4.1 Introduction

In this chapter, experiments devices and procedures that adopted to carry out the experimental measurement will be explained in details. Brief discussions of the instruments are used for measuring, monitoring, recording and analysis of the experimental measurements. Flow chart for experimental procedure is illustrated in figure (**4.1**).

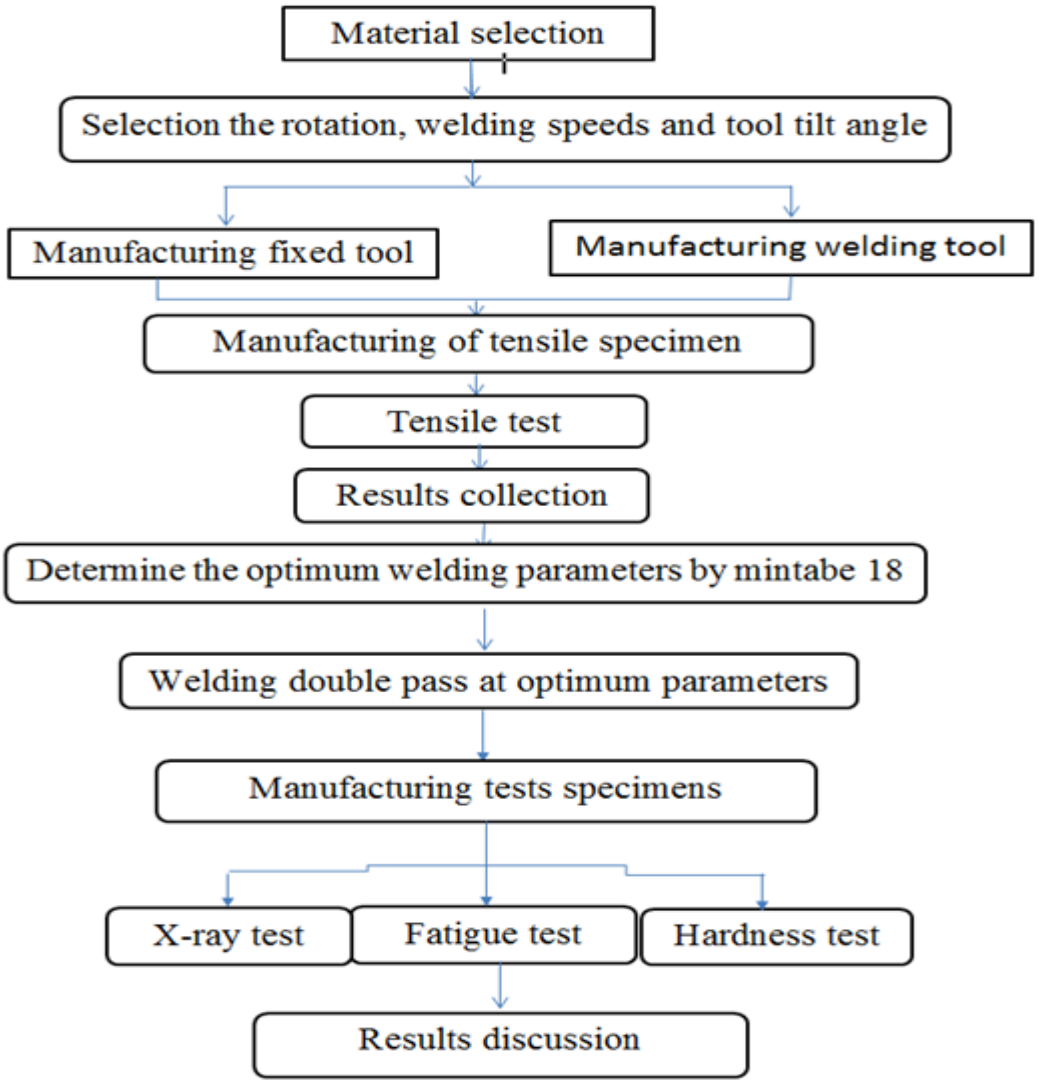


Figure **(4.1):** The flow chart of experimental procedure.

4.2 Material Selection

The chemical composition test performed In the General Company for Examination and Rehabilitation Engineering and the standard and the results are presented in table **(4.1),** the test device is shown in figure **(4.2)**.

