FINITE ELEMENT ANALYSIS AND WELD EFFICIENCY OF FCAW PROCESS WITH DIFFERENT WELD PARAMETERS ON EN8

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Abstract - *In the welding world,Flux-cored Arc Welding (FCAW) is a process commonly used in different industries to join the metals and alloys. It has a few benefits such as high deposition rates, more tolerance of rust and mill scale than GMAW, simpler and more adaptable than SAW, less operator skill required than GMAW, high productivity than SMAW and good surface appearance. For the repairs industry they are performed by used the Manual Metal Arc Welding (MMAW), however the flux cored arc welding (FCAW) process are more benefits and have been appreciated by the industry for many years Flux Core Arc Welding (FCAW) is an arc welding process that using continuous Flux-cored filler wire. The flux is used as a welding protection from the atmosphere environment. In this project work finally concluded that the changes in valve of heat inputs will lead to affect the thermal distribution on the work piece. From the above experimentation, due to higher heat input, the thermal flux is also increased. If current increased thermal flux gets increased both are directly proportional with each other.*

***Key Words*:** *GMAW, SMAW, MMAW, ANSYS WORKBENCH, SOLIDWORKS, VCR system, performance improvement.*

1. INTRODUCTION

Flux Core Arc Welding (FCAW) uses a tubular wire that is filled with a flux. The arc is initiated between the continuous wire electrode and the work piece. The flux, which is contained within the core of the tubular electrode, melts during welding and shields the weld pool from the atmosphere. Direct current, electrode positive (DCEP) is commonly employed as in the FCAW process. The fluxing agents in self shielded FCAW are designed to not only deoxidize the weld pool but also to allow for shielding of the weld pool and metal droplets from the atmosphere. The flux in gas-shielded FCAW provides for deoxidation of the weld pool and, to a smaller degree than in self-shielded FCAW, provides secondary shielding from the atmosphere. The flux is designed to support the weld pool for out of position welds. This variation of the process is used for increasing productivity of out-of-position welds and for deeper penetration.

1.1 FLUX CORE WELDING PROCESS

Flux core welding or tubular electrode welding has evolved from the MIG welding process to improve arc action, metal transfer, weld metal properties, and weld appearance. It is an arc welding process in which the heat for welding is provided by an arc between a continuously fed tubular electrode wire and the work piece. Shielding is obtained by a flux contained within the tubular electrode wire or by the flux and an externally supplied shielding gas. A diagram of the process is shown in figure.

Flux-cored arc welding is also used in machine welding where, in addition to feeding the wire and maintaining the arc length, the machinery also provides the joint travel. The welding operator continuously monitors the welding and makes adjustments in the welding parameters. Automatic welding is used in high production

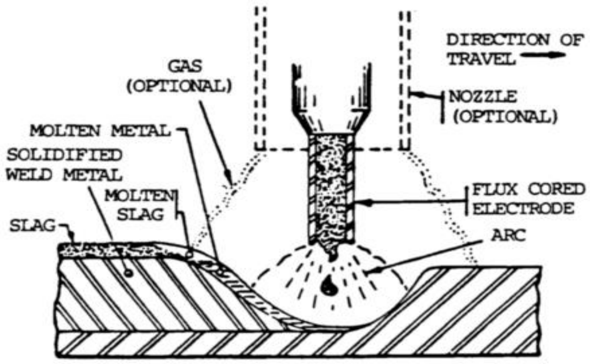


Figure1.1Flux core Arc welding

1.2 SHIELDING GASES

Shielding gas equipment used for gas shielded flux-cored wires consists of a gas supply hose, a gas regulator, control valves, and supply hose to the welding gun. (As noted above flux core can be used without shielding gas depending on the application).The shielding gases are supplied in liquid form when they are in storage tanks with vaporizers, or in a gas form in high pressure cylinders.

Carbon dioxide: Carbon dioxide is manufactured from fuel gases which are given off by the burning of natural gas, fuel oil, or coke. It is also obtained as a by-product of calcining operation in lime kilns, from the manufacturing of ammonia and from the fermentation of alcohol, which is almost 100 percent pure. **Argon and carbon dioxide** are sometimes mixed for use with flux-cored arc welding. A high percentage of argon gas in the mixture tends to promote higher deposition efficiency due to the creation of less spatter. The most commonly used gas mixture in flux-cored arc welding is a 75 percent argon-25 percent carbon dioxide mixture.

