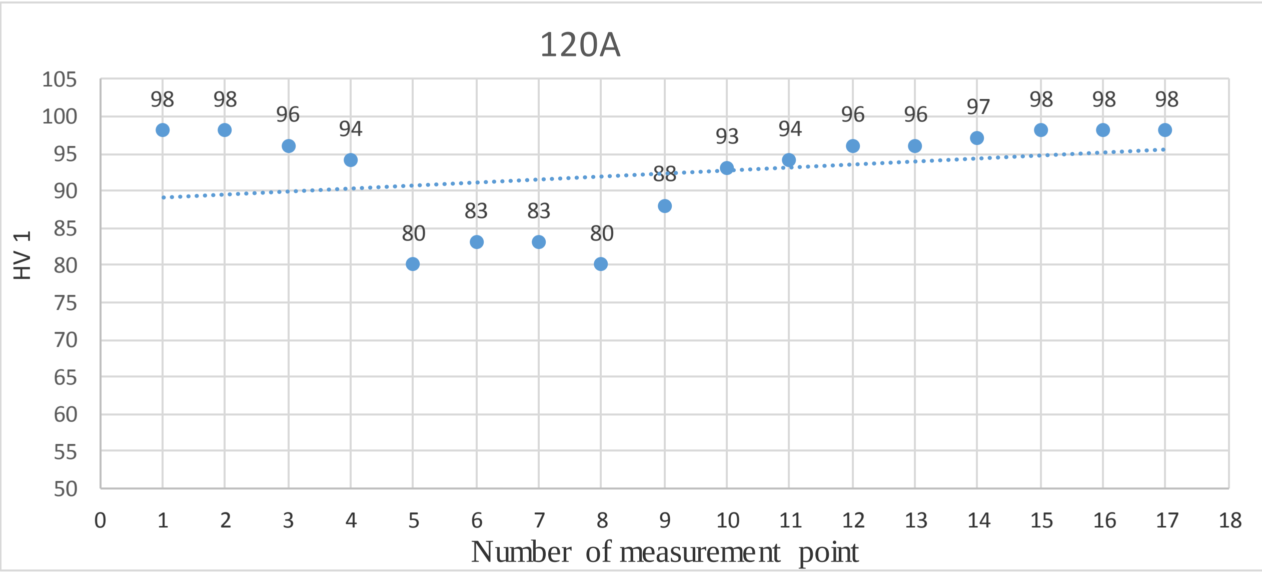


Fig.3.1.2 Hardness variation as a function of lateral distance from the weld line (weld current 120 A)

Material hardness level was measured and the result of base metal was 98 HV in the heat affected zone, where aluminium start to melt, hardness value was 96-94 HV. It means that during melting process, the structure of the aluminium changed and, as the result, it became softer in welded area. According to diagram we can see where is located the softest place of aluminium.

In diagram (fig. 3.1.3) we can see that the hardness HV of the based metal of the specimen does not changes (welding current – 135 A). However, in the area of welding the value of the hardness differs in comparing with the weldment of 120 A. In this case the middle of the seam reaches 92 HV. That means that the middle of the seam is softest area. However, the HAZ, where wire and aluminium reacted becomes harder than the base aluminium structure.

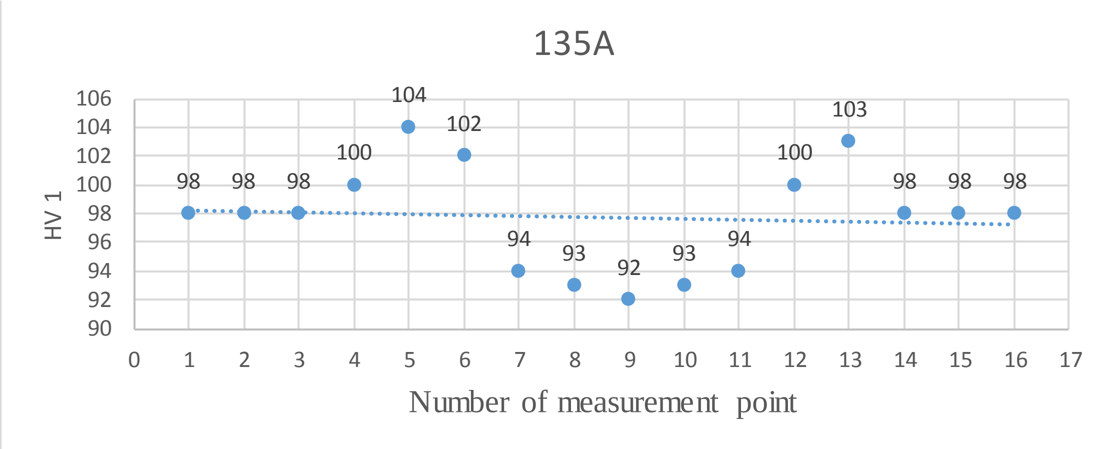


Fig.3.1.3 Hardness variation as a function of lateral distance from the weld line (weld current 135 A)

In (fig3.1.4) we can see that the hardest area is between metals edges and melted wire. The softest area is located around the middle of the seam (86 HV), but in 1.5 mm gap there is 10 HV difference. It means that the metal highest change in hardness is in the structure from the seam middle till the heat affected zone.

