Relation between Different Process Parameters in Gas Metal Arc Welding

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DOI : 10.22486/iwj/2019/v52/i2/181779

ABSTRACT

In this paper, relation between different process parameters has been shown. Mainly six variables were taken which are types of welding, types of material, wire type, wire diameter, types of gas used, CTWD, polarity, etc.... Here types of welding process took as the means only gas meal arc welding has been shown. About fifteen types of welding processes were considered by varying the above given variables. By changing those variables the variation in wire feed speed (WFS) and voltage by changing material thickness has been displayed in the tables. The relation between workpiece thickness with WFS and also with voltage was presented through different graphs in all the fifteen processes of welding.

Keywords : Welding; gas metal arc welding; GMAW; process parameters; material thickness.

1.0 INTRODUCTION

The joining of metal with same or different composition with the help of application heat and pressure is called welding. There are many types of welding. Arc welding is one of them. In arc welding the heat is generated by formation of an arc between electrode and workpiece. Different categories of arc welding are there among which gas metal arc welding has been used to describe the relation between process parameters in this paper. Welding is essential in many production companies. A lot of research works have been done on improvement of weld quality in welding. Research in welding is now a growing field in the world. Recently, many research works are going on different problems in welding operation and how to improve the weld quality. Huissoon et al. [1] developed a model to control the process parameters to get the desire responses. Murugan et al. [2] presented a mathematical model by using design matrix and fivelevel factorial techniques to correlate between input parameters and bead geometry as response by using steel as workpiece material. Abbasi et al. [3] examined the influence of input parameters on weld quality in metal inert gas welding. Moon et al. [4] established a relation between the controllable parameters and responses by taking fuzzy algorithm and neural network to improve weld quality with more accuracy. Garg [5] took mild steel samples to examine the effect of different input parameters on responses by using RSM optimization.

Simulation of fusion welding by finite element method was described by Anca et al. [6]. Sapakal and Telsang [7] have been taken different input welding parameters to find out the effect of the above parameters on depth of penetration as response with the help of Taguchi optimization by taking steel as workpiece material and they found that welding voltage mostly effect on depth of penetration then other parameters.

Haragopal et al. [8] constructed a new design for input parameters to optimize the different output responses of Aluminum alloy. Pal et al. [9] discussed the effect of different input parameters on the tensile strength of welded specimen.

Lincoln Electric [9] which is a USA based company works on mainly different welding processes. The welding experts of their company first virtually operate the welding operation and after that experimental validation was taken place. For error free joint, they found out by changing the workpiece thickness what should be the wire feed rate and voltage of welding. In this paper, fifteen welding process are explained and relation between material thickness and wire feed rate and also workpiece thickness and welding voltage taking other parameters constant using mild steel as workpiece material.

2.0 WELDING PROCESSES

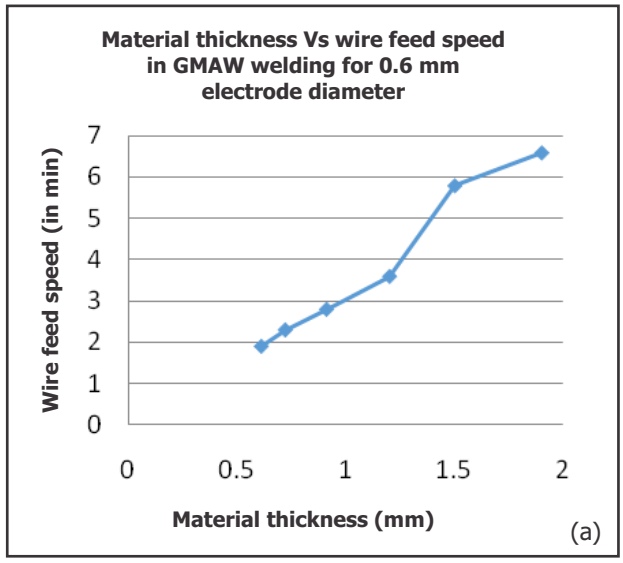
Lincoln Electric mainly took 10 parameters which are types of welding, types of material, wire type, wire diameter, type of welding gas, contact tip to work distance (CTWD), polarity, workpiece thickness, wire feed speed and welding voltage. According to variation of different welding parameters by using steel as workpiece material, there are fifteen welding processes, and how by changing the workpiece thickness there is variation occurring in wire feed, speed and voltage are presented in the form of graphs. In all the welding processes, the common things that have been the same are the type of welding and workpiece material. Gas metal arc welding as welding process and steel as workpiece material have been used. The details of parameters to be applied are specified in each process.

Welding process-1

- Type of welding- gas metal arc welding (GMAW)
- Types of material- steel
- Wire type- super arc, L-50, L-56, L-59
- Wire diameter- 0.6mm
- Gas-75% Ar+ 25% CO_2
- CTWD- 9.525mm
- Polarity- DC+
- A= workpiece thickness (mm), B= Wire feed speed (WFS)(m/min), C= voltage

Table 1 : Process parameters of welding process 1

A	B	C
0.61	1.9	15
0.72	2.3	15
0.91	2.8	15
1.2	3.6	16
1.5	5.8	17
1.9	6.6	17



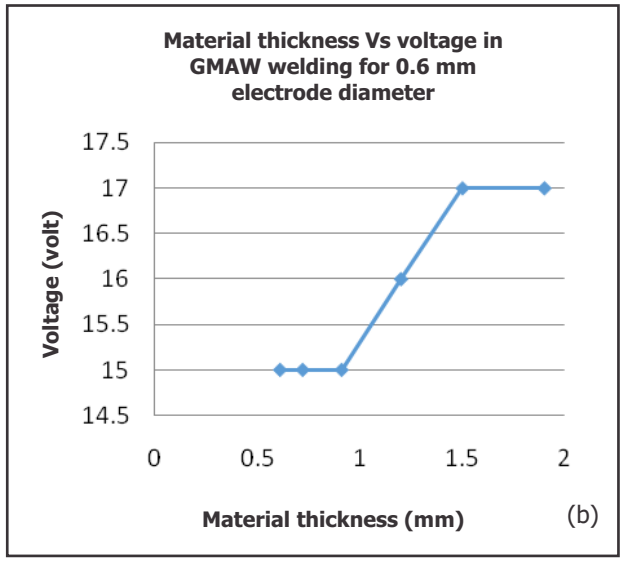


Fig. 1 : (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 0.6 mm electrode diameter

