Investigation of SMAW Joints By Varying Concentration of Rutile (TiO_2) in Electrode Flux

Chirag Sharma[1], Amit Sharma[2], Pushpinder Sharma[2]

[1]Scholar, Mechanical Department, Geeta Engineering College, Panipat, Haryana, India

[2]Assistant Professor, Mechanical Department, Geeta Engineering College, Panipat, Haryana, India

E-Mail- chirag485@gmail.com

Abstract— Our aim to investigate the SMAW joints by varying the concentration of Rutile (TiO_2) in the flux composition on the various characteristics of metal cored coated electrodes for the purpose of developing efficient and better rutile electrodes for structural mild steel. In this work five rutile metal cored coated electrodes were prepared by increasing Rutile (TiO_2), at the expense of cellulose and Si-bearing components like Mica and Calcite in the fluxes. Various mechanical properties like micro hardness, tensile properties and Impact toughness were measured and metallographic studies were undertaken. Qualitative measurements of operational properties like porosity, slag detachability and arc stability were also carried out.

Keywords— Rutile (TiO_2),Composition of Flux in various electrodes, Hardness Test, Tensile Test, Impact Test, Slag Detachability, porosity, Microstructure of weld bead.

INTRODUCTION

Welding is a fabrication process that joins materials permanently, usually similar or dissimilar metals by the use of heat causing fusion with or without the application of pressure. SMAW is the arc welding process known to even a layman and can be considered a roadside welding process. When an arc is struck between an electrode and the work piece, the electrode core wire and its coating melt, the latter provides a gas shield to protect the molten weld pool and the tip of the electrode from the ill effects of the atmospheric gases. The diameter of electrodes usually varies between 3.15 to 12.50 mm. the length varies between 350 to 450 mm.

EXPERIMENTAL METHOD

The method for the accomplishment of the experiment include the production of electrodes, extrusion of electrodes, micro hardness testing, tensile strength testing, impact strength testing and microstructure testing of the weld beads produced by five new developed electrodes.

Process of Electrode Production

The ingredients in dry form were weighted and were mixed appropriately for around 10-15 minutes to obtain a homogeneous dry flux mixture. A liquid silicate binder was then added to the mixed dry flux, followed by mixing for further 10 minutes, this process is also known as wet mixing. The binder consists of a complex mixture of different alkali silicates with a wide range of viscosities.

The flux coating ingredients commonly used are Rutile, Aluminite, $CaCO_3MgCO_3$, Cellulose, Ferromanganese, Quartz, Calcite, China clay, Mica, Iron Powder, Talcum Powder, and Binding agents (Sodium Silicate) etc.

The flux was then extruded onto a 3.15 mm diameter mild steel core wire and coating diameter of flux .4 -.55 mm, final dia. after coating is approximately 3.7 mm. with coating factor of 1.18, where the coating factor represents the ratio of the core wire diameter to the final electrode diameter.

The electrodes were baked after the extrusion. The baking cycle consisted of 90 minutes at 140-150°C. These electrodes were tested by taking weld bead on plates and finally 5 types of flux coating composition were obtained by varying the Rutile (TiO_2) from 27 to 42 % wt. at the expense of calcium fluoride, cellulose, Calcite, and Si-bearing raw materials in the dry mix.

Extrusion of Electrodes

The final five electrodes were finally extruded from injection moulding machine. All the electrodes were produced with the same wire and different powder raw material batches.