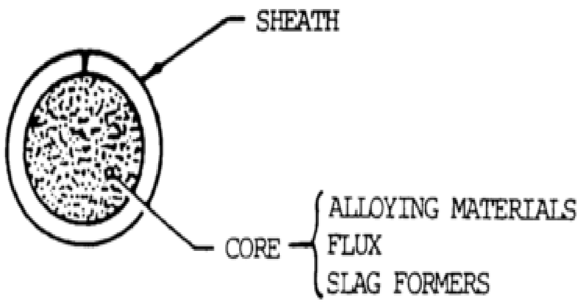


Figure 1.2 ELECTRODES

1.3 ELECTRODES

The electrodes used for flux-cored arc welding provide the filler metal to the weld puddle and shielding for the arc. Shielding is required for sane electrode types. The purpose of the shielding gas is to provide protection from the atmosphere to the arc and molten weld puddle. The chemical composition of the electrode wire and flux core, in combination with the shielding gas, will determine the weld metal composition and mechanical properties of the weld. The electrodes for flux-cored arc welding consist of a metal shield surrounding a core of fluxing and/or alloying compounds as shown in figure . These functions are:

1. To form a slag coating that floats on the surface of the weld metal and protects it during solidification.
2. To provide deoxidizers and scavengers which help purify and produce solid weld-metal.
3. To provide arc stabilizers which produce a smooth welding arc and keep spatter to a minimum.
4. To add alloying elements to the weld metal which will increase the strength and improve other properties in the weld metal.

1.3.1 Classification System for Tubular Wire Electrodes

The classification system used for tubular wire electrodes used as part of flux core welding was devised by the American Welding Society. Carbon and low alloy steels are classified on the basis of the following items:

1. Mechanical properties of the weld metal.
2. Welding position.
3. Chemical composition of the weld metal.
4. Type of welding curre.

1.4 WELDING ENERGY AND HEAT INPUT

In GMAW a sufficient amount of power (energy transferred per unit time) and energy density is applied to the electrode and this cause melting. Heat input is a relative measure of the energy transferred per unit length of weld. It is an important characteristic because it influences the cooling rate, which may affect the mechanical properties and metallurgical structure of the weld and the HAZ .Heat input is typically calculated as the ratio of the power (i.e., voltage x current) to the velocity of the heat source as follows:

Q = η 1000*V* 60EI

Q = Heat input (kJ/mm)

E =Welding voltage (volts)

I = welding current (amps)

V = Travel speed (mm/min)

η = efficiency factor for GMAW is 0.8.

The above equation is useful for comparing different welding procedures for a given welding process. Heat input increases, the rate of cooling decreases for a given base metal thickness.

1.5 WELDING MATERIALS

The GMAW process can be operated in semi-automatic and automatic modes. All commercially important metals, such as carbon steel, high-strength low-alloy steel, stainless steel, and aluminum, copper, and nickel alloys can be welded in all positions by this process if appropriate shielding gases, electrodes, and welding parameters are chosen.

1.6 APPLICATIONS

FCAW may be an "all-position" process with the right filler metals (the consumable electrode)

1. No shielding gas needed with some wires making it suitable for outdoor welding and/or windy conditions.
2. A high-deposition rate process (speed at which the filler metal is applied) in the 1G/1F/2F.
3. Some "high-speed" (e.g., automotive) applications.
4. As compared to SMAW and GTAW, there is less skill required for operators.
5. Less pre cleaning of metal required.

1.7 SCOPE OF THE PROJECT

The main objective of the project is during the welding process we have to get the minimum changes in the physical properties and no metallurgical defect is present. Defect free welding process should be made. To achieve a good weld of different grades of carbon material.

2. LITERATURE REVIEW

2.1 INTRODUCTION

In the welding world, Flux-Cored Arc Welding (FCAW) is a process commonly used in different industries to join metals and alloys. It has a few benefits such as high deposition rates, more tolerance of rust and mill scale than GMAW, simpler and more adaptable than SAW, less operator skill required than GMAW, high productivity than SMAW and good surface appearance.

Syarul Asraf Mohammad [1] et.al Flux Core Arc Welding (FCAW) is an arc welding process that uses continuous flux-cored filler wire. The flux is used as a welding protection from the atmosphere environment. 30V respectively. 20, 40 and 60 cm/min were chosen for the welding speed. The effect will be studied and measured on the penetration, microstructure and hardness for all specimens after the FCAW process. From the study, the result showed increasing welding current will influence the value of depth of penetration increased.

B. Senthilkumar [2] Weld surfacing with super duplex grade stainless steel found to improve corrosion resistance and functional life of the mild steel components used in the process industries. The influence exerted by the process variables on the responses of super duplex stainless steel claddings were modeled using the response surface models. The response surface models developed by the regression techniques using the data collected from central composite rotatable design of experiments.

A. Aloraier [3] et.al Post weld heat treatment (PWHT) is the most common technique employed for relieving residual stresses after general repair welding. Besides, the primary purpose of reducing the effect of stresses induced by welding, PWHT is also intended to temper the metallurgical structure of the heat affected zone (HAZ). Unfortunately, there are significant difficulties in carrying out post weld heat treatment such as; the complexity of weld geometry,, and also PWHT may cause degradation of the material properties (especially creep and tensile strength in the case of multi PWHT cycles).

