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Influence of Number of Weld Passes on Micro-Hardness and Impact Toughness of Gas Metal Arc (GMA) welded AISI 1020 joints

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***Abstract*—** The current study presents the result of investigation being done on determining the influence of multipass welding on micro-hardness and charpy v-notch impact strength of AISI 1020 GMA weld joints. AISI 1020 alloy is commonly used in many industrial applications like manufacturing of spindles, gudgeon pins, light duty gears, ships, structures and many more. Furthermore, the literature survey reveals that thick plates are generally welded in multi passes of welding. In this study, the joints are fabricated in single pass, double pass and triple pass of welding with ER 70S-6 solid filler material. Besides this, welding parameters also influence the mechanical properties and metallurgical properties of weld material. The investigation outcomes show that the thermal gradients were established which affect the micro-hardness and impact toughness. Further, it reveals that due to multi layers of the filler material the heat input in case of triple layer welded joint is maximum which leads to maximum average value of hardness (302 VHN) in joint 3 and minimum of 230 VHN is reported for joint 1. Furthermore, the maximum energy absorption capacity comes out to be maximum (71Joules) for joint 3.

Keyword-AISI 1020, GMAW process, Micro-Hardness, Charpy v-notch impact toughness, Multipass.

I. INTRODUCTION

AISI 1020 is a common type of low carbon steel which finds its applications in machine parts and construction materials due to their moderate properties of strength and ductility [1]. AISI 1020 has good weld-ability, high strength and ductility. Furthermore, it can be used in industrial sector to accelerate machinability and weld-ability. Welding history can be traced in earlier decades even more than thousands of years ago [2]. In today's era numerous products are fabricated by the fusion of two similar or dissimilar materials. Joining of metals plays an obtrusive role in the manufacturing industry and both thick and thin plates can be welded easily [3]. Welding is one of the most orthodox ways of repair and fabrication of various metallic alloys [4]. Welding is considered to be at the paramount for the construction of aircrafts, automobiles, and domestic appliances [5], micro-electronic components, ships, buildings, structures [6]. There are many types of welding techniques available like MIG welding, TIG welding, SMAW, MMAW, Friction welding and many more. GAS metal arc welding is selected to be the part of current research on low carbon steel having 0.22 percent of carbon and thickness of 10 mm. In earlier decades GMAW was thought to be suitable for welding aluminum and other non-ferrous materials. Furthermore, soon GMAW was experimented and applied on steels because of less welding time. Instead of this, wider range of materials can be joined by this particular technique like similar metals, dissimilar materials, alloys etc. [7]. GMAW is known to have flair in enhancing the productivity when compared with GTAW and SMAW process. This may be due to greater rate of deposition and operating face in GMAW [8]. Gas Metal Arc Welding is more efficient, reliable, versatile metal joining process as compared to others both in case of cost and quality [9]. Welding parameters are worth to be considered and holds great importance in performing high quality weld joints because these parameters directly affect the characteristics of weld geometry. Each parameter has its individual importance during welding and theses can be varied to a great extent for the purpose of getting better quality welds [10].

In most of the applications, materials are welded with multi pass welding that affects the mechanical properties of the material. The level of controlling parameters also affects the strength, hardness and toughness of the material. The paper focuses on the evaluation of influence of multiple layers of welding on micro-hardness and charpy v-notch impact toughness of AISI 1020 in GMA welding. The rest of the paper is organized as follows, section – II contains impact of multipass welding on mechanical and metallurgical properties of different materials followed by a research gap and objective of the current study. Section –III highlight the selection of material along with experimental set up to conduct the research in an appropriate manner. Section – IV contains discussion of results obtained after performing micro-hardness test and charpy v-notch impact toughness test. Lastly, the conclusion of the present investigation is discussed in section – V under the name of conclusions.