The coating dry mix composition with the corresponding weight percentage of the components is shown in Table with Coating Composition (wt %):-

Constituents	27% TiO_2	31% TiO_2	34.5% TiO_2	39% TiO_2	42%TiO_2
Aluminite	16.47	16.47	16.42	16.39	16.32
$CaCO_3MgCO_3$	7.6	7.5	7.3	7	7
Cellulose	5.43	5.2	4.6	3.9	3.6
Ferromanganese	6	5.5	5.5	5.5	5.5
Quartz	6.52	6.2	5.9	5.2	4.8
Calcite	9.8	8.3	7.6	7.1	6.3
China Clay	9.8	8.8	7.8	6.6	5.8
Mica	8.7	8.4	7.7	6.7	6.12
Telcom Power	1.6	1.6	1.6	1.6	1.6
Iron Powder	1.6	1.1	1.1	1.1	1.1

RESULTS AND DISCUSSION

Slag Properties

The slag properties by all of the flux coatings are of good quality i.e. all of them covered the bead completely. The bead was in good shape and cleans after the removal of slag. The slag produced by 31 % TiO_2 flux was observed to interfere with the weld pool in both of the current conditions i.e. DCEP and DCEN.

On the other hand the 27 %, 34.5 %, 39 % and 42 % TiO_2 slag did not interfere with the weld pool and the weld beads obtained by these electrodes were smooth and clean.

Spatter

The spatters produced in DCEP welding were observed to be more than in DCEN welding. Further it was observed that in DCEP 27 %, 31 % and 34.5 % TiO_2 electrodes produced more spatters than in other electrodes. In General, the spatters were easy to remove and were of medium size.

Fig. Weld beads obtained on welding with DCEN and DCEP

Operational Properties

In general, the arc stability in DCEN welding for all types of electrodes was better than that in case of DCEP. The slag produced by 27 %, 31 %, 34.5 % and 39 % TiO_2 electrodes was thicker than that of 42 % TiO_2 electrodes.

The slag detachability is good for DCEN welding for all electrodes. The slag was more difficult to detach in DCEP especially with 39 % and 42 % TiO_2 electrodes.

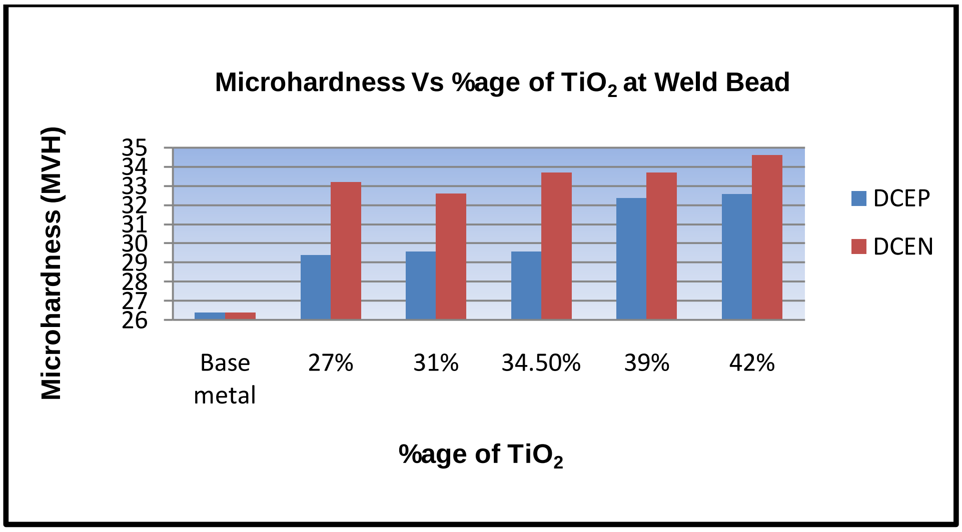
The slag for all electrodes presented porosity but it was more prominent in DCEP especially with 42% TiO_2 electrodes.