N.B. Mostafa [4] et.al This paper describes prediction of weld penetration as influenced by FCAW process parameters of welding current , arc voltage , nozzle-to-plate distance, electrode-to - work angle and welding speed .Optimization of these parameters to maximize weld penetration is also investigated. It deals with the statistical technique of central composite rotatable design to develop a mathematical model for predicting weld penetration as a function of welding process parameters.

Li Yajiang, [5] et a carried out the distribution of the residual stress in the weld joint of HQ130 grade high strength steel was investigated by means of finite element method (FEM) using ANSYS software. Welding was carried out using gas shielded arc welding with a heat input of 16 kJ/cm. The FEM analysis on the weld joint reveals that there is a stress gradient around the fusion zone of the weld joint.

3. WELDING PROBLEM ON DISSIMILAR STEEL

3.1 PROBLEM IDENTIFICATION

In many cases the welder needs only to know the techniques of actual welding and does not need to be concerned about the type or grade of steel being welded. This is because a large amount of steel used in fabricating a metal structure is low Carbon or plain carbon steel (also called mild steel). When welding these steels with any of the common arc welding processes like Stick Mig or Tig there are generally few precautions necessary to prevent changing the properties of the steel.

3.2 THE EFFECT OF WELDING ON CARBON STEEL

Steel is an alloy, or metallic mixture, containing primarily iron. A variety of other metals, such as carbon, are used to promote certain properties in the alloy. Carbon has a strengthening effect when added to iron.

3.2.1 Carbon Rating: There are different types of steel available, including several varieties of carbon steel. Low-carbon steel contains a maximum concentration of 0.3 percent carbon, while high-carbon steel contains a maximum concentration of 1% percent carbon.

3.2.2 Carbon in Steel: Carbon strengthens steel, but also reduces its ductility, or pliability. The low ductility of high-carbon steel makes it more difficult to weld.

3.2.3 Effects of Welding on High-Carbon Steel

- When welding high-carbon steel, a high concentration of martensite may form in the weld. Martensite makes the metal extremely brittle, causing a weak weld that may break as soon as it cools.

3.2.4 Welding High-Carbon Steel

- According to ESAB Welding and Cutting, Inc., a low hydrogen electrode must be used when welding high-carbon steels. Additionally, annealing, or heating, the metal prior to welding slows the cooling process and prevents the concentration of martensite.

3.3 WELDING EFFECTS:

In the correct sense of the word, a defect is a reject able discontinuity or a flaw of reject able nature. Certain flaws acceptable in one type of product. A defect is definitely a discontinuity, but a discontinuity need not necessarily be a defect. Acceptance or rejection of flaws is based on different factors and to mention a vital few are:

- Stresses to which the parts will be subjected during service and Type of material used.
- The temperature and pressure to which the parts will be stressed.Its thickness
- The environment (corrosive or non-corrosive),Safety.

- Cost and accessibility for repair, etc & Consequences of failure.

The weld defects can be broadly classified into two types. They are:

- Planar defects/ two dimensional defects.
- Voluminar defects / three dimensional defects.

3.4 GENERAL REASONS FOR DEFECTS

The importance of weld quality is increasingly felt as we go ahead with the fabrication of sophisticated products using higher strength materials combined with critical design consideration. However, defects are likely to be present in materials produced at economic cost. Defects are generally introduced because of:

- Lack of knowhow and experience and welding process characteristics.
- Base metal composition.Defective welding filler metals.
- Joint design. & welding environment (wind, fit up, temperature, etc.)

3.5 TYPE OF DEFECTS AND THEIR SIGNIFICANCE.

3.5.1 Defects Involving Inadequate Bonding

- Lack of fusion
- Incomplete penetration

4. WELDING AND MATERIAL DETAILS

4.1 MIG WELDING

For this welding investigation the sun power MIG 500 IGBT machine was used with flux cored filler rod.

4.2 INTRODUCTION OF EN8 STEEL

WORK MATERIAL DETAILS

Work material – EN 8 steel

Work material size–100 X 100 mm Square plate 6 mm thickneSS

4.2.1 CHEMICAL PROPERTIES

Table 4.2 Chemical properties

C	C	Mn	Si	S	P	Cr
EN 8	0.42	0.65	0.20	0.026	0.015	0.01

4.3 PHYSICAL PROPERTIES

Table 4.3 Physical properties

SL.NO	PROPERTIES	VALUE
1.	Ultimate Tensile strength (Mpa)	700
2.	Yield Stress (Mpa)	465
3.	Elongation (%)	16
4.	Density(Kg/m^3)	7833.413
5.	Hardness(HRC)	201

4.3.1 APPLICATION

EN 8 steel is a high tensile alloy steel and wear resistance properties and also where high strength properties are required. EN8 is used in components subject to high stress and with a large cross section. This can include aircraft, automotive and general engineering applications for example propeller or gear shafts, connecting rods, aircraft landing gear components.