Table **(4.1)** chemical composition of AA6061 alloy

Sample	**Standard [28]**	**Plate 6061 t = 4 mm**
Si%	0.4-0.8	0.57
Fe%	0.7 max	0.335
Cu%	0.15- 0.4	0.253
Mn%	0.15 max	0.0971
Mg%	0.8-1.2	1.151
Cr%	0.04- 0.35	0.185
Ni%	0.25 max	0.0034
Zn%	0.25 max	0.0632
Pb%	0.005	0.0043
Ti%	0.15 max	0.0216
Al	Rem.	Rem.

Figure **(4.2)** device which is used in chemical inspection

4.3 Welding Tool

Due to lack of friction stir welding machine, therefore the welding operation was done on tradition milling machine and this will impose dimension of welding tool. The design of welding tool must be conformed to milling machine, while rotation and welding speeds were limited. Welding tool made of medium carbon steel AISI 1035 and the chemical composition of the tool is presented in table **(4.2)**.

Table **(4.2)** chemical composition of tool material

Material	Standard [73]	Measured
C	0.31-0.38	0.34
Mn	0.6-0.9	0.71
P	0.04 max	0.019
S	0.05	0.021
Mo	----	< 0.002
Ni	----	< 0.003
V	----	<0.004
Fe	Rem.	Rem.

The heat treatment for tool was performed in Nahrain University by using Italian electric furnace with the maximum temperature 1000^{o}C as shown in figure (**4.3**) to attain better mechanical properties such as hardness and wear resistance. The welding tool and its dimension are shown in figure (**4.4**).

The process of heat treatment is:

1. Annealing at a temperature 850^{o} C for 30 minute.
2. Cooling in the air at room temperature.
3. Tempers at 300^{o} C for 60 minutes.
4. Cooling in furnace.

Figure **(4.3)**: Electric furnace.

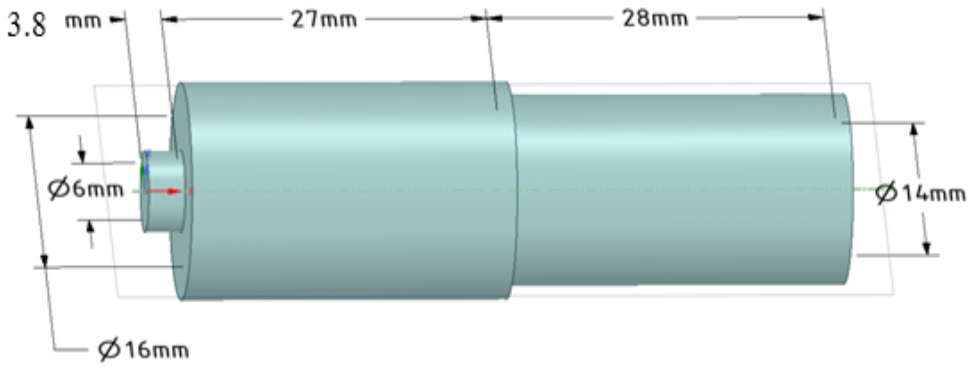


Figure **(4.4)**: welding tool and its dimension.

4.4 Fixture Tool

The fixture tool is very important to clamp the plates and prevent it from motion and reduce the vibration which leads to the field welding operation. The fixture tool is made of steel with length of 300 mm, width 120 mm and thickness 20 mm. It is installed on the moving part of the milling machine with a number of mounting screws with diameter of 20 mm as shown in figure (**4.5**).