Observations of porosity, arc stability, slag detachability during welding:

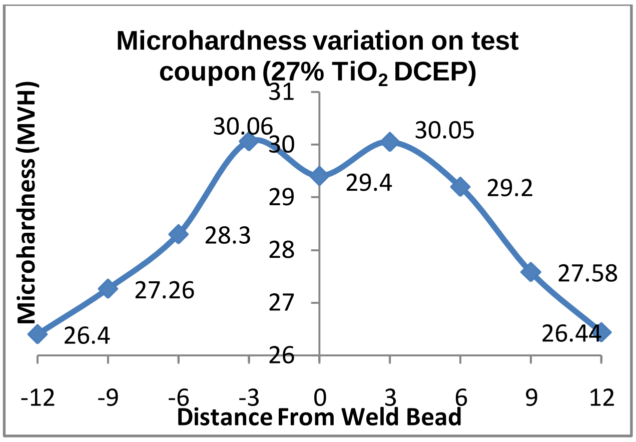
Coating	Current Type	Arc Stability	Slag Detachability	Porosity
27% TiO_2	**DCEP**	**Good**	**Good**	**Present**
	DCEN	**Good**	**Good**	**Present**
31% TiO_2	**DCEP**	**Medium**	**Medium**	**Present**
	DCEN	**Good**	**Good**	**Present**
34.5% TiO_2	**DCEP**	**Medium**	**Medium**	**Present**
	DCEN	**Good**	**Good**	**Present**
39% TiO_2	**DCEP**	**Good**	**Medium**	**Present**
	DCEN	**Good**	**Good**	**Highly Present**
42% TiO_2	**DCEP**	**Excellent**	**Good**	**Present**
	DCEN	**Excellent**	**Good**	**Highly Present**

Micro hardness Measurements— The micro hardness was measured at five points on each sides of the weld bead including the weld bead itself on a specimen.

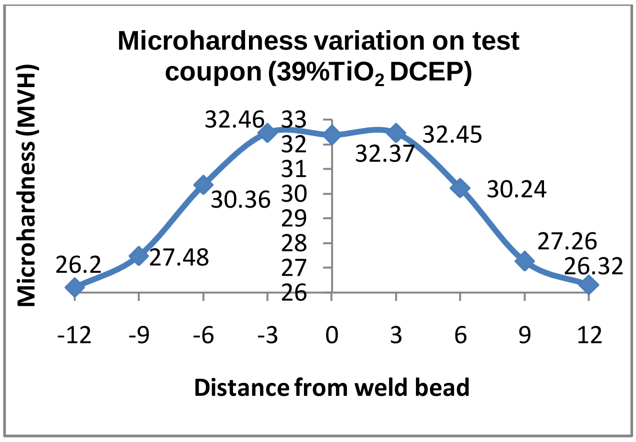
Micro Hardness Test Results (MVH) DCEP:



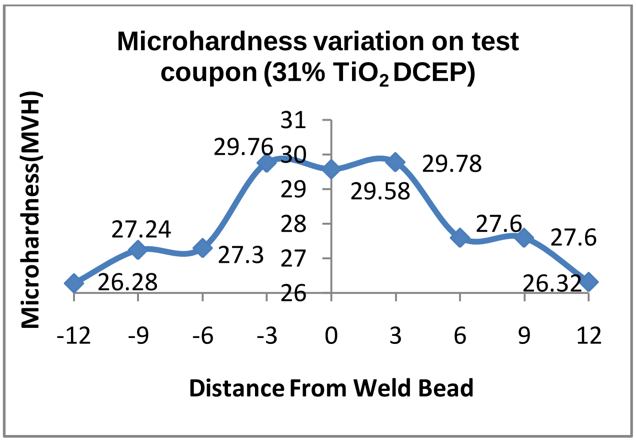
Micro hardness at Weld Bead Vs TiO_2 Composition



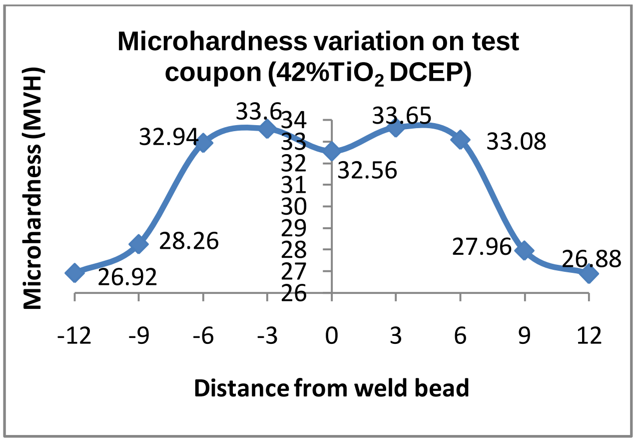
Micro hardness variation along the test coupon 27 % TiO_2 (DCEP)