5. EXPERIMENTAL DESIGN

5.1 TAGUCHI INTRODUCTION

Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of the process parameters is the level with the greatest S/N ratio Furthermore, statistically significant with the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. They are

1. Smaller-The-Better,
2. Larger-The-Better,
3. Nominal is Best.

SMALLER IS BETTER

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the smaller-is-better S/N ratio using base 10 log is:

$$S/N = -10*\log(S\ (Y^2)/n)$$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination.

LARGER IS BETTER

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the larger-is-better S/N ratio using base 10 log is: $S/N = -10*\log(S\ (1/Y^2)/n)$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination.

NOMINAL IS BEST

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the nominal-is-best I S/N ratio using base 10 log is: $S/N = -10*\log(s^2)$

Where s = standard deviation of the responses for all noise factors for the given factor level combination.

5.2 DESIGN OF EXPERIMENT

Table 5.1 Process parameters and their levels

LEVELS	PROCESS PARAMETERS		
	WELDING CURRENT AMPS I	ARC VOLTAGE V	BEVEL ANGLE °
1	140	18	65
2	180	22	70

MINITAB-17 SOFTWARE

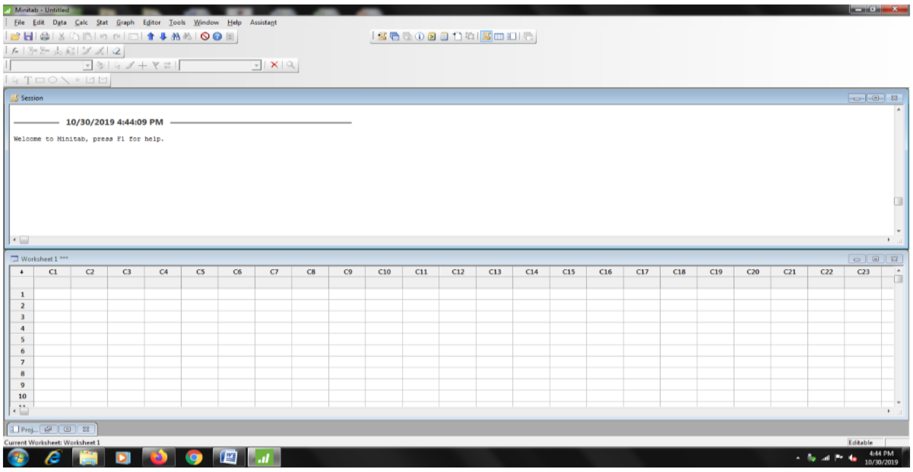


Figure 5.1 Minitab software

5.3 DESIGN OF ORTHOGONAL ARRAY

First Taguchi Orthogonal array is designed in minitab-16 to calculate S/N ratio and means which steps are given below. Create Taguchi Design is selected as shown in figure. Then a window of Taguchi design is opened. To start Minitab, click the shortcut of Minitab on Desktop of the computer. A window is opened in computer as shown in Figure 5.2.

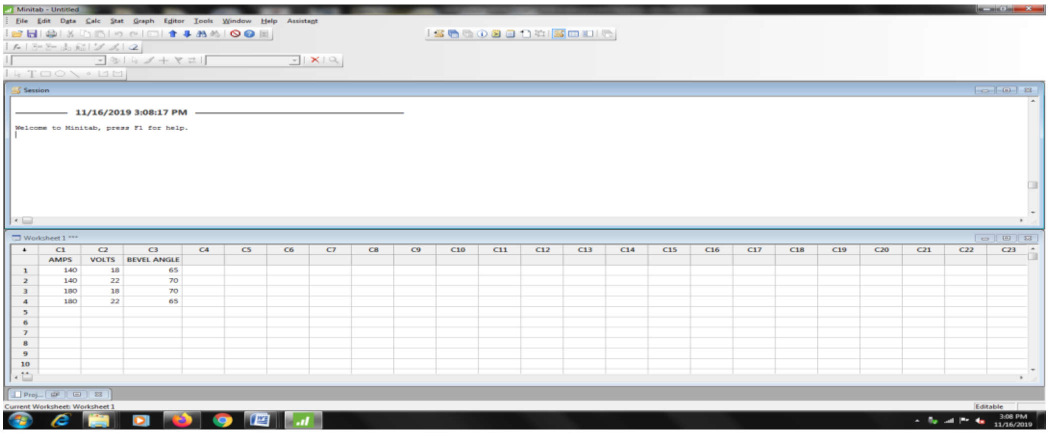


Figure 5.2 Create Taguchi Design

5.4 AN ORTHOGONAL ARRAY L8 FORMATION (INTERACTION)

Table 5.2 L8 Array formation

AMPS	VOLTS	BEVEL ANGLE	TEMP
140	18	65	1300
140	22	70	1350
180	18	70	1450
180	22	65	1500

6. INTRODUCTION TO ANSYS

ANSYS, Inc, founded in 1970 as Swanson Analysis Systems, Inc, develops and globally markets engineering simulation software and technologies widely used by Engineers and designers across a broad spectrum of industries including aerospace, automotive, manufacturing, electronics and biomedical. It also focuses on the development of open and flexible solutions that enable users from decision concept to final stage testing and validation.