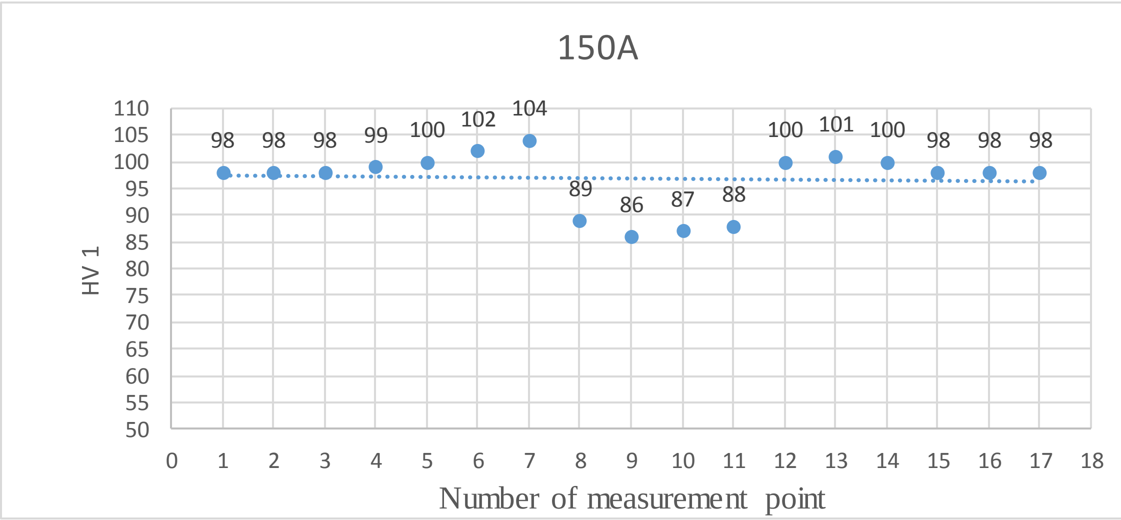


Fig.3.1.4 Hardness variation as a function of lateral distance from the weld line (weld current 150 A)

In (fig 3.1.5) we can see that the hardest area is between material edges and melted wire but in this case the welding current influenced material hardness. It becomes harder as it was before if we compare with the other tests. The fusion zone is approximately the same as it was in previous case. Comparing base material hardness with the fusion zone hardness difference is 16%. The hardness of base material close welding pool was changed approximately in 14%. Material which were affected by higher current change it structure and becomes harder.

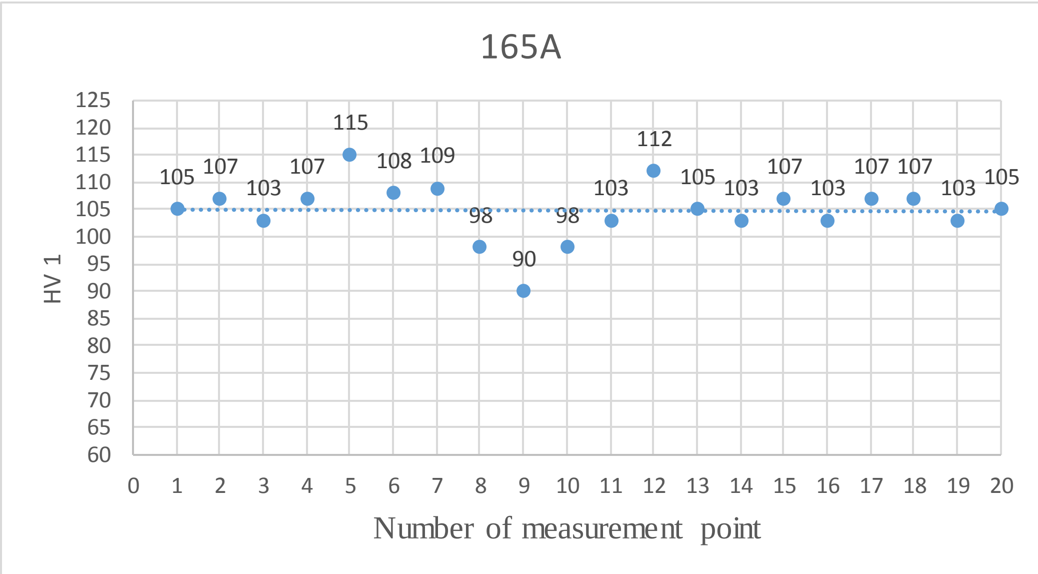


Fig.3.1.5 Hardness variation as a function of lateral distance from the weld line (weld current 165 A)

All these hardness diagrams of a butt joint shows that the fusion zone in all cases are softer than base material respectively by 6-22%. Specimen which were welded with 120A had softest fusion zone comparing with other specimens. HAZ area has not harder area than base material. Maximum difference between areas was 22%. The hardness of base metal close to the welding, pool was not influence significantly by changing welding current. Second specimen which was tested by Vickers hardness in heat affected zone was 5% higher than the base material. The result of the third specimen which was welded with 150A. Was approximately the same as of second specimen. It is interesting to note that the fusion zone area is 7% softer than in the previous case. Most interesting fact of all these test are that with highest current welded specimen it change it structure after the welding becomes 15% harder in heat affected zone than the base material. As well base material change it hardness it increase 4.8% of total material hardness.

We observed 50 times maximized micro hardness picture in the microscope. The lines shows the impacted area of pyramid corners. The area which is used for calculating HV, is located between two vertical lines (Fig. 3.1.6).

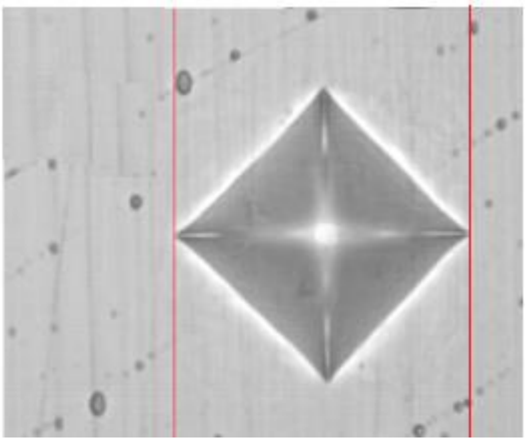


Fig.3.1.6 Micro indentation of HV hardness

Analysing the obtained hardness distributions on cross sections of welded joints, it can be seen that moving from a base material in the direction of the joints axis hardness decreases. The smallest hardness values were recorded in the fusion zone, and they correspond to about 70% of base material hardness.