In **Fig. 1(a)** the graph between material thickness and wire fees speed shows that with increase in material thickness we have to increase the wire feed speed for good quality of welding. According to **Fig. 1(b)** from 0.61 to 0.91 mm material thickness the welding process requires constant voltage i. e. 15 volts. After that from 0.91 to 1.5 mm material thickness voltage also increases from 15 volt to 17 volt and again voltage again becomes constant for change in workpiece thickness from 1.5 mm to 1.9 mm.

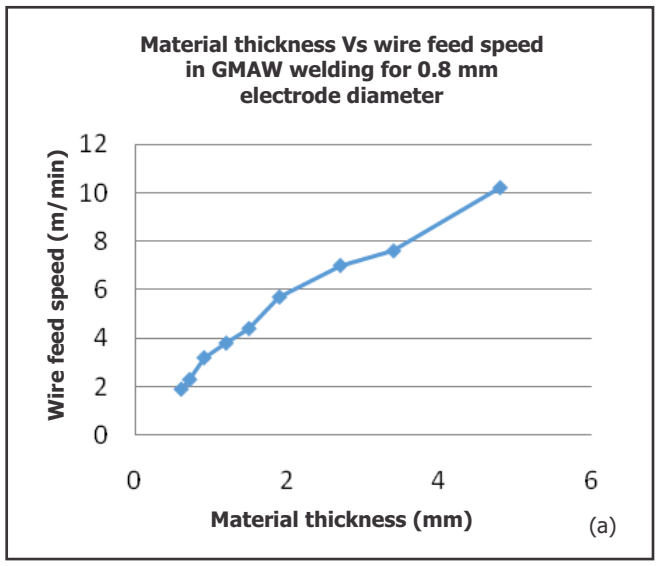
Welding process-2

- Type of welding - gas metal arc welding (GMAW)
- Types of material - steel
- Wire type - super arc, L-50, L-56, L-59
- Wire diameter - 0.8mm
- CTWD - 9.525mm
- Gas - 75% Ar+ 25% Co_2
- A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C= voltage

Table 2 : Process parameters of welding process 2

A	B	C
0.61	1.9	15
0.72	2.3	15
0.91	3.2	16
1.2	3.8	16
1.5	4.4	17
1.9	5.7	18
2.7	7	19
3.4	7.6	20
4.8	10.2	21

As per the graph **Fig. 2(a)** with increases in material thickness wire feed speed also increases but the graph is not a state line. In case of **Fig. 2(b**) the material thickness increases from 0.61 to 0.72 mm voltage remain constant i. e. 15 volt. From 0.72 mm to 0.91 mm voltage increases to 16 volt. Again from 0.91 to 1.2 mm voltage remains same i. e. 16 volt. After that voltage increases with increase in material thickness.



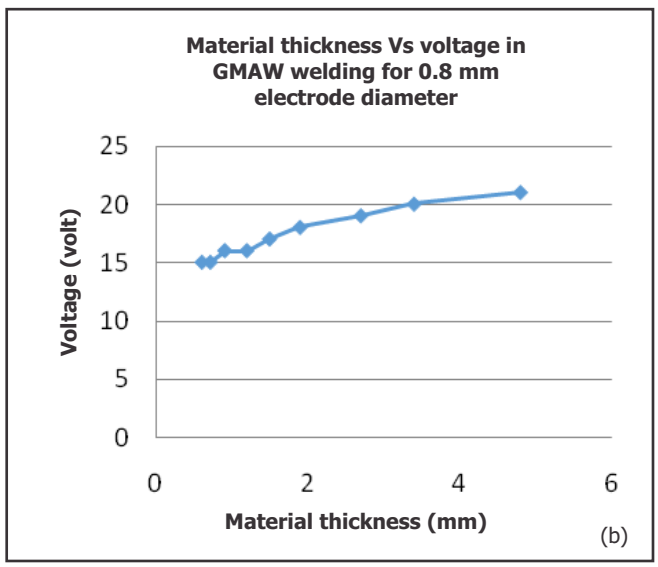


Fig. 2 : (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 0.8 mm electrode diameter

Welding process-3

- Type of welding - gas metal arc welding (GMAW)
- Types of material - steel
- Wire type - super arc, L-50, L-56, L-59
- Wire diameter - 0.9 mm
- CTWD - 12.700 mm
- Gas - 75% Ar+ 25% CO_2