II. Related Work

A. Related Work

Based on the reviewed literature, the welding parameters, and filler material affect the properties of the welded joints and the metallurgical properties of the selected material were affected due to high value of temperature during multi-pass welding [2, 3]. During multi-pass welding the plastic deformation of weldment occur which was found to be the main cause of fatigue failure damage and fracture [11]. Increase in welding current and voltage made hardness to follow rising trend but on the other hand in whole reduction in mechanical properties is observed [12]. Compared the mechanical properties of SS-316L (stainless steel) in GMAW and GTWA process and found that tensile strength, impact strength and hardness in case of GTAW is better as compared to former one [13]. Temperature distribution is prominent for forecasting the residual stresses, microstructure and distortion [14]. Welding current is the attributing factor which helps to ascertain the penetration. Besides this, penetration also relies on arc voltage and welding speed. The quality, efficiency and overall performance of welding process is highly dependent of welding parameters[15]. Study was carried out to analyze effect of passes on mechanical properties of material. Hardness test shows that higher value of hardness can be found at root region while the same is proportional to number of passes of weld. Furthermore, the tensile strength follows downward trend if the multiple layers of weld decreases. Besides this, toughness also decreases with increase in number of layers of weld. To sum up, with increase in welding layers there is increase in delta-ferrite content in root region and also fall in ductility and toughness [16]. The effect of multi-layer welding on mechanical properties of AISI 304 stainless steel in shield metal arc welding was investigated and the greater strength was found in low current welded samples than the high heat input ones. Improved strength can be noticed in joint fabricated with nine weld passes with root pass in low current sample than in 7 weld passes in high heat current sample[17].

B. Problem Statement

The current study aims at determining the influence of multipass welding on the micro-hardness and charpy v-notch impact strength AISI 1020 weld joints in gas metal arc welding. Throughout the literature little information related to temperature distribution and effect of multi-layer welding on micro-hardness and toughness of AISI 1020 low carbon alloy steel during GMA welding process is reported. Very less information is reported related to co-relation of multipass welding with mechanical properties.

C. Objective

The present experimentation is conducted with the aim of to achieve following objectives:

1. To analyze the effect of number of passes on micro-hardness and charpy v-notch impact strength of GMA welded AISI 1020 low alloy steel.
2. To establish co-relation between Charpy v-notch impact toughness and micro-hardness.

III. Methodology

A. Material Selection

In the current study, the material selected for investigation purpose is AISI 1020 (low carbon steel) on the basis of literature survey and wider industrial applications. The base material having a thickness of 10 mm, was cut to the required dimensions. The table numbered 1 and 2 show the chemical composition of the base material and filler material (ER 70S-6) respectively

Table 1: Chemical Composition of base material AISI 1020

Designation	**Chemical Composition, max wt %**				
	C %	**Mn %**	**P %**	**S %**	**Fe %**
AISI 1020	0.22	0.361	0.6	0.4	Bal

Table 2: Chemical Composition of ER 70S-6

Designation	Chemical Composition, max wt %				
	%C	**%Mn**	**%Si**	**%Pb**	**%S**
ER705-6 (Filler metal)	0.06-0.15	1.40-1.85	0.80-1.15	0.025	0.035
	%Ni	**%Cr**	**%Mo**	**%V**	**%Cu**
	0.15	0.15	0.15	0.03	0.5

B. Experimentation

For experimentation purpose hot rolled steel plates of grade 1020 (low carbon steel) based on literature review was selected. The chemical composition of material has been discussed in table number 2. Afterwards the material was cut into equal nine lengths as shown in figure number 1 on power hacksaw at CT group of Institutions, Jalandhar.

