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EFFECT OF NICKEL AND VANADIUM ADDITION ON THE IMPACT TOUGHNESS OF AISI1020 STEEL AT ULTRA LOW TEMPERATURE

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Abstract- In this research work, the Charpy impact test along with Fractography observation was carriedout to evaluate the low temperature impact fracture energy of AISI1020 steel welded joints constructedat low ambient temperatures. For the sake of comparison, the impact fracture energy of AISI1020 steel welded at room temperature was also investigated. Standard V-notch Charpy impact specimens were prepared and tested under dynamic loading condition. The effects of low climatic temperatures during welding on the low temperature impact fracture energy of structural steel welded joints were explored based on the absorbed energies and the microstructures, from which the feasibility of welding in cold weather was assessed. Test results revealed that impact toughness of AISI1020 steel increases with the addition of nickel content as compared to vanadium content at room temperature as well as ultra low temperature conditions.

Keywords- Impact toughness, ultra low temperature.

1. INTRODUCTION

Welding at low atmospheric temperatures is frequently needed for the construction of steel structures incold regions. Because, In the past decade, the increasing demand for the naturalresources such as oil and gas has forced the construction ofsteel structures in cold regions. The application of steel structuresin cold environments requires testing whether the steelssatisfy the required impact toughness at low temperatures, as we know steel becomes more vulnerable to brittle fracture by impactloading as the ambient temperature goes down. Welding isessential for the fabrication of steel structural members. Thus,the low temperature impact toughness of the weld metaland the base metal of the weldedsteel structures constructed at cold regions should be evaluatedso as to secure the structural integrity of the welded parts.

Impactstrength is a very important factor for materials design and application. In recent years, extensive studies on the improvement of impact of the weld metal and/or HAZ of steels have been carried out (Kanzawa et.al.,1975; Wu et.al.,2004). The Impact strength can be improved by grain refinement, enhanced cleanliness of the steel, refinement and spheroidization of inclusions, and formation of intragranular ferrite on inclusions, etc.Two major approaches have been pursued to improve the toughness of the Weld Metal. One is to use different types of fluxes (Dallas et.al., 1995; Fox et.al., 1996); the other of great interest is to alter Weld Metal composition either through the use of newer filler metals (Krishnadev and Zang,1999)or by metal power additions in the Weld Metal(Dixon,1996).

The investigations on the Impact strength improvement of different grades of steel under different condition by using the various kinds of alloying elements like nickel, Niobium, vanadium, titanium, Manganese etc. have been made by a number of workers. Most of these investigation had been made on analysis of Impact strength for room temperature application, a very few studies were made including both the room temperature and sub zero temperature applications. e.g.,Abbasi et.al (2007) studied the effect of vanadium (V) addition on the mechanical properties of a Cr-Ni-Mo-Cu-Ti stainless steel and also investigated its influence on microstructure changes and found that the improvement in mechanical properties is attained when the amount of V is in the range of 0.5% -1.0% (in mass percent).Keeping V content above 1% (in mass percent), leads to the deterioration of mechanical properties.Further,Sun et.al (2012) studied the Effects of nickel on low-temperature Impact strength and corrosion resistance of high-ductility ductile iron alloyed with 0–1.8 wt% Ni. The results reveals that as the content of nickel increases, the Impact strength under low temperature ascents a great deal, and reaches the highest point with 0.71 wt% nickel addition, then descents while the corrosion resistance has always been growing with the increasing of nickel content. Ductile iron containing 0.71 wt% nickel shows the best low-temperature Impact strength (the Impact strength values of the samples reached 16.6 J at -20 ◦C, 12.8 J at- 40 ◦C respectively) and exhibits the optimum combination properties.Pilhagen and Sandström (2014) found, while testing the Influence of nickel on the toughness of lean duplex stainless steel welds that Using filler metal with low nickel content (1.3 wt%) resulted in a weld metal with high ferrite content and low toughness at room temperature and sub-zero temperatures. But when the addition of nickel powder content was increased to 5 wt%, resulted in a weldment with appropriate ferrite content. The ductility and toughness were significantly increased. By using a filler metal with the higher nickel content of 7.3 wt%, the ductility and toughness were

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further increased compared to the 5 wt% nickel weldment. And finally concluded that the fracture toughness at sub-zero temperatures increases with increasing nickel content in the range from 1 to 9 wt% nickel.Effect of nickel content addition is also studied by Pamnani et.al.,(2016) and concluded that the sub-zero impact toughness of the weld metals of arc welded joints was directly proportional to the Nickel present in the weld metal. Also, at sub-zero temperatures, the impact toughness of the weld metals of various arc welded joints is influenced by the weld metal grain size, chemical composition of weld metal, acicular ferrite and inclusion content.