A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C= voltage

Table 3 : Process parameters of welding process 3

A	B	C
0.91	2.5	16
1.2	3	16
1.5	3.8	17
1.9	4.4	18
2.7	5.7	19
3.4	6.4	20
4.8	8.9	21
6.4	9.5	22
7.9	11.4	23

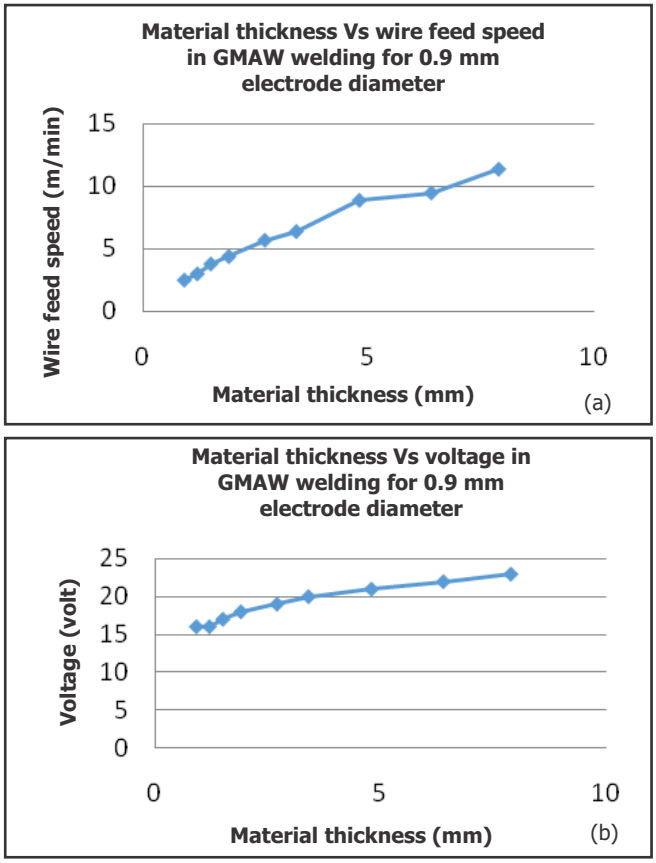


Fig. 3: (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 0.9 mm electrode diameter

From 0.91 mm to 7.9 mm thickness the WFS also increase with non-linearly as per graph **Fig. 3(a)** and from 0.91 to 1. 2 mm thickness of material there is not any change in voltage and then voltage increases with increase in material thickness. According to **Fig. 3(b)** with increase in material thickness there is less increase in voltage for 0.9 mm electrode diameter by taking 75%Ar+25%CO_2 as shielding gas.

Welding process-4

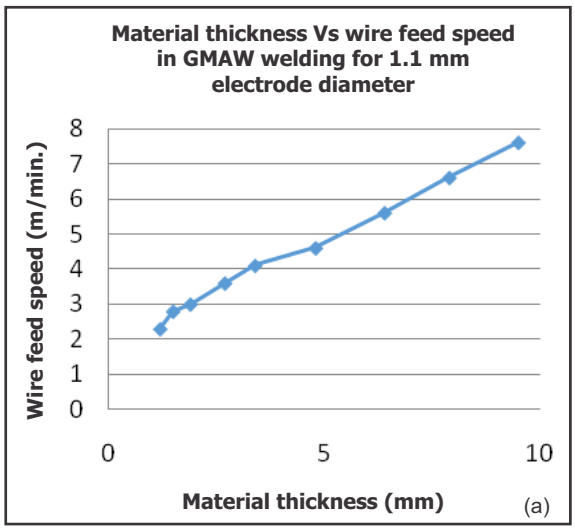
- Type of welding - gas metal arc welding (GMAW)
- Types of material - steel
- Wire type- super arc, L-50, L-56, L-59
- Wire diameter- 1.1mm
- CTWD - 19.050mm
- Gas - 75% Ar+ 25% CO_2

A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C= voltage

Table 4 : Process parameters of welding process 4

A	B	C
1.2	2.3	15
1.5	2.8	16
1.9	3	16
2.7	3.6	16
3.4	4.1	17
4.8	4.6	17
6.4	5.620	
7.9	6.6	22
9.5	7.6	23

The welding process 4 is same as process 3. The main difference is electrode diameter in case of process 4 which is 1.1 mm and CTWD is 19.050 mm. Both WFS and voltage increase with change in workpiece thickness from 1.2 mm to 9.5 mm. Wire feed speed starts from 2.3 m/min to 7.6 m/min and voltage varies from 15 volts to 23 volts. In **Fig. 4(a)** change in workpiece thickness from 1.2 mm to 9.5 mm WFS also increases from 2.3 m/min to 7.6 m/min. But in **Fig. 4(b)** material thicknesses from 1.2 to 1.2 mm voltage increases from 15 to 16 volt then voltage remains constant from change in workpiece thickness from 1.5 to 2.7 mm. Then from 2.7 to 3.4 mm thickness voltage increases from 16 to 17 volt and 3.4 to 4.8 voltages remains constant. Then from 4.8 to 9.5 material thicknesses voltage goes on increasing way.



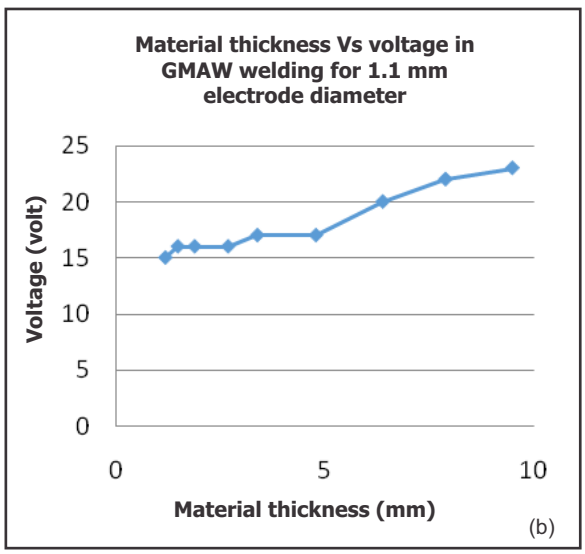


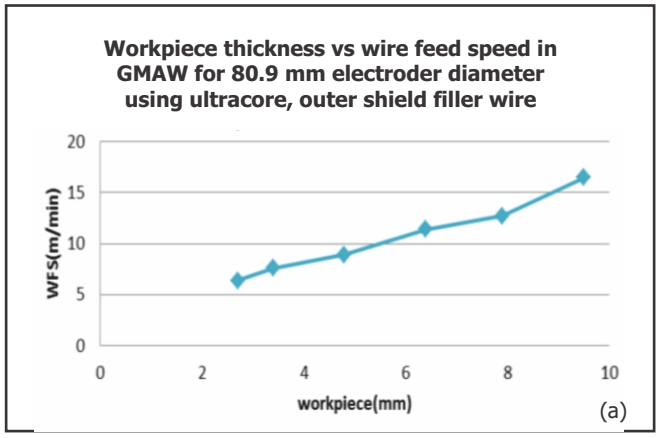
Fig. 4 : (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 1.1 mm electrode diameter