The following modules are available with ANSYS/Multiphysics:

1. Structural. 2. Thermal. 3. CFD. 4. Acoustics. 5. Electromagnetic. 6. Coupled fluid.

With the following solvers namely.

1. Iterative. 2. Direct. 3. Eigen solver. 4. CFD

Structural allows us to perform.

a. Linear.

b. Non-linear.

c. Static.

d. Dynamic.

1. Geometric. 2. Material. 3. Elements. 4. Contact.

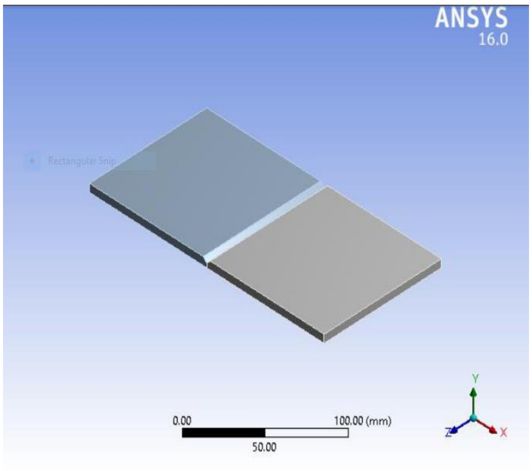


Fig-6.1 Geometry Modal**.**

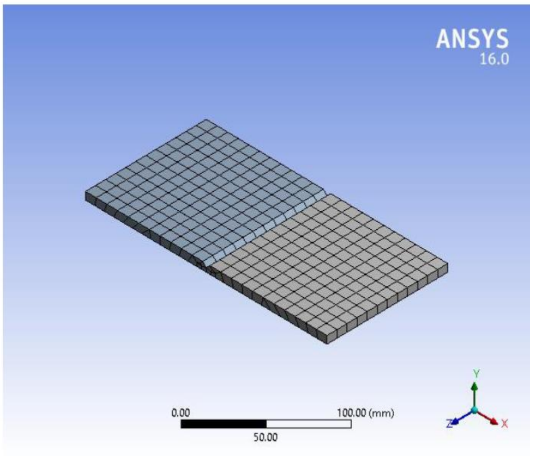


Fig-6.2 Mesh Modal.

1. $A_1B_1C_1$

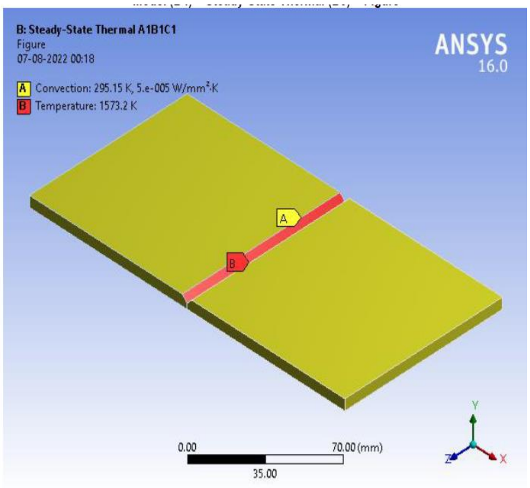


Fig-6.3 Boundary Condition of $A_1B_1C_1$.