3.2 Tensile experiments:

The specimen with a gauge minimal length 90mm for tensile experiment were adjusted. Each of specimens was tight clamped in the test machine clamps. One side of a machine are rigidly fixed other side are pulling with increasing a load while at the same time measurement changing. This test inform us how much the weight can hold cross section which are measuring. The cracks comes respectively with a time when the load increasing. If it is not properly welded seam in the inside we can see increasing free space gap. All experiments were made at the laboratory at the room temperature (at 20±2 ^{0}C and 48±5 humidity). Versatile electromechanical testing machine is shown in the (fig3.2.1). Standard EN ISO 4136 indicates procedure for destructive test in metallic materials in plate pipes, full section pipes and cylindrical test specimens [20]. International standard ISO 9018 shows destructive test on welds in metallic materials for tensile test on cruciform [21]. Both standards are not specifically for transverse tensile test which were accomplished. There are no in EU specific standard for tensile that is why these standards were joined together.

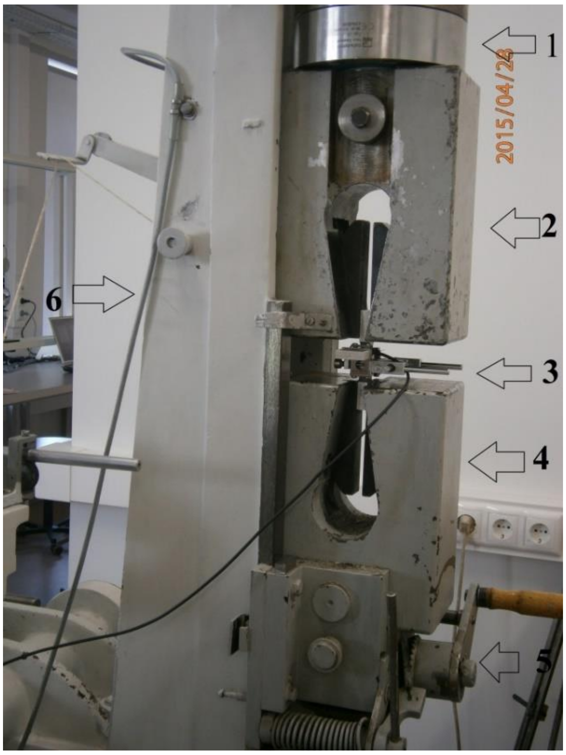


Fig 3.2.1 The experimental stand for tensile testing of aluminium specimens: 1- strength measuring equipment HBM TYP U5 Germany. 2- upper crosshead 3- strength and deformation equipment HBM Germany 4- lower crosshead 5- gearbox 6- support

The (fig3.2.1) shows versatile electromechanical experiments machine. The maximum force of this machine is 50 KN which means it can load 5 tons

3.3 Tensile tests

In nowadays tensile testing is one of the most popular fundamental tests for engineering, and provides valuable information about a material properties. These properties can be used for analysisi of engineering and design structures, and for developing new materials that better suitability. For better understanding of material properties were tested four specimens of different welding conditions.

First test was made with 120 A welded specimen. In (fig.3.3.1) the diagram shows the load which is expressed in kN and displacement which is expressed in mm. During the tensile test the diagram starts and shows displacement just from 7 KN because aluminium is soft metal. When the load is increasing, clampers engrave to the metal and just then when clampers stop ripping thru the material, the measuring is possible. The true stress at the point of maximum load where the ultimate tensile strength were for the 6082 aluminum specimen had a value of 20,076kN.

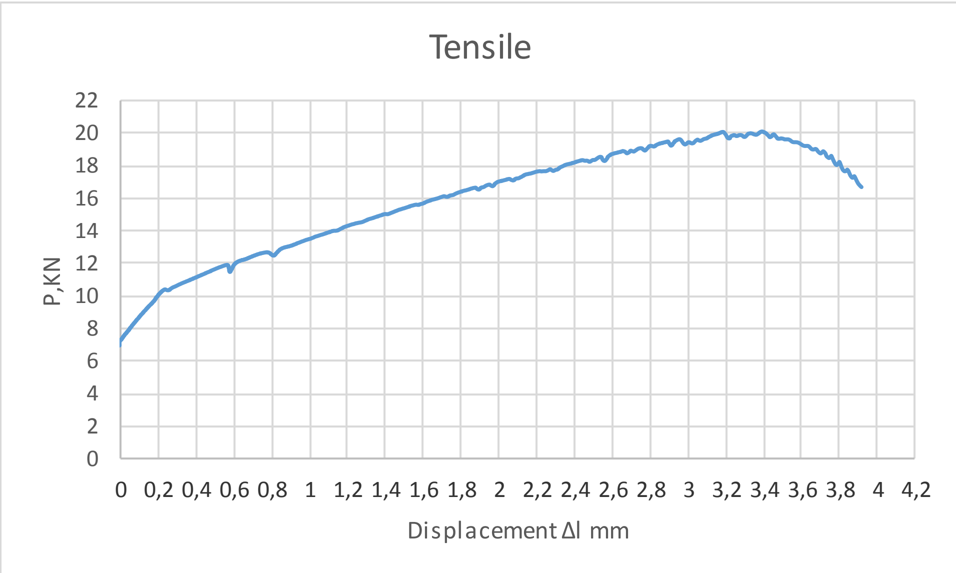


Fig.3.3.1 Diagram of displacement and load ratio when specimen were welded with 120A

The diagram (fig3.3.2) shows maximum load the ultimate tensile strength was 21.198 kN that means 2119.8 kG while displacement was 6.203 mm. The specimen was welded with 135 A current, specimen failure occurs after 56.82 s of the testing and increasing load.