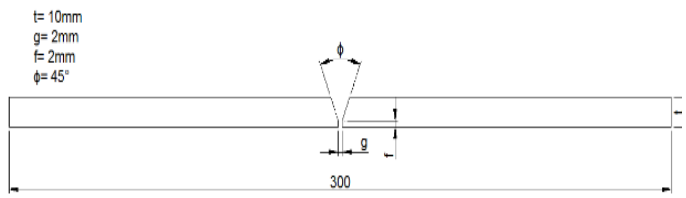

Figure 1: Schematics shows the groove design of the base plates

The edges of the base plates were beveled (groove angle of 45^0) on the milling machine by using angled milling cutter. The dimensions of the plates were 300 mm x 100 mm x 10mm width, length and thickness respectively. Before starting the welding the edges were cleaned and base plates were tacked to minimize distortion. Gas metal arc welding process was used to fabricate the joints. The joints were fabricated by single layer, double layer and triple layers of ER 70S-6 filler material. For the purpose of carrying out the study the samples were welded with varying current. For each layer different value of current was maintained and average value of current for single pass in samples 1, 2 and 3 (named joint-1) was taken, similarly, for samples 4, 5 and 6 (joint–2) having two layers of weld and for samples 7, 8 and 9 (namely joint-3) average value of current was taken. The table No. 3 represents the welding parameters being considered during experimentation process.

Table No 3: Table shows the welding parameters being incorporated in the investigation.

S No.	Sample No	No. of Layers	Current (A)	Voltage (V)	Arc Travel Time (Min)	Arc Travel Speed (mm/min)	Heat Input (kJ/mm)	Total heat input (I)
1	1	1	150	16	0.7	70	0.0274	0.0274
2	2	1	150	16	0.8	80	0.0240	0.0240
3	3	1	150	18	0.9	90	0.0240	0.0240
4	4	2	130	14	0.6	60	0.0243	0.0467
			140	16	0.8	80	0.0224	
5	5	2	125	15	0.6	60	0.0250	0.0497
			145	17	0.8	80	0.0247	
6	6	2	130	14	0.65	65	0.0224	0.0478
			140	17	0.75	75	0.0254	
7	7	3	105	12	0.6	60	0.0168	0.0576
			125	14	0.7	70	0.0200	
			130	16	0.8	80	0.0208	
8	8	3	110	12	0.65	65	0.0162	0.0602
			125	14	0.7	70	0.0200	
			125	18	0.75	75	0.0240	
9	9	3	110	12	0.6	60	0.0176	0.0579
			120	14	0.65	65	0.0207	
			130	16	0.85	85	0.0196	

The welding process was carried out at HR tools, Jalandhar by certified welder. Besides this, thermocouples (temperature indicators) were incorporated for the purpose of measuring the temperature distribution during the welding. Total nine samples in above mentioned passes were prepared. In addition to this; samples for micro-harness testing and Impact Toughness (Charpy V-notch) were extracted from the each plate as per the ASTM standards. The dimensional detail of Impact Toughness (Charpy V-notch) specimen is shown in figure 2.

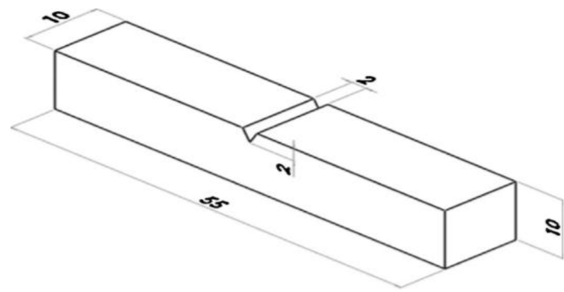

Figure 2: Schematic view shows the dimensions of charpy v-notch test.