Welding process-5

- Type of welding - gas metal arc welding (GMAW)
- Types of material - steel
- Wire type - ultra core, outer shield
- Wire diameter - 0.9 mm
- CTWD - 19.050mm
- Polarity - DC+
- Gas - 75% Ar+ 25% Co_2
- A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C = voltage

Table 5 : Process parameters of welding process 5

A	B	C
2.7	6.4	21
3.4	7.6	22
4.8	8.9	23
6.4	11.4	25
7.9	12.7	26
9.5	16.5	28



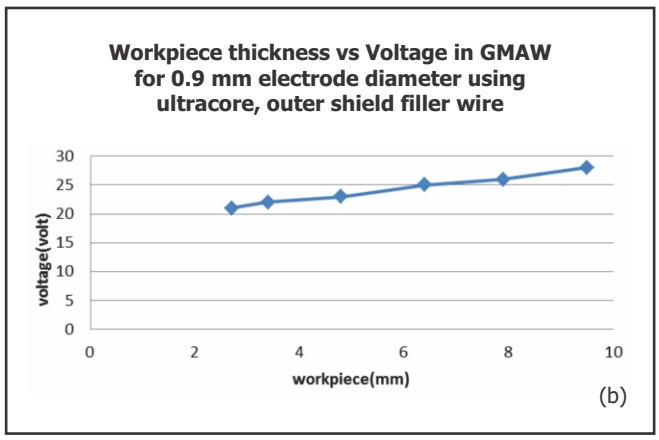


Fig. 5 : (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 0.9 mm electrode diameter by taking ultra-core, outer shield filler wire.

Both in **Fig. 5(a)** and **Fig. 5(b)** with increase in material thicknesses from 2.7 mm to 9.5 mm both WFS and voltage increases. WFS increase from 6.4 to 16.5 m/min and voltage increase from 21 to 28 volt. The main difference between process 4 and process 5 is that in process 4 filler wire used is super arc, L-50, L-56, L-59 and in process 5 filler wire is ultra-core, outer shield.

Welding process-6

- Type of welding - gas metal arc welding (GMAW)
- Types of material - steel
- Wire type - Ultra core, Outer shield
- Wire diameter - 1.1mm
- CTWD - 19.050mm
- Polarity - DC+
- GAS - 75% Ar+ 25% Co_2
- A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C = voltage

Table 6 : Process parameters of welding process 6

A	B	C
2.7	5.1	23
3.4	5.8	24
4.8	8.3	26
6.4	11.4	28
7.9	12.1	28
9.5	12.7	29
12.7	15.2	31

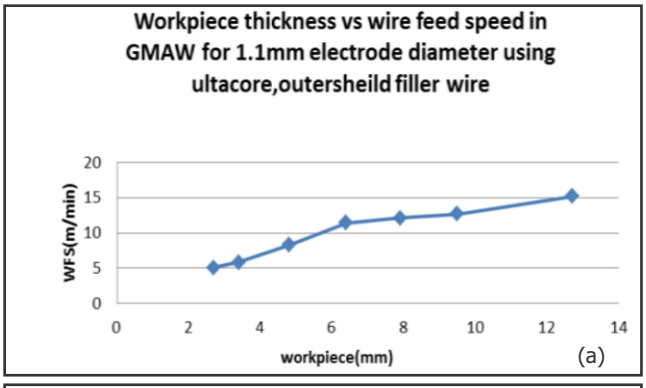


Fig. 6: (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 1.1 mm electrode diameter by taking ultra-core, outer shield filler wire.

With increase in material thickness increase in WFS none linearly as per **Fig. 6(a)**. In the same way with increase in material thickness from 2.7 to 6.4 mm voltage increases from 23 to 31 volt. Then from 6.4 to 7.9 mm material thicknesses voltage remains constant. After that voltage increases due to increase in material thicknesses from 7.9 to 12.7 mm which is shown in **Fig. 6(b)**.

Welding process -7

- Type of welding - gas metal arc welding (GMAW)
- Types of material - steel
- Wire type - Ultra core, Outer shield
- Wire diameter - 1.1mm
- CTWD - 19.050mm
- Polarity- DC+
- Gas - 75% Ar+ 25% CO_2
- A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C = voltage

Table 7 : Process parameters of welding process 7

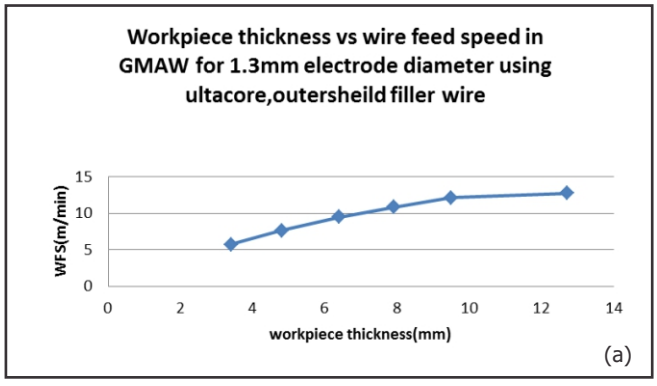
A	B	C
3.4	5.7	23
4.8	7.6	25
6.4	9.5	26
7.9	10.8	29
9.5	12.1	31
12.7	12.7	32

With increase in material thickness increase in WFS none linearly as per **Fig. 7(a)**. In the same way with increase in material thickness from 3.4 to 7.5 mm voltage increases from 23 to 32 volt which is shown in **Fig. 7(b)** for 1.3 mm electrode.