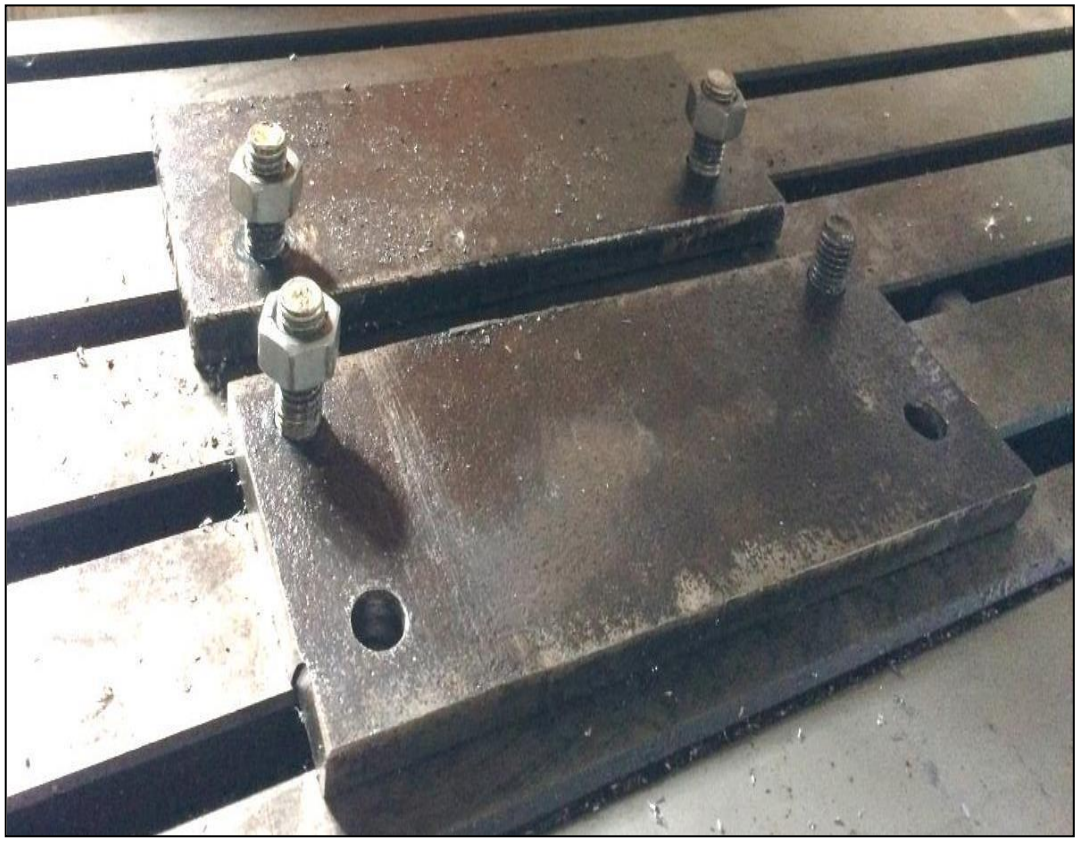


Figure **(4.5)** fixed tool.

4.5 Plates Before Welding

The plates of aluminum alloy AA 6061 were cut and machined to rectangle specimens 200, 100, 4 mm length, width and thickness respectively. For the purpose of adjusting the face and remove the appendages for full contact between the two pieces, as shown in figure (**4.6**).

Figure **(4.6):** Preparation plates before welding operation.

4.6 The Welding Operation

A vertical Milling machine made by Knuth Company (Germany) used to perform welding operation. The machine was appropriate to do the job has some features such as

1. Different welding and rotational speed.
2. Ability to resist vibration and higher force during the welding process.
3. Three-axis auto feeding motions.
4. Available to tilt spindle axis.

Two plates are placed in a hook as shown in figure (**4.7**). The tool tilt angle was 2^o with vertical axis and the optimum tool tilt angle range from $0^o - 3^o$ [32].