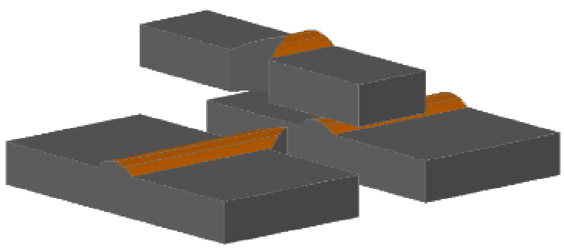

Figure 3: Solid model view of charpy v- notch

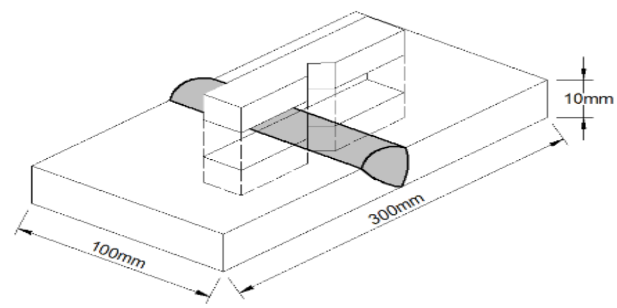

Figure 4: Isometric view of charpy v- notch

IV. RESULTS AND DISCUSSION

Multiple passes of weld, welding current, electrode angle, groove design, shielding gasses, and voltage are amongst that important variable that influences the weld geometry, mechanical properties of material and also the metallurgical properties of material. The quality, efficiency and life of products being manufactured depends upon the welding parameters

A. Micro-Hardness – For the purpose of variation in hardness both towards left side and right side of weld bed Vickers Micro-hardness value of welded zone has been measured. The figure 5.1, 5.2, and 5.3 shows the variations in the micro- hardness on from fusion zone towards the parent metal. The center line in the graph represents fusion line. As mentioned above that total nine samples were prepared. The average value of three samples fabricated with single layer, double layer and triple layer has been calculated and plotted in the graph. Joint 1, joint 2 and joint 3 are the names given to samples fabricated in single pass, double pass and triple pass respectively.