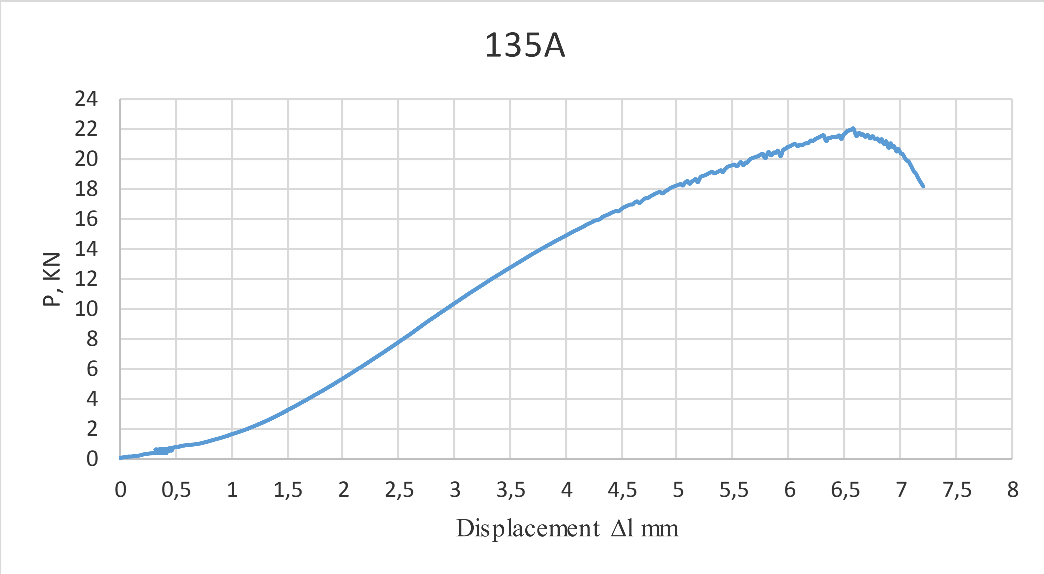


Fig3.3.2 Diagram of displacement and load ratio when specimen were welded with 135A

The diagram (fig3.3.3) shows that the maximum load where the ultimate tensile strength of the 150A welded specimen was 25,278 kN, tensile testing time was 62.5s, maximum displacement was 7.9 mm

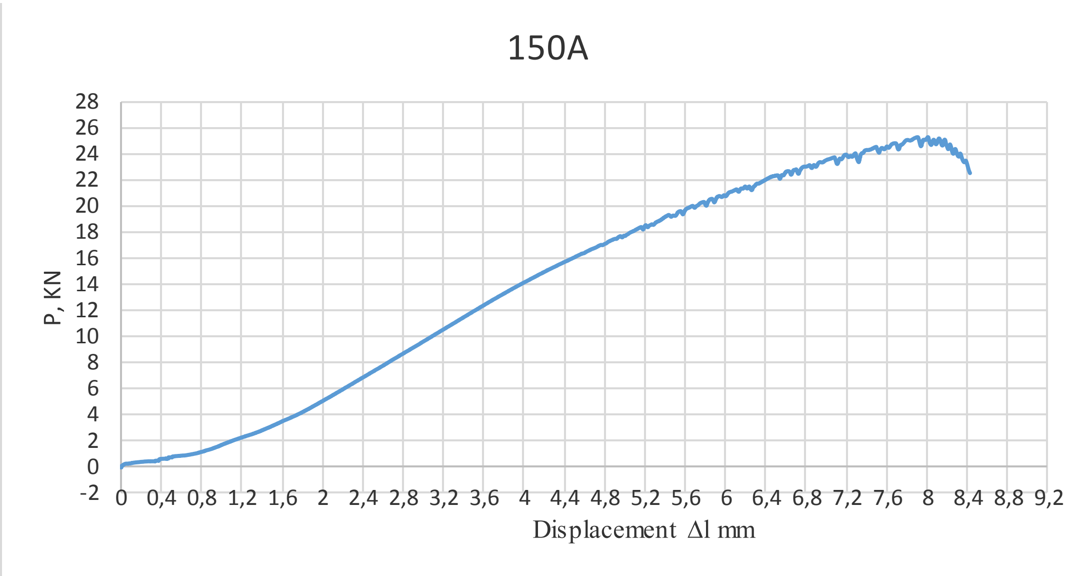


Fig3.3.3 Diagram of displacement and load ratio when specimen were welded with 150A

The diagram (fig3.3.4) shows maximum load where the ultimate tensile strength of the 165A welded specimen was 24.112 kN. This specimen was not welded correctly. During visual examination it had small cracks in the middle of the seam. This crack affected the results which were lower than before with 150A. The maximum displacement was 7.01mm. The duration of the test was 56s.