2. RESEARCH GAP

Impact strength being the most desirable property for welding application, a number of researchers had worked on the enhancement of Impact strength of different materials. Much work had been dedicated to evaluate the room temperature impact fracture energy of structural steel welds, But the Titanic and Liberty ship accidents focused the mechanical industry to work for sub zero temperature application. From the literature survey, it is found that a very little work had been reported till now for the ultra low temperature application.So need has been realized to work on impact strength enhancement of AISI 1020 structural steel, having so many applications in ultra low temperature conditions.

3. MATERIALS AND WELDING

The base metal used in this study is AISI 1020 structural steel plates having size 304x50x10 mm which is widely used in ship buildings and is guaranteed for use in cold environments.The plates were cut into required length with the help of a power hacksaw. Further in order to perform welding operation V-groove were made by joining tapered edges of two structural steel plates. In order to alter the impact toughness of material, three types of electrodes are used namely,MS Filler metal,Filler metal1 (V 0.2- 0.4 %) andFiller metal2 (Ni 20-22%).The chemical compositions of the welding consumable are presented in Table 3.2. and Table3.1shows the chemical compositionof the base material based on the mill test certificate. Welding machine used for welding is a Shielded metal Arc Welding machine. The selection of this welding machine is based on the previous study of Lee et.al (2012)in which, SMAW is defined as, the optimal welding method to guarantee the higher impact fracture energy at low temperatures of structural steel welded joints made at room temperature.The process parameters were kept constant during the experimentation as represented in table 3.3. The values of these parameters are selected by the trial method.

Table-3.1: Chemical Composition of the used AISI 1020 structural steel specimens (weight%)

Sample Identity	C	Si	Mn	P	S	Cr	Mo	Ni
AISI 1020	0.24	0.15	0.47	0.035	0.042	0.085	.00	0.075

Table-3.2: Chemical composition of the Filler metals

Filler metal	Composition (%)								
	C	Mn	Si	Ni	P	S	V	Cr	Fe
MS Filler metal	0.08	0.45	0.28	0	0.03	0.03	0	-	Balance
Filler metal 2(Ni 20-22%)	0.15	1.5	0.75	20	0.03	0.03	0	14	Balance
Filler metal 1(V 0.2- 0.4 %)	0.10	1.5	0.4	0	.03	.03	0.4	3/0	balance

Table-3.3: Process parameters used in the experimentation

S. No.	Filler metal Used	Welding voltage(V)	Welding current(A)	Arc time(sec)	Welding speed*(v) (mm/sec)
1	MS Filler metal	28±2	125±2	90	3.38
2	Filler metal1 (V 0.2- 0.4 %)	28±2	125±2	90	3.38
3	Filler metal2 (Ni 20-22%)	28±2	125±2	90	3.38

4. TESTING PROCEDURE

The testing task is completed by using the following steps:

4.1 Preparation of Test Specimen

The Choice of sample for a microscopic study is very important. In the manual welding process the speed of welding varies along the length. Therefore samples are taken from the middle section of the welded plate where the welder's speed of welding is assumed to be constant.After welding, transverse section of the weld beads were cut from the middle portion of the specimens as. These specimens were prepared by standard metallurgical polishing methods. The impact testing was carried out in strength of material lab (civil engineering department), GZS PTU CAMPUS Bathinda. Standard Charpy impact specimens of dimension 55x10x10 mm with a notch angle of 45^0 and 2 mm depth located in the middle is prepared for testing purpose.

4.2 Temperature Measurements of Specimens before Subjecting them To Charpy Testing

A pair of specimens is tested at individual temperatures range, which is maintained by using the mediums as listed in table 4.1.After taking the specimens from liquid nitrogen, temperature of the specimens is measured with the help of a infrared thermometer having temperature range -80^0C to 550^0C.