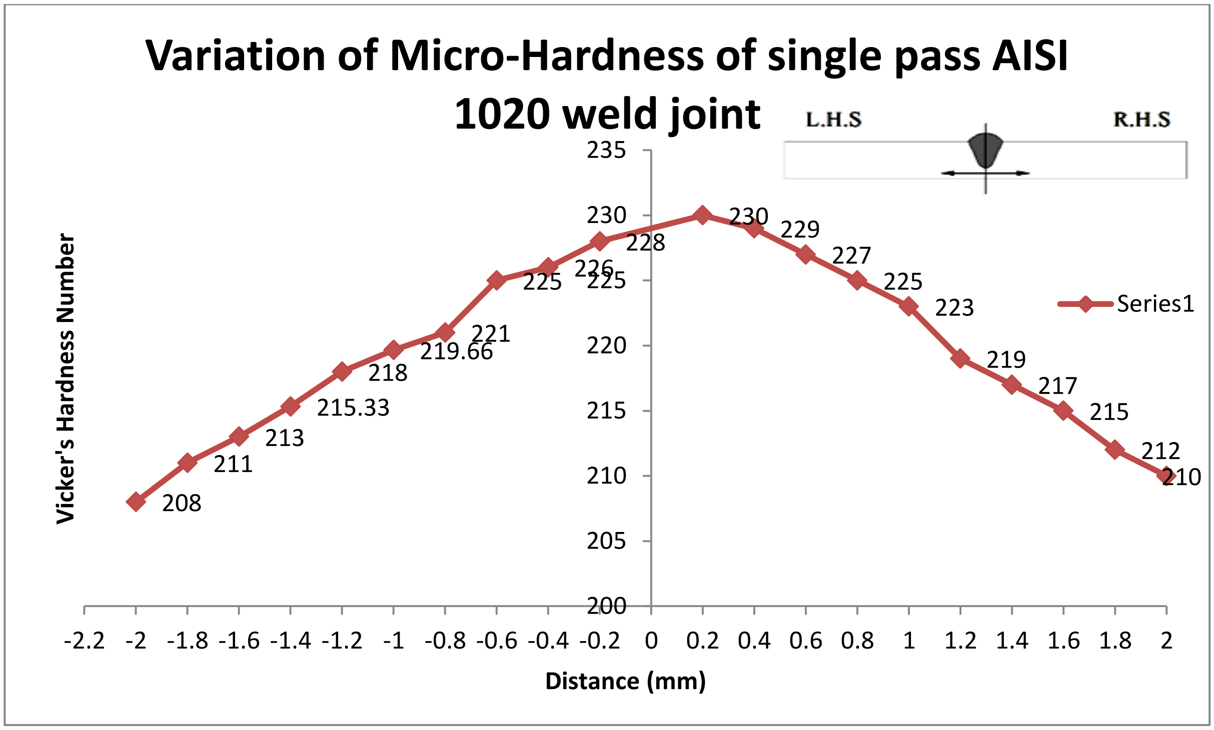

Figure 5.1: Hardness profile of GMAW joints of AISI 1020 in single pass of filler material

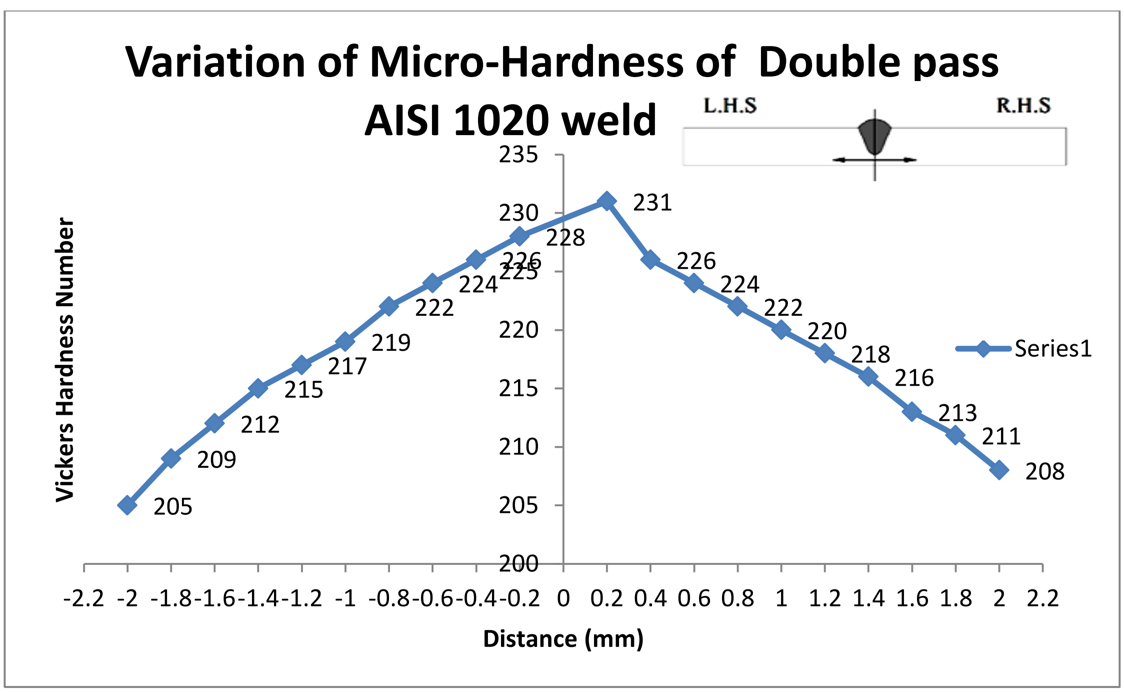

Figure 5.2: Hardness profile of GMAW joints of AISI 1020 in two passes of filler material