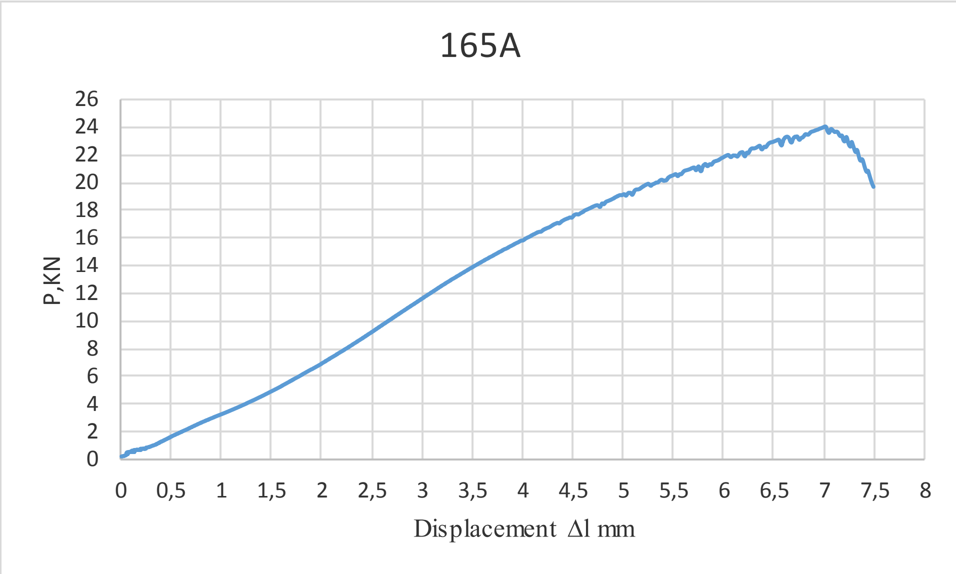


Fig3.3.4 Diagram of displacement and load ratio when specimen were welded with 165A

The diagram shows (Fig3.3.5) specimen which was not welded. This tensile test was made to ensure maximum load of a specimen. Waviness of diagram shows that the specimen has slipped in clampers many times. This specimen failure zone was 31,944KN when displacement were 11.13mm.

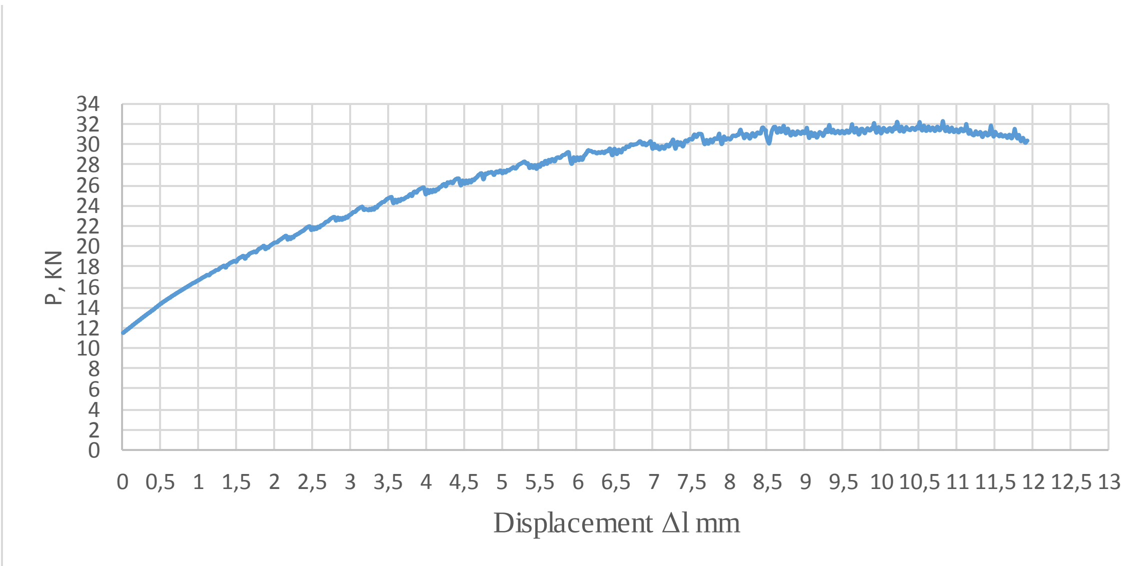


Fig3.3.6 Diagram of displacement and load ratio of a specimen

The specimens after tensile are shown in (fig3.3.6). The number shows AC influence to fracture zones.

Fig3.3.6 welded specimens on after tensile testing procedure.

4. The companies trend of aluminium market in 2010-2015

Distinct price indices associate with different domains of goods and services, such as household consumption, production, investment, and foreign trade flows. Export price indices (XPIs) measure changes in the prices of the goods and services provided by the residents of a given economic territory (usually, country) and used by nonresidents (that is, the rest of the world). Import price indices (MPIs) measure changes in the prices of goods and services provided by nonresidents (rest of the world) and used by residents of the economic territory. XPIs and MPIs, or XMPIs, are the concern of this Manual. Price indices preferably weight the price relative (change) of each specific item they cover by the item's value share. For example, an XPI is a weighted average of the price relatives of its components where the weights are the share of each component in the total value of exports covered by the index. Having collected the appropriate set of prices and the weights, the second question concerns the choice of formula to average the price relatives. Alternative aggregation formulas are considered in Chapters 2, 16–18, and 20–21 of this Manual. The price relatives may take the form of ratios of prices between the current and price reference period of specified representative items with detailed commodity descriptions, so that the prices of like items are compared with like items. Such price relatives can generally be obtained only from establishment surveys. However, unit values for commodity groups may be obtained from customs declarations and their ratios [32].