Welding process 8

- Type of welding - gas metal arc welding (GMAW)
- Types of material - steel
- Wire type - Super arc, L-50, L-56, L-59
- Wire diameter - 0.6mm
- CTWD - 19.525mm

- Polarity - DC+
- GAS - 100% Co_2
- A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C = voltage



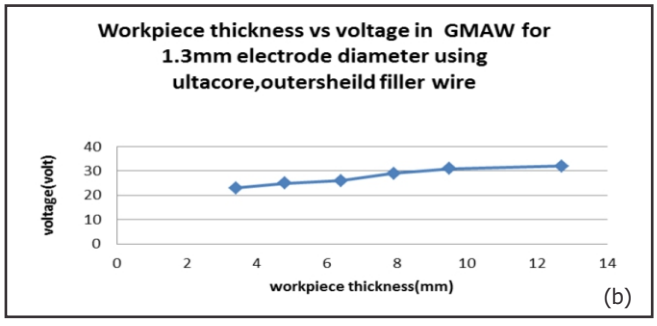
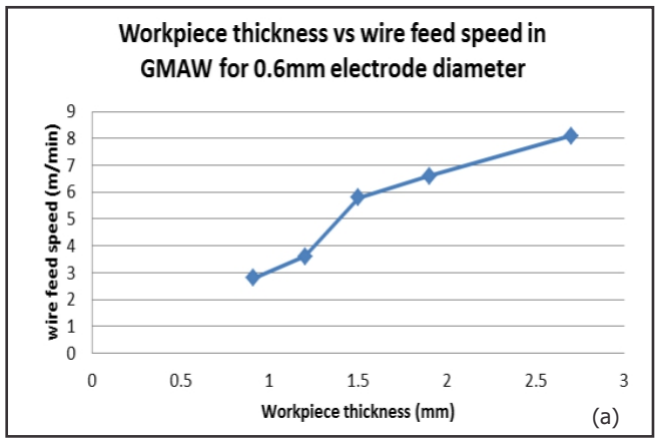


Fig. 7 : (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 1.3 mm electrode diameter by taking ultra-core, outer shield filler wire.

Table 8 : Process parameters of welding process 8

A	B	C
0.91	2.8	16
1.2	3.6	17
1.5	5.8	18
1.9	6.6	18
2.7	8.1	19



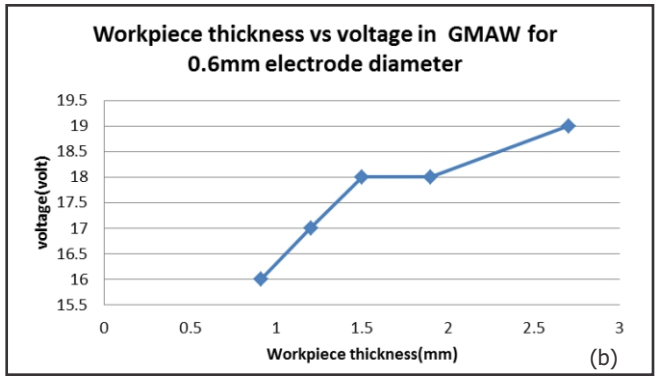


Fig. 8 : (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 0.6 mm electrode diameter by taking Super arc, L-50, L-56, L-59 filler wire and 100% CO_2

With increase in material thickness increase in WFS none linearly as per **Fig. 8(a)**. In the same way with change in workpiece thickness from 0.9 to 1.5 mm and the voltage increases from 16 to 18 volt and after that from 1.5 to 1.9 mm material thickness voltage remain same. Then linear relation is seen between voltage and material thickness which is shown in **Fig. 8 (b)** for 0.6 mm electrode 100 % CO_2 as shielding gas.

Welding process - 9

- Type of welding - gas metal arc welding (GMAW)
- Types of material - steel
- Wire type - Super arc, L-50, L-56, L-59
- Wire diameter - 0.8mm
- CTWD - 19.525mm
- Polarity - DC+
- GAS - 100% Co_2
- A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C = voltage

Table 9 : Process parameters of welding process 9

A	B	C
0.61	1.9	17
0.72	2.3	17
0.91	3.2	18
1.2	3.8	18
1.5	4.4	19
1.9	5.7	20
2.7	7	21
3.4	7.6	22
4.8	10.2	23

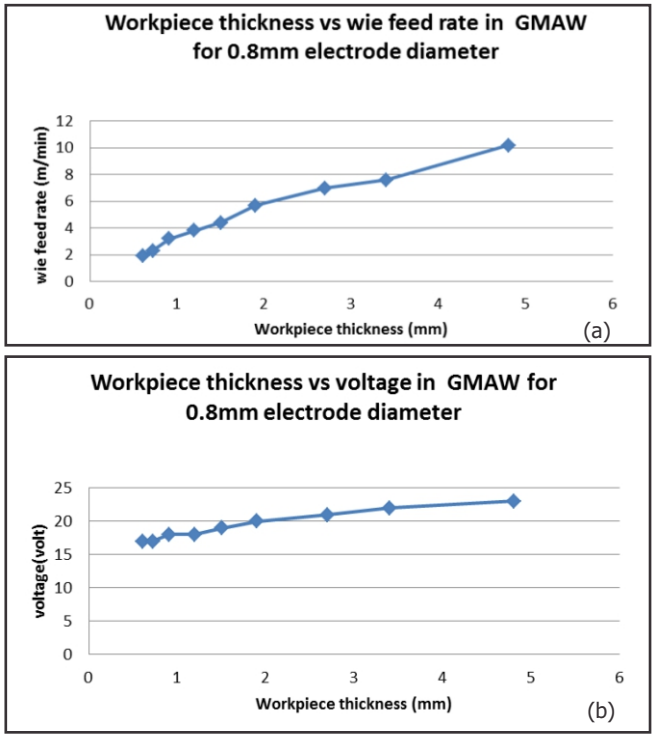


Fig. 9: (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 0.8 mm electrode diameter by taking Super arc, L-50, L-56, L-59 filler wire and 100% CO_2

With increase in material thickness increase in WFS none linearly as per **Fig. 9(a)**. In the same way with increase in material thickness from 0.61 to 0.72 mm voltage remains constant and then voltage increases with increase in material thickness as per **Fig. 9(b)** for 0.8 mm electrode 100 % CO_2 as shielding gas.