4.3 Room temperature test specimen is first carried out by placing the Charpy impact specimen on the anvil and positioning it in the middle location using a positioning pin where the opposite site of the notch is destined for the pendulum impact.Thenraised the pendulum to a height corresponding to the maximum stored energy of 300J.

Release the pendulum to allow specimen to get impact. Safely stop the movement of the pendulum after swinging back from the opposite side of the machine.

Table 4.1: Temperature and mediums used for Charpy impact testing.

Temperature	25^0C	0^0C	-30^0	-60^0C
Medium	Room Temp.	Ice	Liquid nitrogen + Ethanol	Liquid nitrogen

When the pendulum is stopped, safely retrieve the broken specimen without damaging fracture surfaces. Record the absorbed energy. Repeat the test at the same test condition using another specimen to average out the obtained values.

4.4 Further, Charpy impact testing at temperatures (0^0C, $-30^{0,}$ -60^0C$^{.}$) other than room temperature is carried out by following same steps as that for the room temperature specimen . Prior to specimen impact, specimen is submerged in the medium for at least 5 minutes to ensure uniform temperature across the specimens as shown in figure 3.8 Specimen impact must be within 5 seconds after removing from the medium. The absorbed energy is recorded.Repeat the test at the same test condition using another specimen to average out the obtained values.

5. RESULTS AND DISCUSSION

5.1 IMPACT TOUGHNESS TESTING

The Absorbed energy (J) of each specimen (cut from centre of weld) tested at different temperatures as presented in table 5.1.It is clearly observed from the Table 5.1 that, the tested specimens absorb minimum energy under deep cryogenic temperature conditions and energy absorbed per specimen increased as ambient conditions changed from deep cryogenic (-60^0C) to 0^0C temperature and finally room temperature conditions.As we know at room temperature each sub atomic particle has its own internal energy.

Table-5.1: Absorbed energy (J) of each specimen (cut from centre of weld) tested at different temperatures

Temp (^{0}C)	Weld made by MS Filer metal	Weld made by Filler meatl-2 (20-22% Ni)	Weld made by Filler metal-1 (0.2-0.4% V)
25	130	260	200
0	110	230	180
-30	40	120	70
-60	26	100	50

Because of which they vibrates continuously about their mean position, but under deep cryogenic conditions vibratory motion get seized. So, it could not bear the impact load safely.Since, it has already been established in literature that at subzero temperature conditions, impact strength of weldments is the direct function of the percentage of nickel, vanadium and some other alloy elements. Thus, because of obvious reasons, AISI 1020 Structural steel weldment with higher nickel content showed maximumimpact strength value as compared to the other specimens. Increment in impact strength is more with the addition of nickel as compared to vanadium. This could be attributed to the fact that the specimen fabricated using the filler metal-2 containing (20-22%) percentage of nickel resulted in the formation of finer grains in the weld metal.This small grain size leads to finer microstructure and greater number of dislocations as observed in microscope images. These discontinuities (flaws) act as a resistant to the propagation of fracture and also helpful to enhance the impact strength value under all ambient conditions, as seen in the weldment laid by electrode-2.

5.2 Fractography Testing

Fractography is used to investigate the type of fracture took place and effect of nickel and vanadium on the weldments of AISI1020 structural steel.