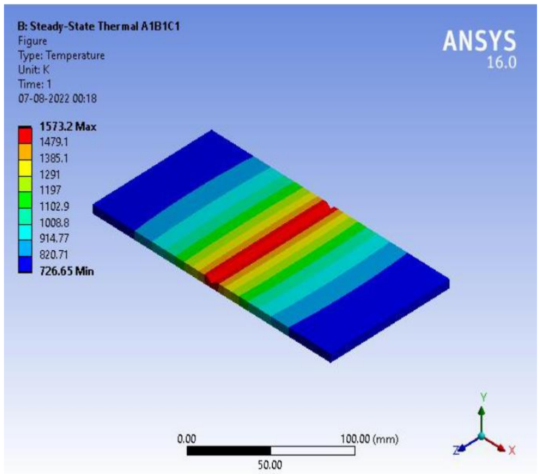


Fig-6.4 Temperature Distribution of $A_1B_1C_1$

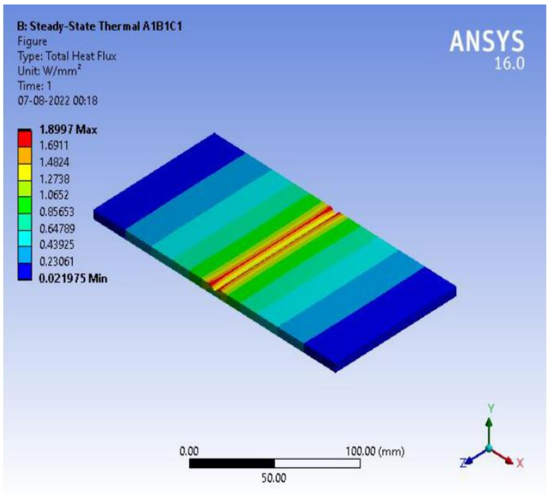


Fig-6.5 Total Heat Flux of $A_1B_1C_1$.

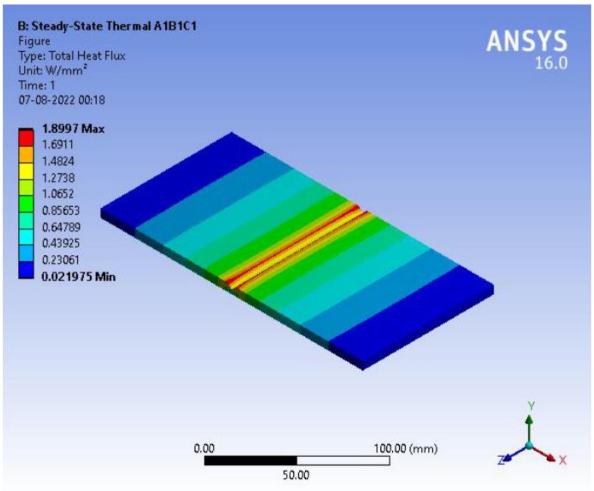
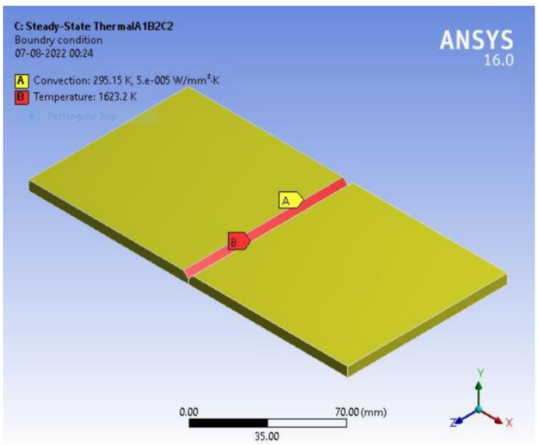


Fig-6.6 Directional Heat Flux of $A_1B_1C_1$

2. $A_1B_2C_2$.



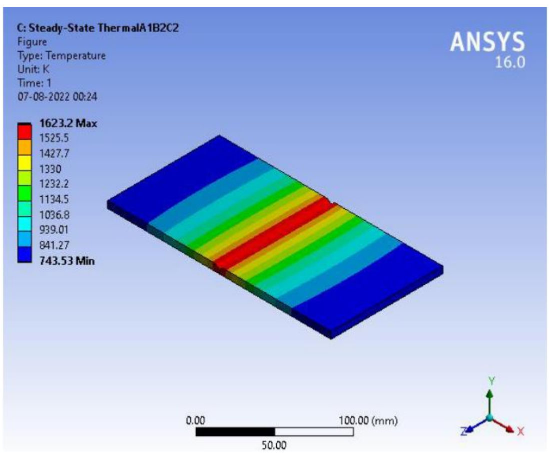


Fig-6.7 Boundary Condition of $A_1B_2C_2$.