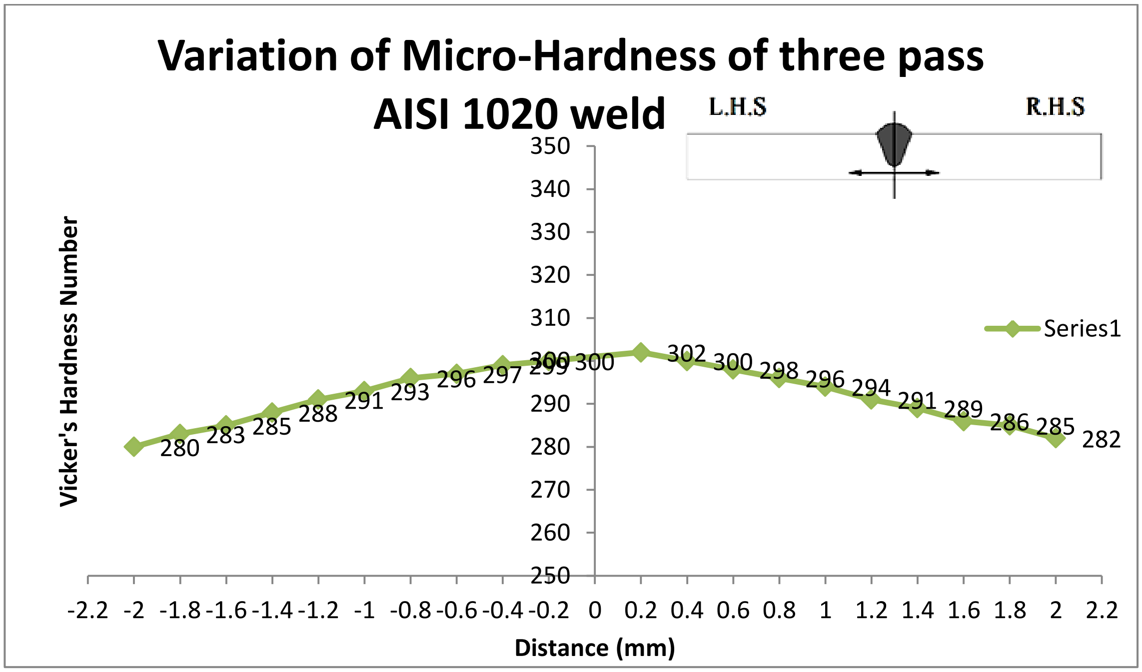

Figure 5.3: Hardness profile of GMAW joints of AISI 1020 in three passes of filler material

Comparison Hardness profile of GMAW joints of AISI 1020 in single, double and triple pass