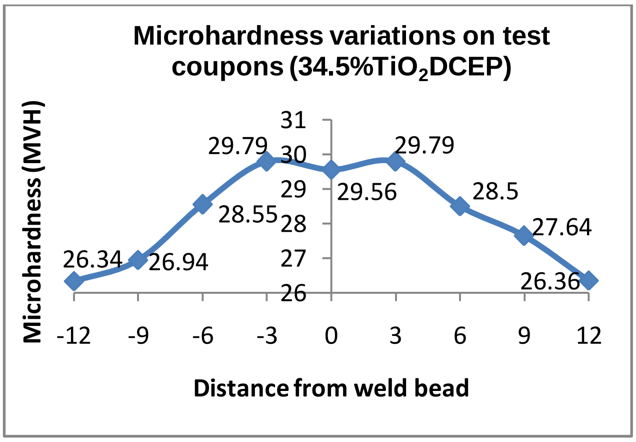
Micro hardness variation along the test coupon 39 % TiO_2 (DCEP)



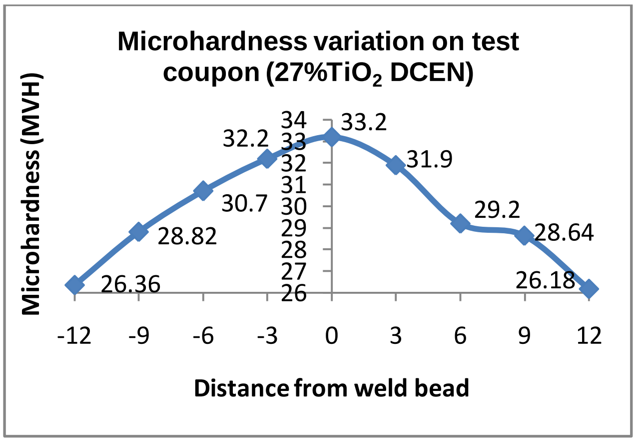
Micro hardness variation along the test coupon 31 % TiO_2 (DCEP)



Micro hardness variation along the test coupon 42 % TiO_2 (DCEP)



Micro hardness variation along the test coupon 34.5 % TiO_2 (DCEP)



Micro hardness variation along the test coupon 27 % TiO_2 (DCEN)