The export-base model continues to be one of the more widely used in regional economic analyses. Although it has been widely criticized for its theoretical weaknesses (see for example, Krikelas 1992; and Isserman 1980), it remains one of the most widely accepted economic models utilized by economic development practitioners and regional economic policy analysts. The primary reasons for this acceptance are that it is easy to use and the costs associated with implementing alternative methodologies, such as I-O models or Computable General Equilibrium models (CGES), are relatively high [33]. The traditional export-base model is comparatively static in nature. The multipliers derived from the model are used to 'forecast' changes in income or employment attributed to a change in regional exports. Some recent research, however, has applied structural econometric and time-series methodologies to the export-base model (Kraybill and Dorfman 1992; Lesage and Reed 1989; Lesage 1990). This paper departs from the traditional export-base study by applying time-series methodology and combining it with the concept of cointegration introduced by Granger (1983, 1986) [34]. The. model presented in this paper allows sectoral interactions. In addition, the time-series model fully estimates the long-run equilibrium relationships among a region's economic sectors, thereby increasing the efficiency of estimation with nonstationary time-series data. First, the temporal regional multiplier literature is briefly reviewed and a multi-sector economic growth model is developed, in addition to a discussion of the underlying properties of cointegration. This is followed by the construction of dynamic location quotients used in the separation of total employment into export and local employment, the empirical results, and a discussion on the implications of the empirical results in the regional economic analysis [35].

Efficient use of productive factors: The biggest advantage of international trade relates to the advantages accruing from territorial division of labour and international specialization. International trade enables a country to specialize in the production of those commodities in which it enjoys special advantages. All countries are not equally endowed with natural resources and other facilities for the production of goods and services of various kinds. Some countries are richly endowed with land and forest resources, which others happen to have abundant capital resources. Some others have abundant supplies of labour power. Without international trade, a country will have to produce all the goods it requires irrespective of the costs involved. But international trade enables a country to produce only those goods in which it has a comparative advantage or an absolute advantage and import the rest from other countries. This leads to international specialisation or division of labour, which, in turn, enables efficient use of the productive factors with minimum wastages. Specialisation would also lead to economies of scale and which, in turn, would lead to reduction of cost of products and services [36].

The most significant indicator of the success of an export-led growth policy is the change in the structure of demand for domestically produced products. Export-led growth policies are pursued because of the recognition of extraordinary success which some countries have experienced using this strategy.' This is a demand-oriented strategy which relies on the export rather than the domestic market for innovation and industrial growth. But it also has implications for supply. Efficient production of goods destined for export is seen as critical to the performance of the economy as a whole. The underlying premise of the export-led growth approach is that increased foreign demand will result in production efficiencies arising from the positive relationship between the rate of growth of output and the rate of growth of productivity [37].

The new aluminium market in a company have recovered from the economic crisis of 2010-2014, it fell 7 per cent. According to the new manufacturing registration for thousand capital according aluminium products company is only taking the place from the back. The new market is stable, and it is undiscovered. The new market processes - like the European Union. During the twelve months of 2014 the company market increased 1.7 per cent. Products sales increases by almost all major markets: Spain, France, Germany. Each of these markets has those categories of product which requires high quality.

In 2010 – 2014 the quantity of registered parts in factory sales has grown (see table 1) averagely by 22000 thousand and at the end of the four year period there were around 89000 units newly registered

Table 1.1 Number of Registered solded part during 2010-2014

	Years				
	2010	2011	2012	2013	2014
Sold number of parts	1836	1866	1888	1930	1964

It is seen that since 2010 to 2014 quantity of sold in Europe has grown by 128units units. So it's can be said, that the market is growing each year.

Also it is important for us to take into account which product brands are the most popular in Europe. To find out product which are most common in Europe. Statistical registration of company sold parts was taken to analyze market possibility to grow and expect bigger profit from the market. Analyzing the market was products were separated by amount of selling, clients, and product types... Statistical data has been taken from company.

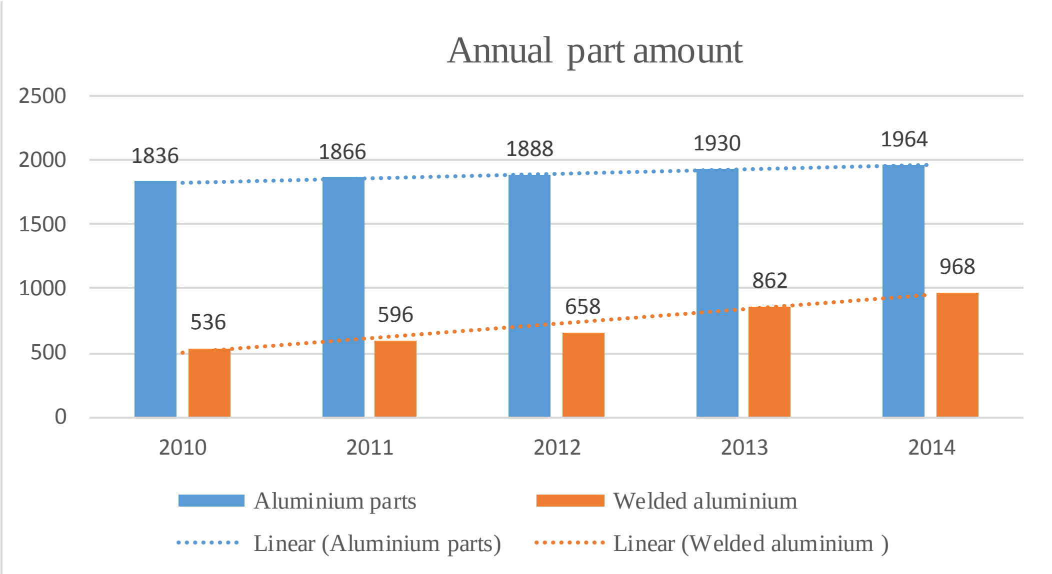
Table 1.2 Company solded parts according to the Brand, Year 2010-2014

	Year				
	2010	2011	2012	2013	2014
Alimak	321	331	333	335	340
Skeie	173	173	173	190	192
Bosal	190	190	200	220	230
Steelcase	141	146	140	143	150
Renhen	108	108	132	132	136
Noreg	660	660	700	670	650
Normet	243	258	218	248	273

It appears that most common part in company are "noreg" and "Alimak" make. Next come "Normet","Bosal",Skeie", and at the end of top are – "Renhen" and "Steelcase". From this diagram we can say that "Noreg" client makes highest profit of sold parts but it is not true, because price calculation depends on a part size, shape, and manufacture process.