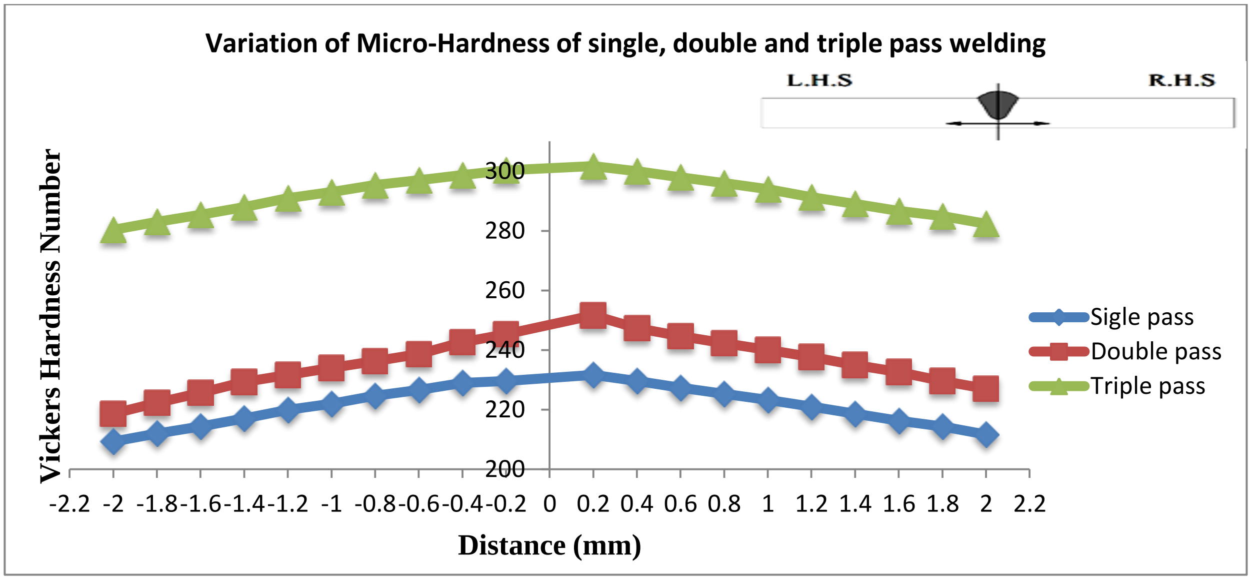

Figure 6: Comparison Hardness profile of GMAW joints of AISI 1020 in single, double and triple pass of filler material

The hardness study shows that the maximum hardness (micro-hardness) 302 HVN is achieved by the triple pass AISI 1020 welded joint namely joint 3 and the minimum hardness (micro-hardness) 230 HVN is possessed by the joint welded in two passes (joint-2). The reason for maximum value of hardness may be due the effect of fast heat flow rate in joint-3 which leads to formation of fine grain size. Similarly, the heat flow rate in joint-1 fabricated with single pass of weld is slow as compared to joint-3due to grain coarsening. Furthermore, re-melting effect is also present in multi-layer welded joint which is also a contributing factor in promoting hardness.

B.Impact Toughness (Charpy V-Notch) – The Charpy V-Notch test is also carried out in order to analyze the impact toughness of AISI 1020 GMA welded joints. The table No 4 reports the average value of impact toughness of single layer welded specimens, double layer welded specimens and triple layer welded specimens respectively.

Table 4: Average value of toughness of AISI 1020 joints

SR NO	WELD JOINT	AVERAGE CVN VALUE
1	Joint – 1 (Single pass)	53 J
2	Joint – 2 (Double pass)	62 J
3	Joint – 3 (Triple pass)	71 J

The results of impact toughness (Charpy V-notch) testing shows that the joint which was fabricated by with triple layers of filler material having maximum energy absorption capacity i.e., 71Joules. On the flip side, the joint which is fabricated by single layer of filler metal possesses minimum energy absorption capacity.

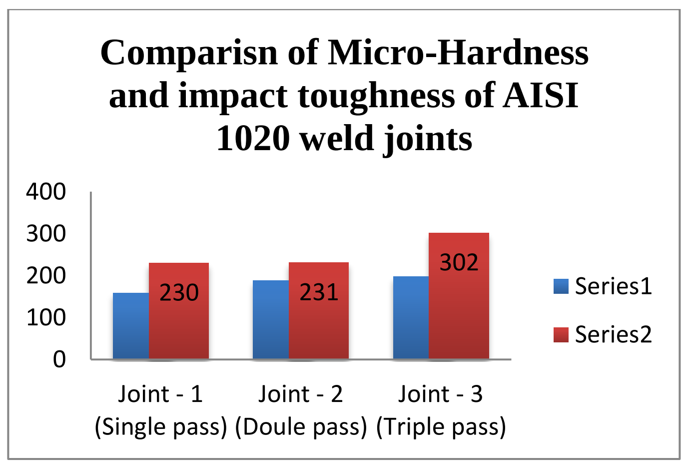

Figure No. 7- Plot shows the relationship between micro-hardness and Charpy V-notch impact toughness.

V: CONCLUSION

AISI 1020 low carbon alloy steel was used for the analysis of impact of multiple passes of welding on Micro-Hardness and Charpy v-notch impact toughness of weld joints in Gas metal arc welding process. The average micro-hardness of triple layer weld specimens (joint-3) comes out to be maximum (302 VHN) whereas the value of average micro-hardness for double layer weld specimen and single layer weld specimen was 231 VHN and 230 VHN respectively. In addition to this, the charpy v-notch impact toughness is maximum (71 Joules) for joint 3 (three passes) whereas 62 Joules and 53 Joules toughness is noticed for joint-2 (two passes) and joint 1(single pass) respectively.

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