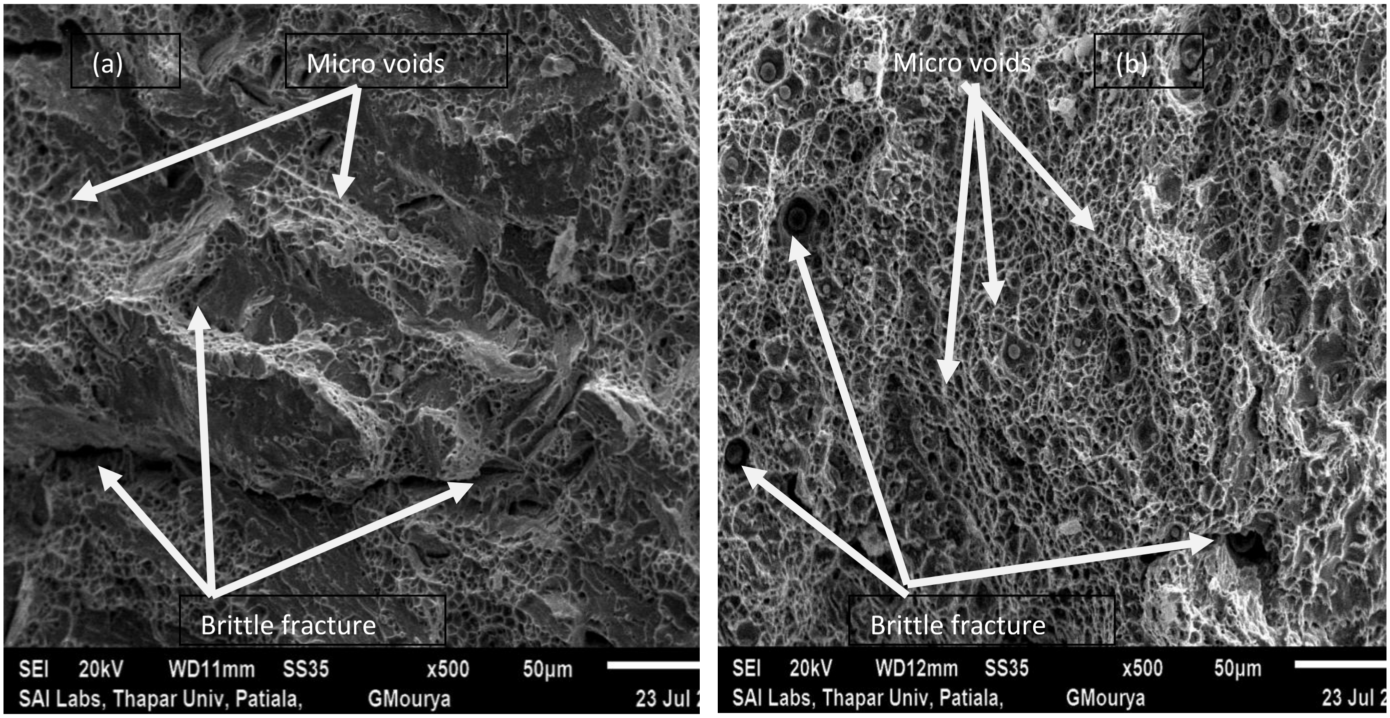

Figure-5.1.:SEM of weldments fractures surfaces (a) with Vanadium 0.4% and (b) with nickel 20%, of Charpy impact broken specimens tested at 25^0C temperature