Welding process -10

- Type of welding - gas metal arc welding (GMAW)
- Types of material - steel
- Wire type - Super arc, L-50, L-56, L-59
- Wire diameter - 0.9mm
- CTWD - 112.700mm
- Polarity - DC+
- GAS - 100% Co_2
- A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C = voltage

Table 10 : Process parameters of welding process 10

A	B	C
0.91	2.5	18
1.2	3	18
1.5	3.8	19
1.9	4.4	20
2.7	5.7	21
3.4	6.4	22
4.8	8.9	23
6.4	9.5	24
7.9	11.4	25

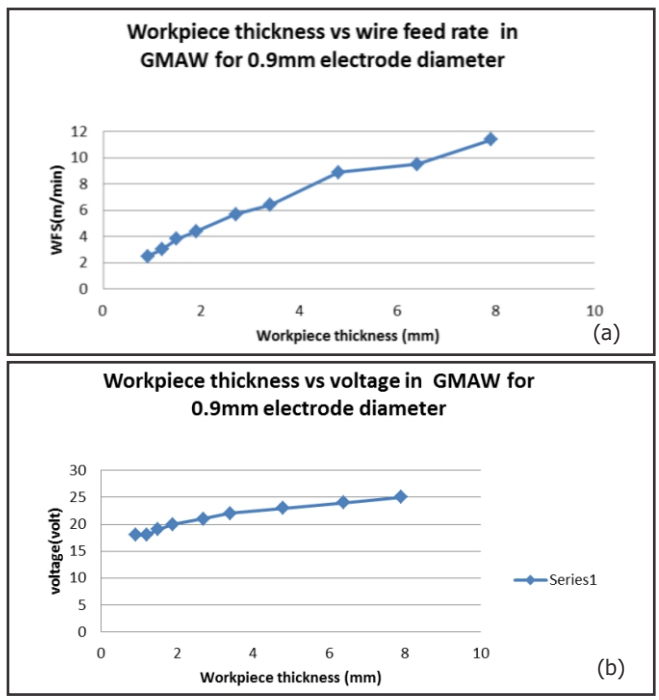


Fig. 10: (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 0.9 mm electrode diameter by taking Super arc, L-50, L-56, L-59 filler wire and 100% CO_2

With increase in material thickness increase in WFS none linearly as per **Fig. 10(a)**. In the same way with change in workpiece thickness from 0.91 to 0 1.2 voltage remains constant and then voltage increases with change in workpiece thickness as per **Fig. 10(b)** for 0.9 mm electrode 100 % CO_2 as shielding gas.

Welding process -11

- Type of welding - gas metal arc welding (GMAW)
- Types of material - steel
- Wire type - Super arc, L-50, L-56, L-59
- Wire diameter - 1.1mm
- CTWD - 12.700mm
- Polarity - DC+
- GAS - 100% Co_2
- A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C = voltage

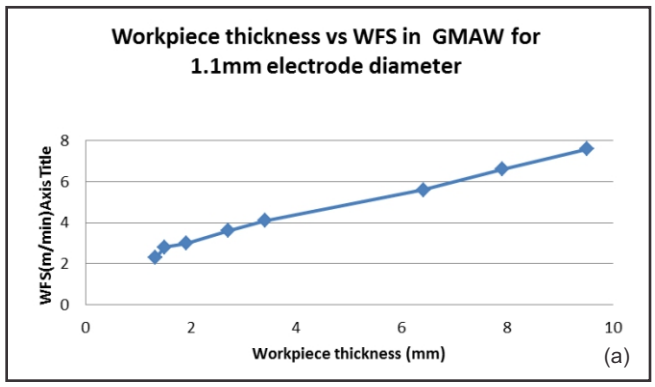
Table 11 : Process parameters of welding process 11

A	B	C
1.32	2.3	17
1.5	2.8	18
1.9	3	18
2.7	3.6	18
3.4	4.1	19
6.4	5.6	22
7.9	6.6	24
9.5	7.6	25

With rise in workpiece thickness increase in WFS none linearly as per **Fig. 11(a)**. In the same way with change in material thickness from 1.32 to 0 1.5 voltage increases from 17 to 18 volt. After that with increase in material thickness from 1.5 to 3.7 mm voltage remains constant and then voltage increases with rise in workpiece thickness as per **Fig. 11(b)** for 1.1 mm electrode 100 % CO_2 as shielding gas.

Welding process -12

- Type of welding - gas metal arc welding (GMAW)



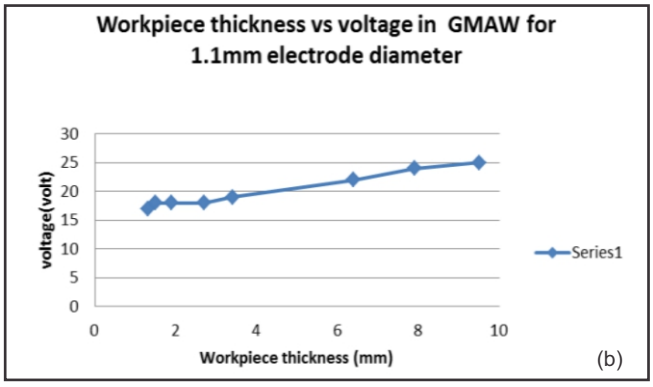
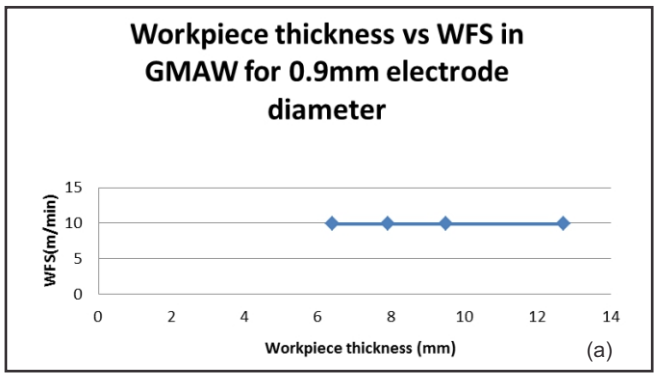