Fig-6.8 Temperature Distribution of $A_1B_2C_2$

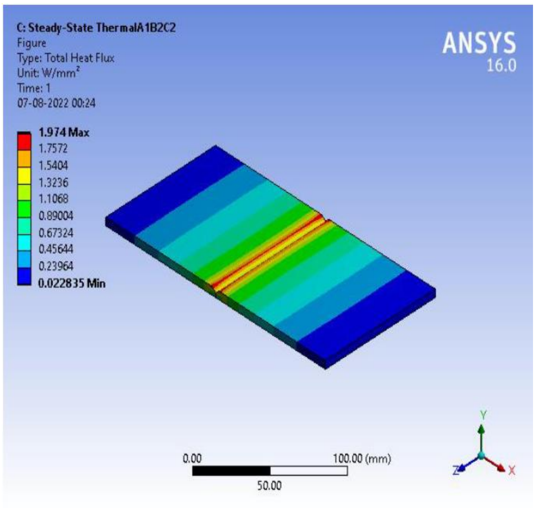


Fig-6.9 Total Heat Flux of $A_1B_2C_2$

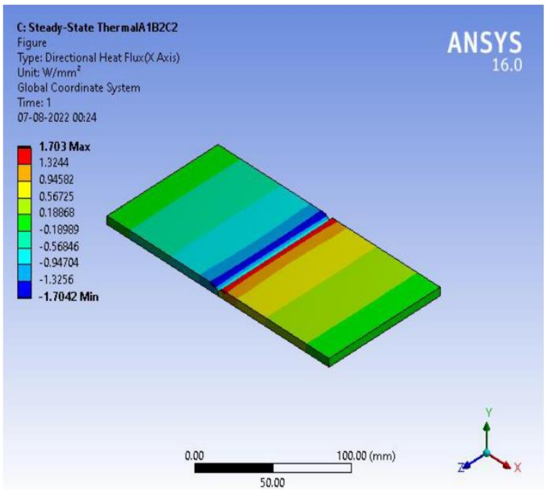


Fig-6.10 Directional Heat Flux of $A_1B_2C_2$

4. $A_2B_2C_1$

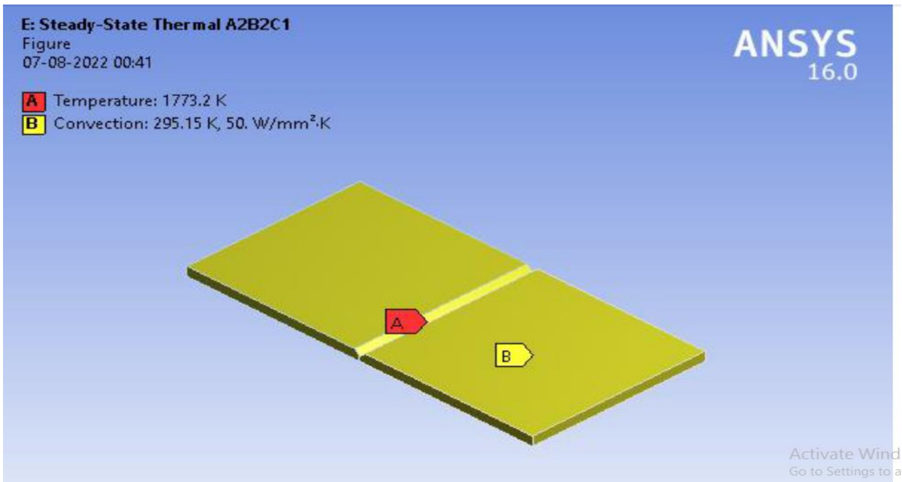


Fig-6.15 Boundary Condition of $A_2B_2C_1$

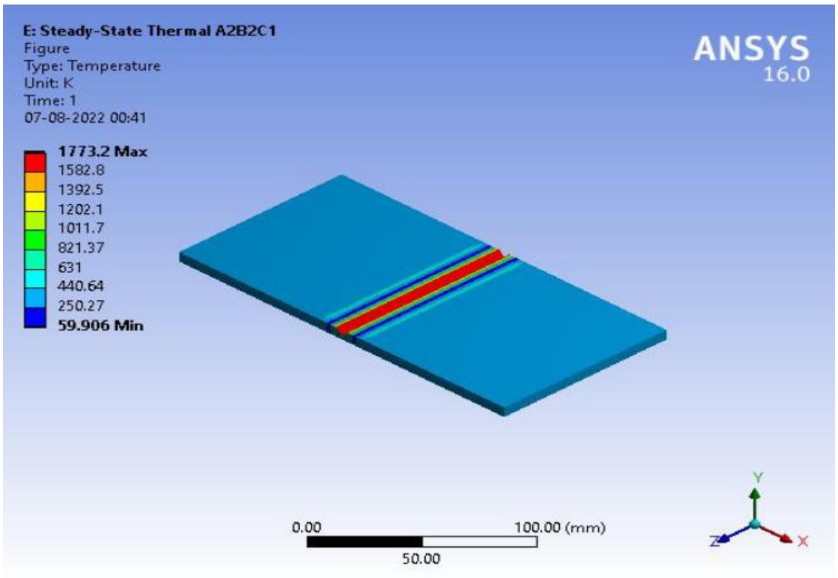


Fig-6.16 Temperature Distribution of$A_2B_2C_1$

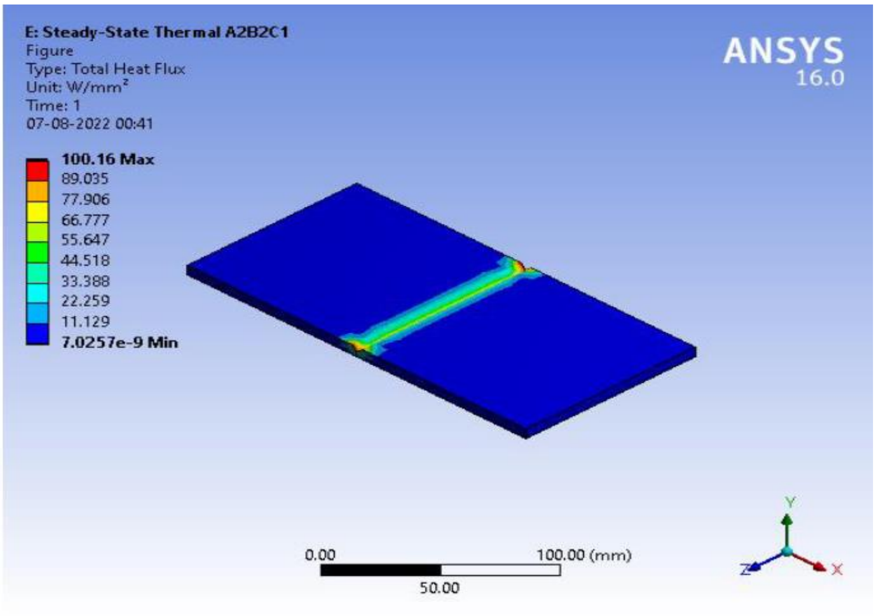


Fig-6.17 Total Heat Flux of$A_2B_2C_1$

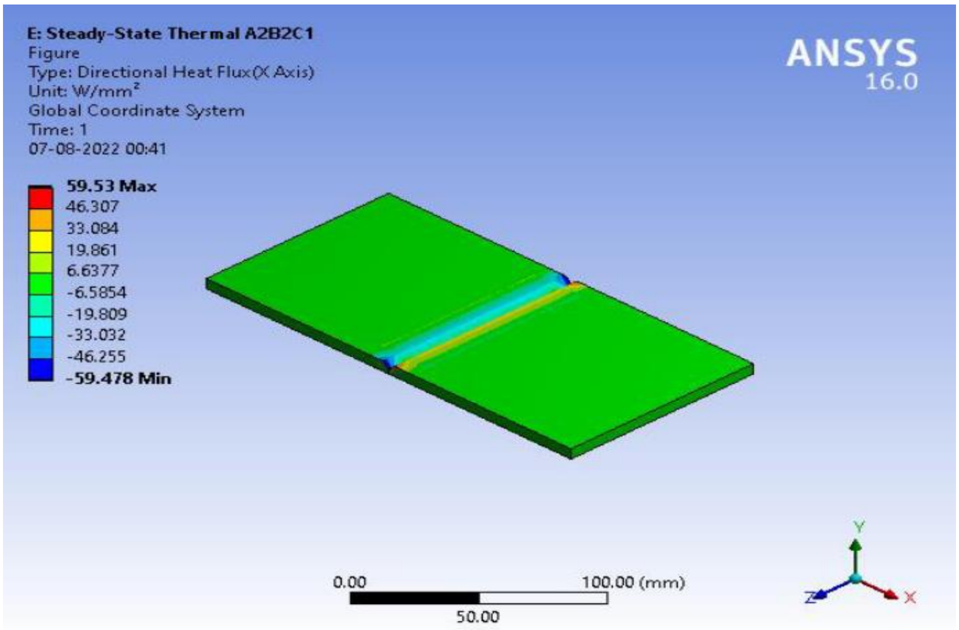


Fig-6.18 Directional Heat flux

Table 6.1 THERMAL ANALYSIS TABLE FCAW –EN8

Dign	Temperature (K)		Total Heat Flux (W/m^2)		Directional Heat Flux (W/m^2)	
	Min	Max	Min	Max	Min	Max
$A_1B_1C_1$	1	$A_1B_1C_1$	726.65	1573.2	0.021975	1.8997
$A_1B_2C_2$	2	$A_1B_2C_2$	743.53	1623.2	0.022835	1.974
$A_2B_1C_2$	3	$A_2B_1C_2$	67.864	1723.2	6.7881e-9	96.776
$A_2B_2C_1$	4	$A_2B_2C_1$	59.906	1773.2	7.0257e-9	100.16

6.1 ANSYS CONCLUSION

In this project work finally concluded that the changes in value of heat inputs will lead to affect the thermal distribution on the work piece. From the above experimentation, due to higher heat input, the thermal flux is also increased If current increased Thermal flux gets increased both are directly proportional with each other. If the current maximum Thermal gradient also increases both are directly proportional with each other.

7. CONCLUSION

The various Input parameters were selected for EN 8 for the FCAW process through the Taguchi approach. The test plates were analyzed with FEA due to higher heat input, the thermal flux also increased. If current increased Thermal flux gets increased both are directly proportional with each other. If the current maximum Thermal gradient also increases both are directly proportional with each other.

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