To see how popular welded part to our clients we have made new analysis of current make to a company. I have investigated how many part were welded through 2010-1014.

Table 1.3 Statistic of sold parts in 2010-2014



All these statiscs shows that the market of welded part are geting more higher influce in Europe market. Mostly welding operation of all manufacturing process are one of the most expensive operations. The cost of this operation mostly influence size of welding, size of a part welding area, welder quality, gases, wire cost, depreciation of equipment. All these separate part makes hold total price of welding. Also in these diagrams are shown just, aluminium parts which were ordered and welded. Since 2010 year welded parts of aluminium increased by 45 percent of sales what means that the demand of such a kind parts in nowadays are higher thant it was. Mostly aluminium price of welding are 20-50 percent higher than sheet metal welding.

According this statistics number of parts through 2010-2014 was 7 percent of difference. Demand of welded parts are increased more than 40 percent. These results could be affected by European union (EU) market, because all theese part are selling in EU countries. The statistics as well as shows not even market of a company, but also EU recuparation.

4.1. Previous situation of a cost

A welded assembly is made in a discrete welding cell. The total cycle time for the part is 3.4 min.-of welding . Two welds are made on the part: two 2000 cm long butt weld joints,. MIG/MAG is used for all the welds, using the same weld procedure: 1 mm wire and E726-2 electrode; 7,8 m/min wire feed speed; 75%Ar shielding gas; 1m^3 /hour gas flow rate. The shielding time is 20 sec each for the two butt welds, 82 sec each for the two plug welds. Total weldind time is 164 sec. the remainder of the welding cycle time involves removal of the parts from the bin, cleaning oil of the parts, fixturing the pieces, manipulating the fixture, removing the part, cleaning off spatter, visually inspecting the welds and stacking the welded components onto a rack. [38]

L&O*/unit = (welding-related time/unit) x (L&O rate) (2)

Where L&O- labor and operating work cost

L&O*/unit =(3.4 min) x (1 hr/60 min) x (4.39€/hr) = 0.24€/piece

Filler metal cost/unit = (wire fed speed) x (welding time) x (wt. Of electrode/m) x (electrode cost/Kg) (3)

Filler metal cost/unit = (7.8m/min) x (204 sec) x (1 min/ 60 sec) x (0,0096Kg/m) x(6€/Kg)= 1.52€/piece

Shielding gas cost/piece = (flow rate) x (welding time) x (gas cost/m3) (4)

Shielding gas cost/piece = (1 m3 /hr) x (204 sec) x (1 hr/3600 sec) x (13.6€/m3) = 0,77€/piece

Cost/Unit = (L&O/unit) + (filler metal + shielding material cost/unit) (5)

Cost/Unit = 0.24+1.52+0.77=2.53 €/piece

4.2.Current situation of a cost

Lean production accelerates production while eliminating many types of waste such as setup, excess inventory, unnecessary handling, waiting, low equipment utilization, defects, and rework . Lean it provides a way to do more and more with less and less – less human effort, less equipment, less time, and less space – while coming closer and closer to providing customers with exactly what they want.” It is a key prerequisite for Build-to-order and mass customization. The key prerequisites of lean production are product line rationalization and standardization which simplify both the supply chain and manufacturing operations. This will make implementation easier and faster and ensure the success of lean production as well as build-to-order and mass customization.

There are two types of lean production: replacement and spontaneous build-to-order. In replacement lean production parts are common enough to be already built and available to be pulled into assembly from kanban bins. If not, then parts are made by spontaneous build-to-Order with common parts made available through kanban and the non-common parts built on-demand from standard.[38]

There are many opportunities to reduce total cost in supply chains, which are responsible for many unnecessary overhead costs to generate forecasts, count inventory on-hand, generate purchase order inputs through MRP (Material Requirement Planning) systems, place purchase orders, wait for parts to arrive, expedite those that are late, receive (and maybe inspect) materials, warehouse, group into kits for scheduled production, and distribute within the plant. These costly and time-consuming steps can be avoided with a spontaneous supply chain, which is able to pull in materials and parts on-demand [39].

Calculated situation with newier MIG welding machine.

L&O*/unit = (welding-related time/unit) x (L&O rate) (6)

L&O*/unit= (2.9 min) x (1 hr/60 min) x (4.39€/hr) = 0.21€/piece

Filler metal cost/unit = (wire fed speed) x (welding time) x (wt. Of electrode/m) x (electrode cost/Kg) (7)

Filler metal cost/unit = (7.2m/min) x (196 sec) x (1 min/ 60 sec) x (0,0086Kg/m) x(6€/Kg)= 1.21€/piece

Shielding gas cost/piece = (flow rate) x (welding time) x (gas cost/m3) (8)

Shielding gas cost/piece = (0.9 m3 /hr) x (196 sec) x (1 hr/3600 sec) x (13.6€/m3) = 0,66 €/piece

Cost/Unit = (L&O/unit) + (filler metal + shielding material cost/unit) (9)

Cost/Unit = 0.21+121+0.66=2.08€/piece

Difference between welding automats prices are : 21.6 percent

The new automat of welding were cost with all equipment: 10653,38 Eur.
Companies average weldiing load to a day are 23.4 metres a day

Price of welding calculated with old equipment

Total price = (load of a day) * (Cost unit) (10)

Total price of old= 23.4*2.53=59.2Eur

Price of welding calculated with new equipment

Total price = (load of a day) * (Cost unit) (11)

Total price of new = 23.4*2.08=48.67Eur

Difference

Difference = Total price of old- Total price of new (12)

Difference = 59.2-48.67=10.52 Eur

Yearly difference are seenable if we would multiply difference a day with total number of working days in a year.