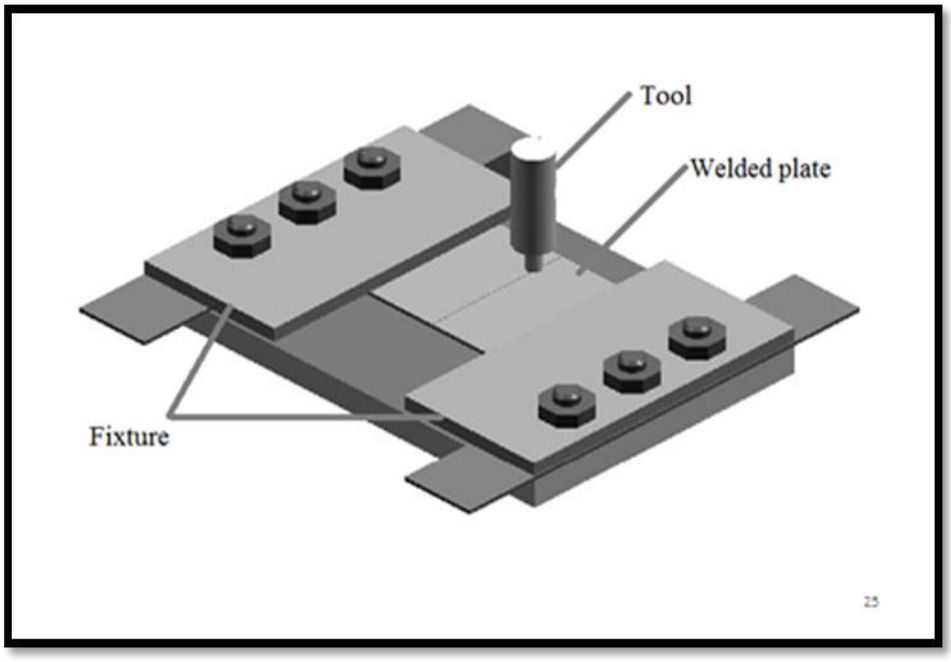


Figure **(4.7):** The welding operation [74].

4.7 The Parameters Used in Welding Operations

The parameters which used in welding operation was three rotation speeds and three welding speeds, as well as after welding carried out used three angles for welding orientation. This is shown in the table (**4.3**) and the welding plates are shown in figure (**4.8**).

Table (4.3) the welding parameters.

Rotational speed (rpm)	Welding speed (mm/min)	OWL
630	20	45°
		60°
		90°
	32	45°
		60°
		90°
	45	45°
		60°
		90°
1000	20	45°
		60°
		90°
	32	45°
		60°
		90°
	45	45°
		60°
		90°
1600	20	45°
		60°
		90°
	32	45°
		60°
		90°
	45	45°
		60°
		90°