Fig. 11: (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 1.1 mm electrode diameter by taking Super arc, L-50, L-56, L-59 filler wire and 100% CO_2

- Types of material - steel
- Wire type - Super arc, L-50, L-56, L-59
- Wire diameter - 0.9mm
- CTWD - 12.700mm
- Polarity - DC+
- Gas - 90% Ar+ 10% Co_2
- A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C = voltage

Table 12 : Process parameters of welding process 12

A	B	C
6.4	9.9	25
7.9	9.9	25
9.5	9.9	25
12.7	9.9	25



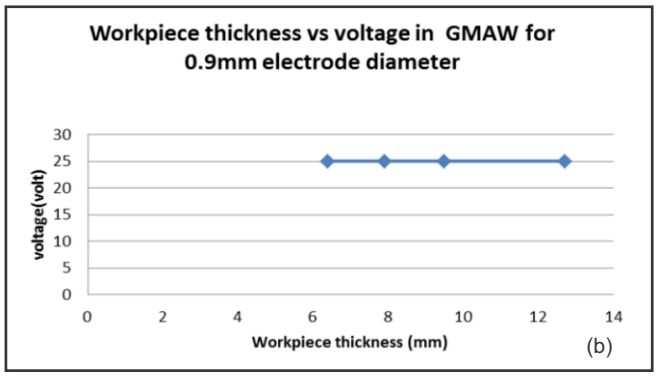


Fig. 12: (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 0.9 mm electrode diameter by taking Super arc, L-50, L-56, L-59 filler wire and 90%Ar+10%Co_2 as shielding gas

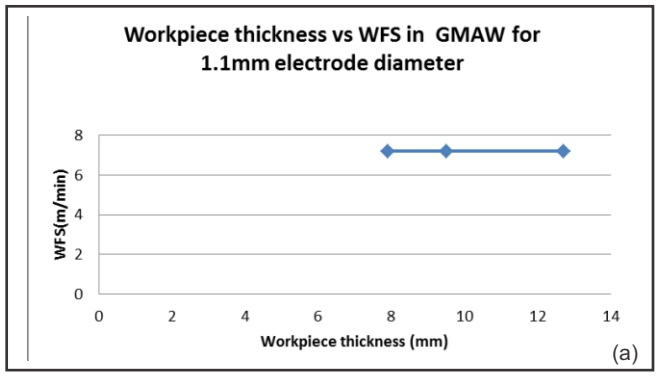
With increase in material thickness from 6.7 to 12.7 mm both WFS and voltage remain constant as per **Fig. 12(a)** and **Fig. 12(b)** respectively. Voltage is 25 volt and WFS is 9.9 m/min.

Welding process -13

- Type of welding - gas metal arc welding (GMAW)
- Types of material - steel
- Wire type - Super arc, L-50, L-56, L-59
- Wire diameter - 1.1mm
- CTWD - 19.050mm
- Polarity - DC+
- Gas - 90% Ar+ 10% CO_2
- A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C = voltage

Table 13 : Process parameters of welding process 13

A	B	C
7.9	7.2	26
9.5	7.2	26
12.7	7.2	26



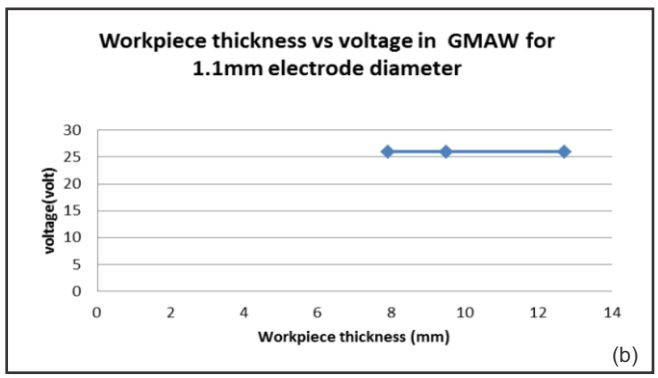


Fig. 13: (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 1.1 mm electrode diameter by taking Super arc, L-50, L-56, L-59 filler wire and 90% Ar+ 10% CO_2 as shielding gas

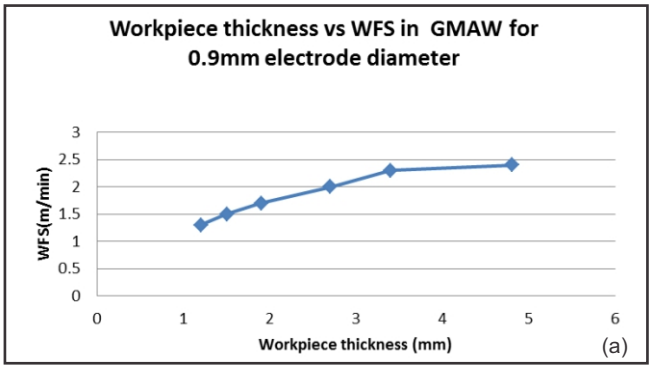
With increase in material thickness from 6.7 to 12.7 mm both WFS and voltage remain constant as per **Fig. 13(a)** and **Fig. 13(b)** respectively. Voltage is 26 volt and WFS is 7.2 m/min.