Yearly difference

Yearly dif.= Difference*Nr of a working days in a years (13)

Yearly dif.= 10.52*251=2640.52Eur

Payback of new welding machine

Payback = price of a machne/ Yearly dif (14)

Payback = 10653.38/2640.52= 4.03 year

Table 1.4 Statistic of comparison between new and old welding machine

	L&O	**Filler metal cost/unit**	**Shielding gas cost/piece**	**Cost/Unit**
Previous situation	0.24€	1.52€	0,77 €	2.53 €
Current situation	0.21€	1.21€	0,66 €	2.08€

A market of economy is related with the price system. Costs of production- finally consist of the cost of a worker hourly rate of working instead of taking a vacation, depreciation of equipment, material price, filler metal cost, shielding gas cost, resource for one purpose, and many other factors which are depends on each different case.

At this table 1.4 are shown comparison results between new and old welding machines which were calculated to realize manufacturing cost. The results was positive. Labor and operating work cost with new welding machine decreased 12.5 percent. It happens because welder through the same time weld the same seam faster. This factor do not have any influence for workers salary because labor working faster. All properties which was calculated decrease price 21 percent. New equipment has controler which automaticaly stops feed rate of wire and gas when the welder swich off the gun swicher thats why in our comparance shielding gas cost decrease by 14.3 percent. The material which are necessary for welding with new equipment has longer time of usability. In the final cost of these two machines we find out that the efficiency of new welding machine are 21.6 percent. At the factory average of welding distance are 23.6 meter. According average distance of welding and efficiecy of welding machine, payback are after 4.03 years.

All calculation was made acording market demands which was increasing from 2010 year. Investigations which were calculated gives positive reaction to invest to new equipment.

5. RESULTS AND DISCUSSIONS

5.1 Hardness testing

Obtained analysis of the hardness distributions on cross section of butt-joints welded by MIG, it can be seen that moving from a base material in the direction of welded joints axis hardness decreases in first specimen which were welded with 120A. Smallest hardness value was found in a fusion zone and it corresponds to about 18 percent of nominal base material hardness. Thermomechanical affected zones are harder than base material. Each case differs by 7 to 15 percent from the base material. Where specimens were welded with a higher than 120A current, the heat affected zone was softer than thermomechanically affected zones. The maximum value achieved was with a current of 165A.

5.2 Tensile testing

In this work tensile tests were used to evaluate the effect of different welding parameters on the mechanical properties, characterise weld deformations, failure ways and evaluate load and displacement of MIG welded specimens. Standard size specimen were used for tensile tests and results were compared with base material standardized specimen.

The results of welding parameters and loads of specimens are presented in diagrams 3.3.1-3.3.6. The curves of diagrams show the results of load and displacement of a specimen. The highest influence on specimens was current. Specimen which were welded using 120A current had minimum tensile strength of all tested specimens – 20.076KN. Maximum tensile strength were found in specimens welded with 150A current, tensile strength was 25.278KN, 21 percent more than in the first case. Higher current should produce higher yield force, but our case was different. Last specimen which were welded with 165A current were with micro cracks which had a large impact for results. The tensile strength was lower 5 percent that in our previous case. All specimens fracture happens through the weld seam (fig 3.3.7) because the wire used has a maximum of 250MPa tensile force. Base material fracture zone was 310MPa which is shown in diagram 3.3.6.

6. CONCLUSIONS

This study investigated MIG butt joints with different welding parameters. It analysed and discussed experimental setup and procedures, background literature, applications of International and European standards evaluation of weld ability and mechanical properties of the thick section in butt joints from structural aluminium AW-6082. MIG has three types of fundamental parameters: feed rate of wire, transmitted power, and alternating current. Different results according to the combination of parameters were found.

The experimental conclusions are as stated below.

1. With the constant voltage and alternative current welding feed rate of a wire would be constant. Variety of welding parameters i.e. alternating current, feed rate of wire has a huge influence on the MIG welding thick section of structural aluminium. The most suitable parameter for 10mm thickness of aluminium specimen of butt joint was 150A alternating current. The voltage used during the experiment 18V ±2V.
2. All welded specimens had different features. Measurements show that the lowest alternating current welded specimen has the highest gap between two welded edges of a specimen. Micro hardness testing shows that the heat affected zone was harder than the thermomechanically affected zone. The difference was 14 HV units. Second test of micro hardness gave us new results because in this case the HAZ was much harder than the THAZ, the difference between these two zones was 10HV units with maximum point 104HV in a second specimen. Third specimen which was welded under 150A shows a fusion zone 7 percent softer than the second specimen. Specimens welded with highest alternative current changed its mechanical properties the most. Specimen zones turned harder. A change on the base metal to 6.3 percent was reflected. Experimental observation shows stronger alternative current affects the material mechanical properties.
3. Comparison tensile experiments with different specimens denote curves increasing with higher alternative current. Minimum tensile force on tested specimens was 20.07kN. Welding was done with 120A current, maximum force used with 150A case reached up to 25.3kN. The specimens which were welded with a higher current had some visible cracks which could be the welder's fault. The fracture zone of a specimen which was not welded was 31.94kN. This fracture zone is the same which was given in a material ISO standard.
4. During the tensile test, each specimen showed cracks through the seam which means that the wire used does not suit this structural aluminium. According to the standard of the wire, the maximum tensile force is 250MPa . Experiment once more time confirmed the maximum load of a wire.

5. Research of this project specifies one variation of MIG welding parameters and metal's ability to react in each case of welding when AC is changing.

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