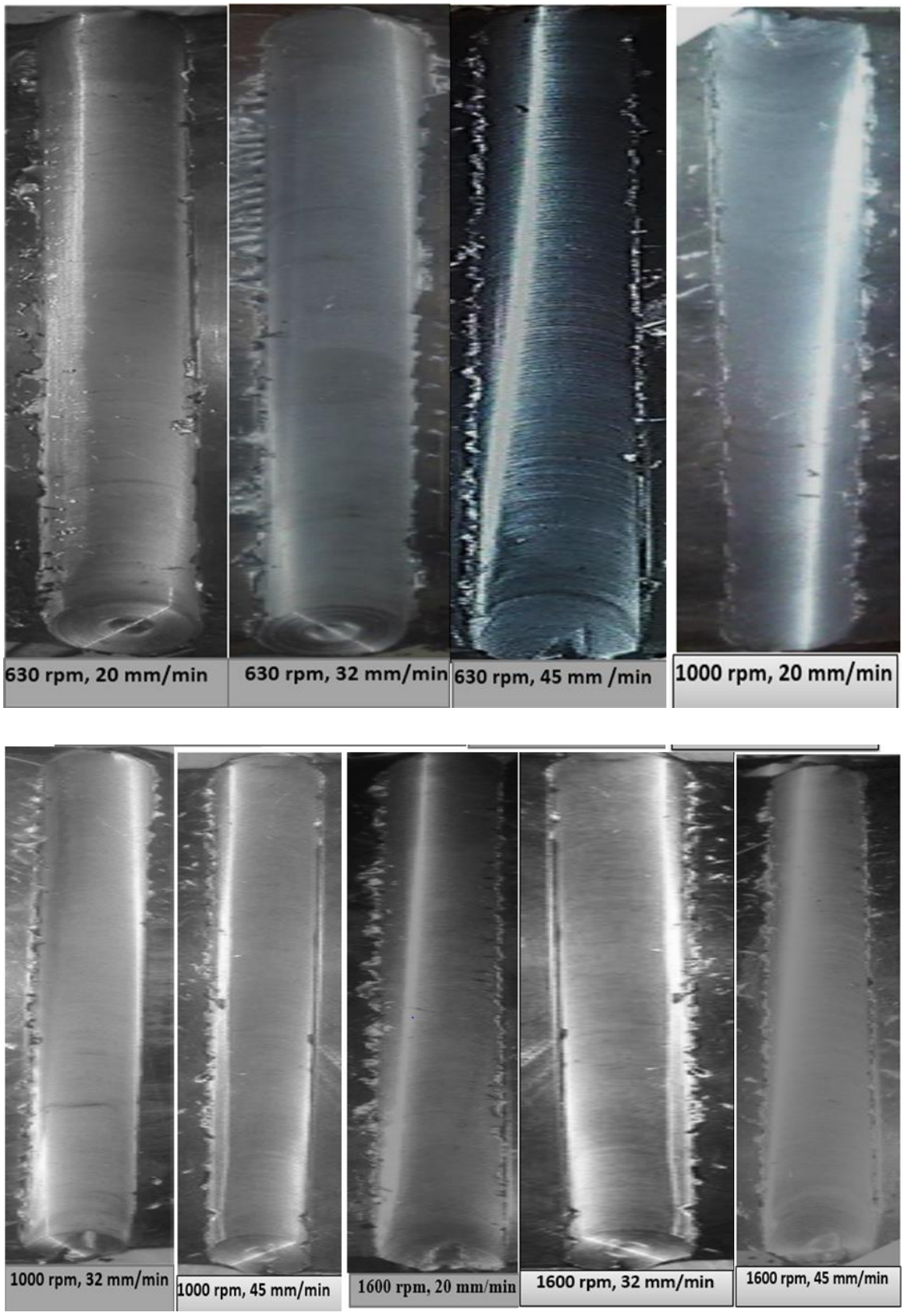


Figure **(4.8):** Welding plates at different welding and rotational speeds**.**

4.8 The Specimens After Welding

For tensile, fatigue, X-ray and hardness tests, specimens were manufactured by using American water-jet CNC [TK-TRUMP50-G3020]. Water-jet CNC has maximum pressure 4000 psi the utilized pressure is 2000 psi figure (**4.9**). The tensile test specimens were in three groups responding to orientation welding line with the applied load. The dimension and three orientation welding line of tensile specimen are shown in figure (**4.10**) and (**4.11**) respectively.

The tensile tests specimens are classified into three groups:

1. Orientation welding line (OWL) 90^{o} with applied load for three rotation speeds (630, 1000, 1600) rpm and three welding speeds (20, 32, 45) mm/min as shown in figure (**4.11 A**).
2. Orientation welding line (OWL) 60^{o} with applied load for three rotation speeds (630, 1000, 1600) rpm and three welding speeds (20, 32, 45) mm/min as shown in figure (**4.11 B**).
3. Orientation welding line (OWL) 45^{o} with applied load for three rotation speeds (630, 1000, 1600) rpm and three welding speeds (20, 32, 45) mm/min as shown in figure (**4.11 C**).

Figure (**4.9**): Water jet CNC machine.

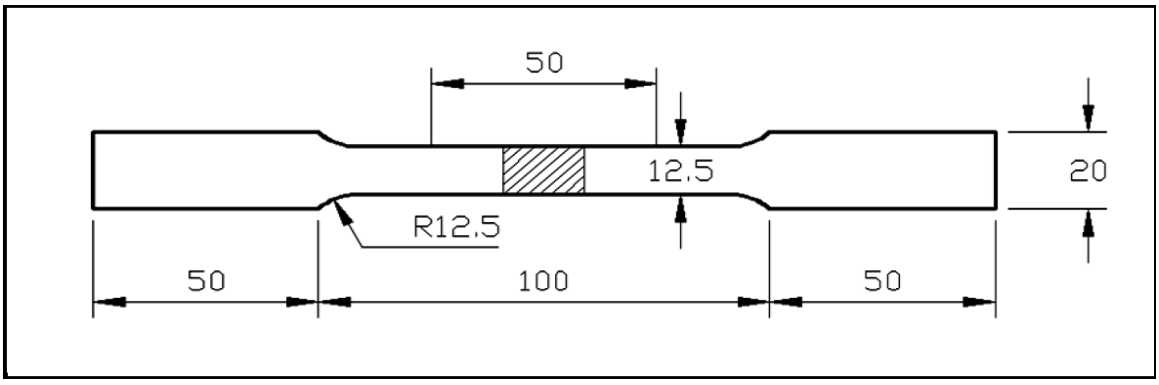
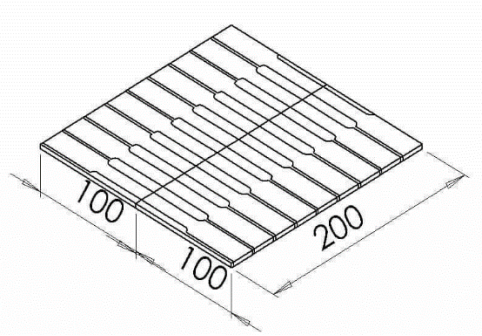
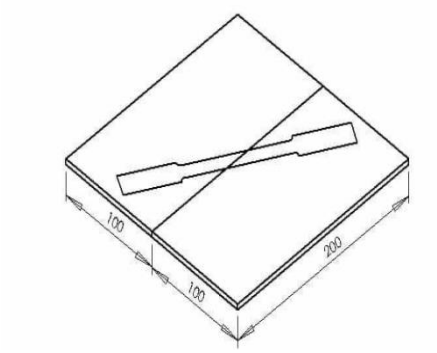