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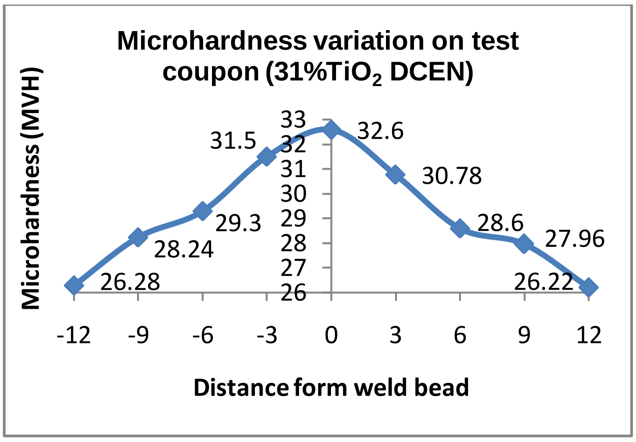
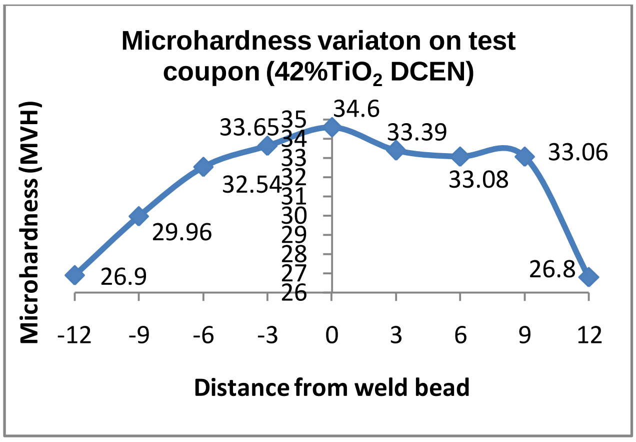
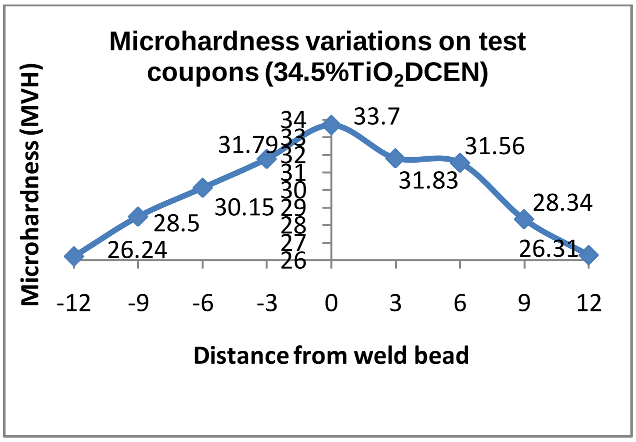


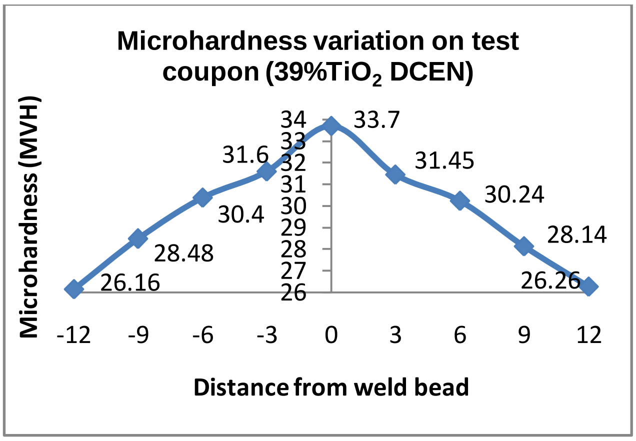
Micro hardness variation along the test coupon 31 % TiO_2 (DCEN)



Micro hardness variation along the test coupon 42 % TiO_2 (DCEN)



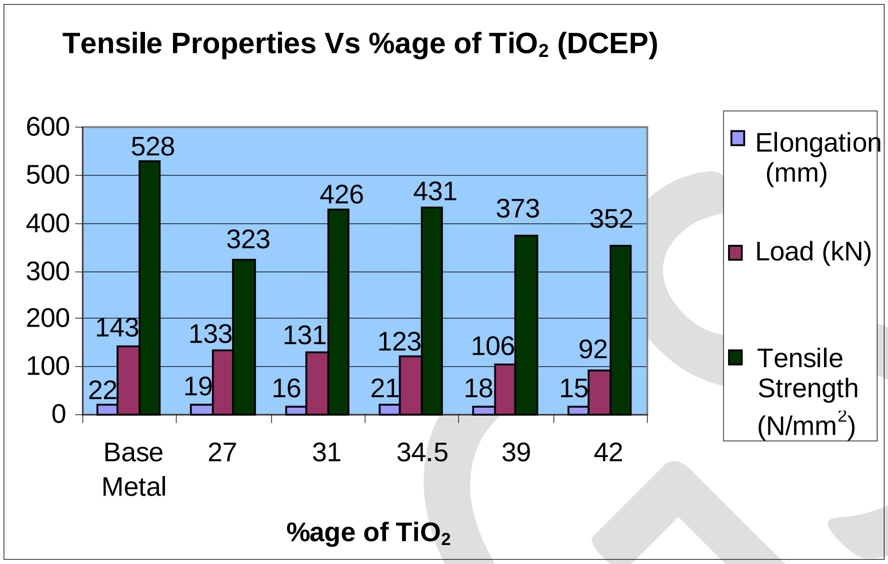
Micro hardness variation along the test coupon 34.5 % TiO_2 (DCEN)