Welding process -14

- Type of welding - gas metal arc welding (GMAW)
- Types of material - steel
- Wire type - Inner shield
- Wire diameter - 0.9 mm
- CTWD - 12.700mm
- Polarity - DC-
- Gas - None
- A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C = voltage

Table 14 : Process parameters of welding process 14

A	B	C
1.2	1.3	14
1.5	1.5	15
1.9	1.7	15
2.7	2	16
3.4	2.3	16
4.8	2.4	16



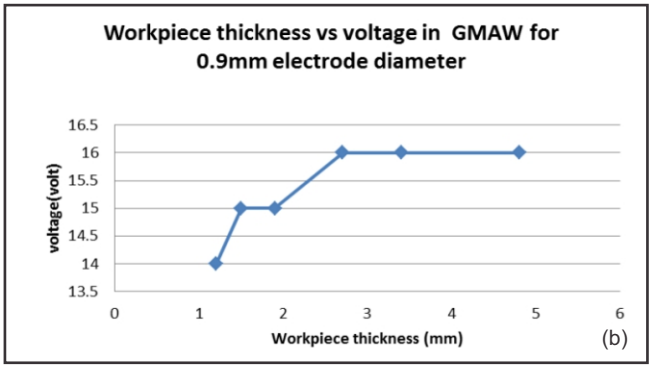


Fig. 14 : (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 1.1 mm electrode diameter by taking Inner shield wire and DC- polarity with no shielding gas

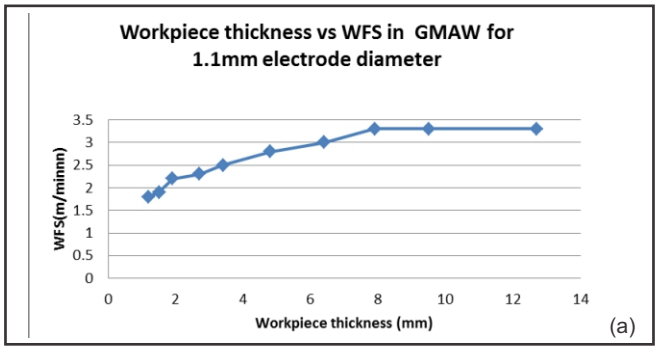
With increase in workpiece thickness increase in WFS none linearly as per **Fig. 14(a)**. In the same way with change in workpiece thickness from 1.2 to 0 1.5 voltage increases from 14 to 15 volt. After that with change in workpiece thickness from 1.5 to 1.9 mm voltage remains constant and then voltage increases with increase in material thickness from 1.9 to 2.7 mm. after that voltage remains constant with change in workpiece thickness from 2.7 to 4.8 mm as per **Fig. 14(b)** for 0.9 mm electrode and DC- polarity with no shielding gas.

Welding process -15

- Type of welding- gas metal arc welding (GMAW)
- Types of material- steel
- Wire Type - Inner shield
- Wire diameter - 1.1mm
- CTWD - 15.875mm
- Polarity - DC-
- Gas - None
- A = workpiece thickness (mm), B = Wire feed speed (WFS)(m/min), C = voltage

Table 15 : Process parameters of welding process 15

A	B	C
1.2	1.8	15
1.5	1.9	16
1.9	2.2	16
2.7	2.3	16
3.4	2.5	17
4.8	2.8	17
6.4	3.0	18
7.9	3.3	18
9.5	3.3	18
12.7	3.3	18



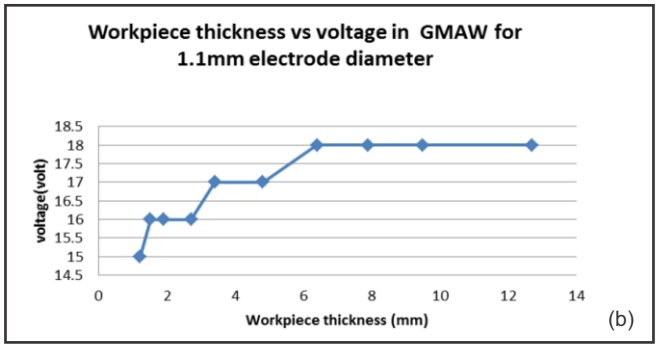


Fig.15 : (a) Graph between Material thickness and wire feed speed (b) Graph between material thickness and voltage in 1.1 mm electrode diameter by taking Inner shield wire and DC- polarity with no shielding gas

With change in workpiece thickness from 1.2 to 7.9 mm WFS increases none linearly and then WFS remains constant i. e. 3.3 m/min with change in workpiece thickness from 7.9 to 12.7 mm as per **Fig. 15(a)**. In the same way with change in workpiece thickness from 1.2 to 0 1.5 voltage increases from 15 to 16 volt. After that change in workpiece thickness from 1.5 to 2.7 mm voltage remains constant and then voltage increases change in workpiece thickness from 2.7 to 3.4 mm. After that voltage remains constant up to 4.8 material thickness and again voltage increases change in workpiece thickness from 4.8 to 6.4 mm. Then voltage remains constant with increase in material thickness according to **Fig. 15(b)** for 1.1 mm electrode and DC- polarity with no shielding gas.

3.0 CONCLUSION

In this paper, type of welding, types of material, wire type, wire diameter, contact tip workpiece distance, polarity, welding gas, material thickness are taken as input process parameters and wire feed rate (WFS), welding voltage as output parameters according to Lincoln Electric company. Steel is taken as the workpiece material fifteen types of welding process are chosen by changing the different input process parameters which are mentioned above. In every process, material thickness is varied and according to that the variation in wire feed rates and welding voltages are calculated through experiments. By the help of the above data, different graphs between material thickness with wire feed rate, and material thickness with welding voltage are shown to explain how input parameters influence on output parameters.

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