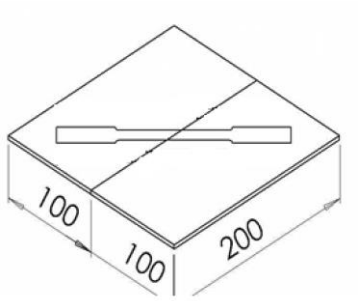
Figure (**4.10**): Dimensions of tensile test sample in mm [75].



A



B



C

Figure (**4.11**): Different orientation welding line (OWL) for tensile specimen.

4.9 Tensile Test

The tensile test was carried out in the University of Technology with production engineering and metallurgy department at room temperature by using computerized (WDW-200E – 200KN) at constant crosshead speed 1mm/min and its shown in figure (**4.12**).

Figure (**4.12**): The tensile test machine.

4.10 Fatigue Test

Fatigue test is done at mechanical engineering department laboratory in Nahrain University by using fatigue (HI-TECH)-Rotating device as shown in figure (**4.13**). It is done at a constant stress amplitude cantilever with fully reversed (R = -1), and the specimen dimensions were 60, 10, 4 mm length, width, and thickness respectively as shown in figure (**4.14**). The value of the tensile stress (σ_u), measured by MPa for a known value of load (P) measured by Newton (N), is extracted from applying the relation below [76]. These tests were conducted for base material, optimum case (single pass), and double pass: The position of welding line is near to the fixed point, the reason of chosen this position return to the higher reduction in fatigue strength occurs in this position [22].

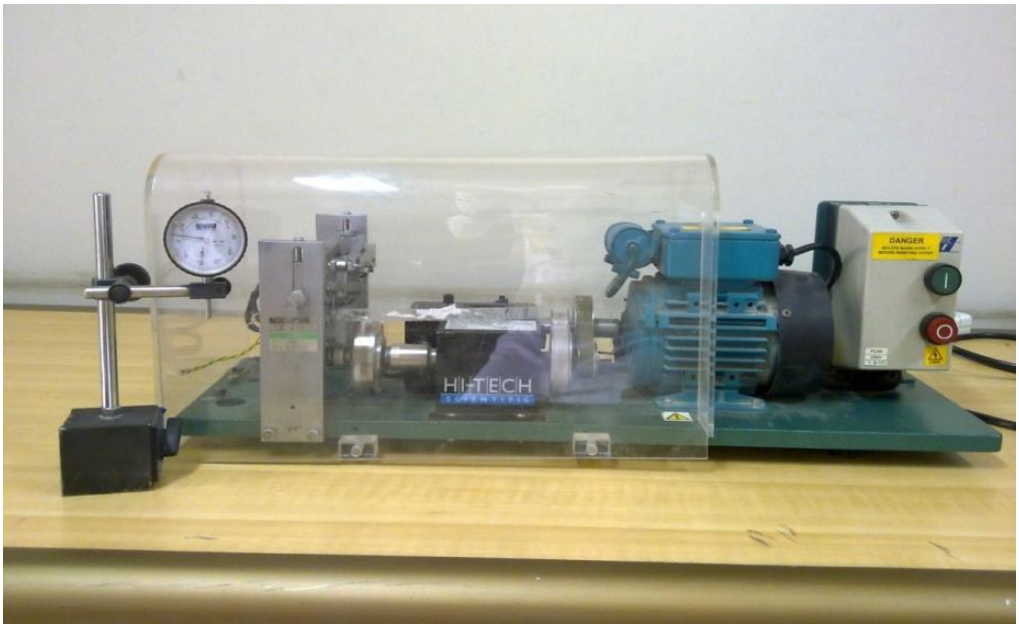


Figure (**4.13**): Fatigue alternating bending test machine.