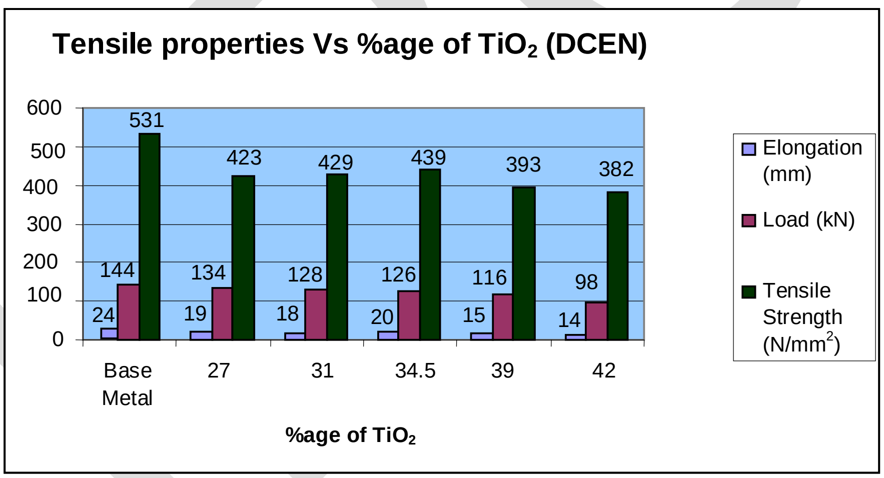
Micro hardness variation along the test coupon 39 % TiO_2 (DCEN)

Tensile Properties Test Results

The results of tensile properties measurements are recorded in Tables for DCEP and DCEN currents respectively. The elongation is decreased with decrease in tensile strength.