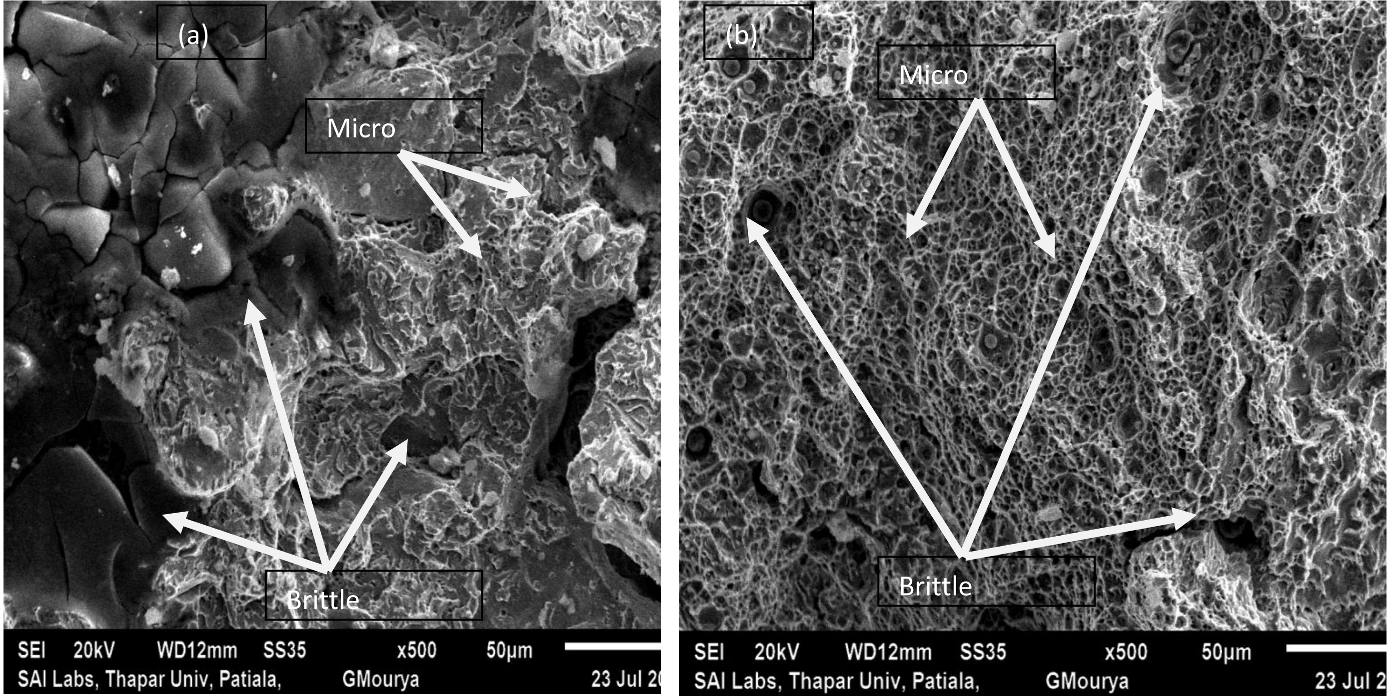

Figure-5.2 : SEM of weldment fracture surfaces (a) with Vanadium 0.4% and (b) with nickel 20%, of Charpy impact broken specimens tested at deep cryogenic temperature (-60^0C).

For the present research work, fracture surface of two impact broken samples at -60^0C and two impact broken samples at

25^0C temperature was compared, two with high nickel content (20%) and two was with vanadium 0.4 % content as shown in the Figures 5.1. and Figure 5.2.Both the fracto graphs are to be compare. So, electrons were accelerated with same energy i.e. 20 KeV and the electron spot were adjusted on to the fractured weldment surface excluding the edge of v notch.

Figures 5.1. Show fracture surface of specimen with 20% nickel (Figure 5.1. (b)) tested at 25^0C, fracture proceeded by micro-void coalescence manner. Both large and micro voids, in the case of welded specimen with vanadium 0.4 % (Figure 5.1 (a)) are clearly observed rather than finer dimples in the case of (Figure 5.1. (b)).

In the case of fracture condition at deep cryogenic temperature range (-60^0C), weldment with 0.4% vanadium displays cleavage mode of fracture characterized by large cleavage facets (Figure 5.2(a)). Alternatively, the high nickel weldment fracture surface (Figure 5.2. (b)) contains smaller facet-like arrangements with river patterns formed by cleavage lines and steps. The cleavage facet size in both cases can be compared to their grain size. At the end we can conclude that high nickel weldment fracture surface contains micro voids at both 25^0C temperature as well as cryogenic temperature while weldment with vanadium possesses micro voida at 25^0C temperature. But fails in brittle manner at cryogenic temperature.

6. CONCLUSIONS

After comparing the results of various tests (which were conducted within the range of parameters investigated), some conclusions were drawn represented as follows:

1) The Impact strength at room temperature increased with addition of nickel and vanadium.
2) Maximum impact strength 260 joules were achieved with addition of nickel (20-22 %) under 25^0C temperature conditions.
3) Increment in impact strength is more with the addition of filler metal 2 as compared to filler metal 1 and MS electrode. This could be attributed to the fact that the specimen fabricated using the filler metal-2 containing highest percentage of nickel resulted in the formation of finer grains in the weld metal. This finer grain size enhances the impact strength value under all temperature conditions.
4) The percentage increment in impact strength of weldment specimens made by electrode-1, electrode-2 and as compared with the Impact strength of mild steel were found to be 35%, 50% at 25^0C temperature, 38.8%, 52.17% respectively at 0^0C temperature conditions 42.85% and 66.6% respectively at -30^0C temperature condition and 48%and 74% respectively at -60^0C temperature condition.

5) The impact strength increment of weldment specimens made by electrode 2 (20-22%Ni) as compared with the impact strength of weldment specimens made by electrode 1 (0.2-0.4% V) were found to be23.07% at 25^0C temperature, 21.7% at 0^0C temperature conditions, 41.6% at -30^0C temperature condition and 50% at -60^0C temperature condition.

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