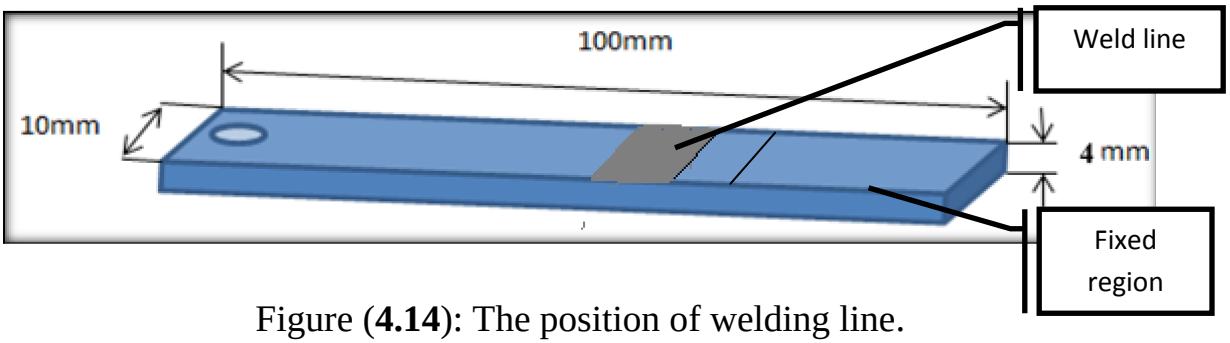


Figure (**4.14**): The position of welding line.

4.11 X-RAY Diffraction Test

The X-Ray diffraction tests were performed in the Ministry of Science and Technology by the (XRD-6000/ SHIMADZU) machine type as shown in figure (**4.15**). The supplied current was (20 mA) and voltage (40KV). The target is Copper with a wavelength (λ=1.5406 A^0), and the filter is Nickel.

Figures (**4.15**): X-Ray diffraction machine.

4.12 Grinding and Polishing

- **Grinding**

  The specimen was then prepared as per ASTM E3. For a grind used paper of SiC with different grades (180, 280,400,600, 800, and 1000).

- **Polishing**

  Polishing used to get on a mirror finish with different grades of diamond paste by Universal grinding and polishing machine.

  Grinding and polishing were done in mechanical engineering laboratories at Nahrain University. These were conducted only to base material, optimum case, and double pass. These are shown in figure (**4.16**).

Figure (**4.16**): the grinding and polishing devices.

4.13 Hardness Test

The hardness test was performed by digital micro Vickers hardness THV-50IE shown in figure (**4.17**) in mechanical engineering department at Tikrit University. The positions of the test are explained in figure (**5.18**). The test done under applied load (500 g) with a time of 5 sec. The specimens were taken perpendicular on the weld line.

Figure (**4.17**): The hardness device.

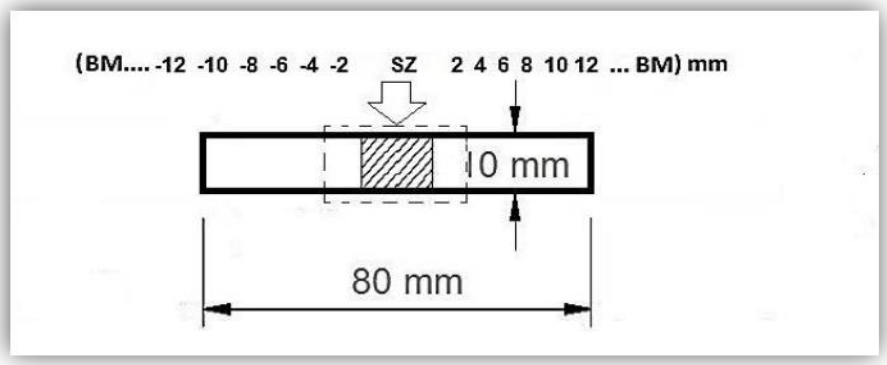


Figure (**4.18**): The hardness specimen and position test.