Histogram for Tensile Properties for DCEP

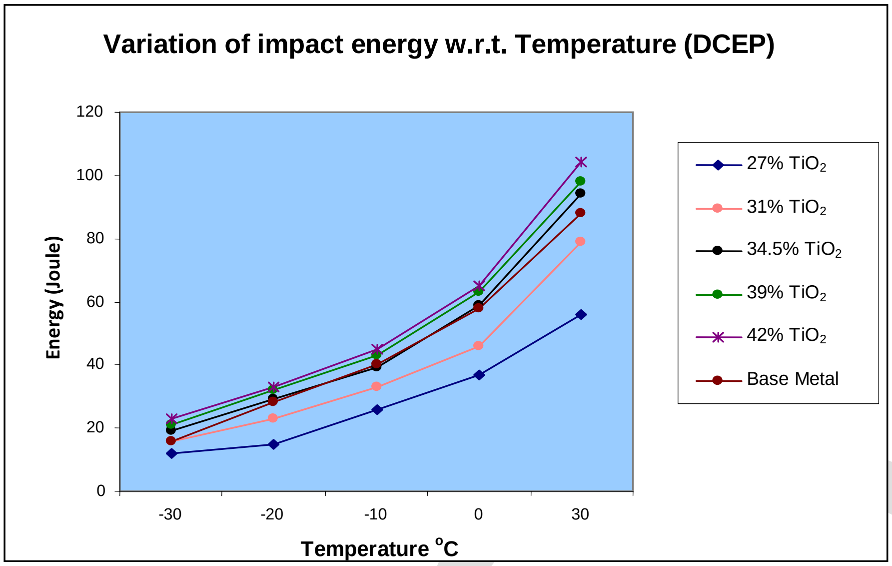


Histogram for Tensile Properties for DCEN

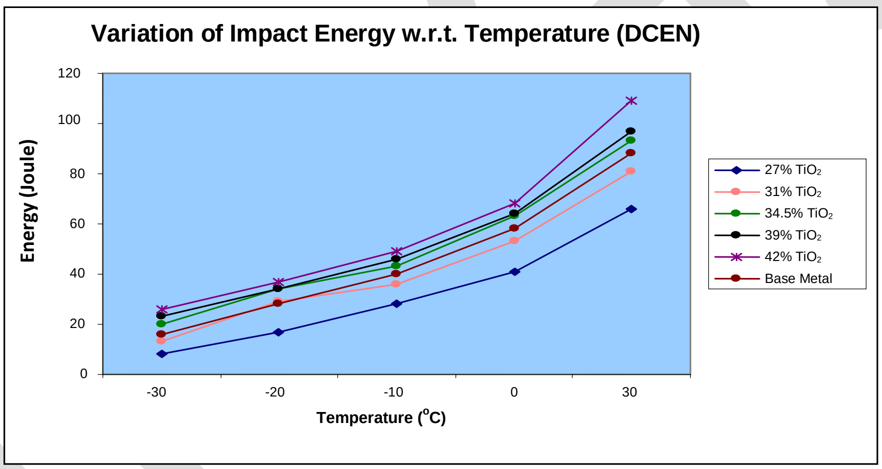
Charpy V Notch Impact Test Results

Charpy V notch test samples were prepared for the impact strength measurements. These test coupons were dipped in liquid nitrogen to drop their temperature from room temperature to -30 ^{o}C, -20 ^{o}C,-10 ^{o}C and 0 ^{o}C by varying the dipping time of test coupons in the liquid nitrogen.

The results showed that the toughness of the weld coupon increases as the percentage of TiO_2 is increased for both types of current conditions. The variations of impact energy with temperature for DCEP and DCEN are shown in figures respectively. Toughness is related to the hardness and tensile properties of the material. The toughness of the weld metal is reported to be increased with a reduction in tensile strength of the weld coupon and an increment in toughness is also observable with an increment in micro hardness of the weld coupon.



Energy Vs Temperature graph of impact Test Results (DCEP)



Energy Vs Temperature graph of impact Test Results (DCEN)

Microstructure Test Results

The microstructure of base metal shows ferrite grains and small quantities of pearlite at the grain boundaries.

In the electrodes having 27 % TiO_2 and 31 % TiO_2 small quantity of grain boundary ferrite is observed whereas the acicular ferrite is prominently present. The presence of pearlite is also observable with a minute quantity of martensite which results in small increment in micro hardness.

For electrodes having 34.5 %, 39 % and 42 % TiO_2 acicular ferrite is much less than that of 27 % and 31 % TiO_2 electrodes microstructure. With the presence of pearlite, aggregates of cementite are also observable. Precipitates of aligned martensite are also noticeable. The presence of cementite and aligned martensite results in increased micro hardness. Such type of microstructure renders the weld metal with low ductility and increased toughness. The presence of martensite is more prominent in DCEN welding than that of DCEP.

CONCLUSION

The penetration and bead width was increased with increase in TiO_2 percentage in general for all types of electrodes and for DCEN type of current conditions.

The bead geometry produced in DCEN welding was better than that produced in DCEP.

The arc stability is observed to be good for 42 % TiO_2 electrodes. Smoke level was seemed to be reduced at higher percentage of TiO_2. Slag detachability was generally good for 34.5 %, 39 % & 42 % TiO_2 electrodes.

An overall increase in the Micro Hardness at the weld bead was observed with the increase in the amount of TiO_2.The micro hardness is observed to be increased due to the increase in percentage and migration of carbon and silicon.

An overall decrease in the tensile strength was observed with the increase in TiO_2. The increment in silicon and carbon resulted in reduction in the tensile strength of the weld metal.

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