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DEVELOPMENT AND EXPERIMENTAL INVESTIGATION OF MECHANICAL AND MICROSTRUCTURAL BEHAVIOUR OF WELDED DUAL PHASE STEELS (DPS)

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Abstract - This investigation first envisages the development of series of DP microstructures by inter-critical annealing of initial martensitic and initial austenitic microstructures of micro alloyed steel. Subsequently, these together employing a shielded Metal Arc Welding (SMAW) and investigated in order to understand their structure properties relations with the major aim to assess their potential as structural materials for applications in thicker sections. The wide acceptance of DP steel in structural applications will not be appreciable due to insufficient knowledge regarding its weldability under different welding process. Hence the objective of the presence investigation is to study the mechanical properties of the butt-welded dual phase steel by Shielded Metal Arc Welding process for thicker sections.

Keywords: DP microstructures; Intermediate Quenching; SMAW;

I. INTRODUCTION

Dual phase steel is a new class of high strength low alloy steel (HSLA) having microstructure of strong martensite, ferrite and small amounts of retained austenite. It is well known that this has a number of unique properties such as continuous yielding, high initial strain hardening, superior combination of strength and ductility. The influence of the microstructure on the mechanical properties of conventional dual phase steels are well documented in the literature and it is known that the nature of microstructure in a dual-phase steel depends on the chemistry of the material. The microstructural features, which govern mechanical properties of these steels, are: the nature, relative amount, morphology, and distribution of the phases.

II. PREPARTATION OF DUAL PHASE STEELS

A Commercial micro alloyed steel supplied by M/s Swedish steel; Oxelosund, Sweden was selected as the starting material for making dual phase microstructures by suitable heat treatments. The as-received steel was in the form of 14mm thick hot rolled plates in quenched and tempered condition. The chemical composition of the steel was ascertained with the help of a Baird optical Emission spectrometer (model: DV4).Plates of dimension 400*150*20mm were suctioned from large plate using oxy-acetylene cutting. The specimens blank were subjected to intermediate quenching using a Muffle Furnace.The specimens was first soaked at 920°Cfor 60 minutes and was quenched in iced brine solution (-7°C).

TABLE.1 CHEMICAL COMPOSITION (WT. %) OF THE STEEL

C	Mn	S	P	Si	Cr	Mo	V	B	N
0.2	1.3	0.002	0.01	0.44	0.03	0.09	0.056	0.0019	0.4

These were then held at different intercritical temperatures of (ICT) 730°C, 760°C, 800°C and 820°C for 60 minutes and were finally quenched in oil 25°C. Precautions were taken to obtain uniformity of cooling during all quenching operations. Cooling characteristics of iced brine solution and that of oil were determined using a Drayton Quench Master. To know the microstructure of above heat-treated plates, the specimens were prepared for metallographic examinations. Test coupons for metallographic examinations were cut from the heat-treatment blanks.

TABLE.2 HEAT TREATMENT SCHEDULE

Type of heat treatment	Specimen Code	Austenitizing treatment for 30min at 920°C followed by cooling in	Intercrtical soaking temp (°C) for 60 min	Final Cooling media
Intermediate Quenching (IQ)	A73	Iced brine Solution(-7°C)	730	Oil
	A75		750	
	A78		780	
	A81		810	

In order to avoid any deformation or burning of the surfaces, these were first ground on successively finer silicon carbide abrasive papers, followed by polishing. The polishing was carried out on Texmet paper cloth using a colloidal suspension (Buehler Master Polish) at a wheel speedof140rpm. Then the polished test specimens (A73, A75, A78 and A81) were cleaned with proper etchants (NItal sodium Meta bi sulphide) and there by the test specimens of the base material were prepared and placed under the microscope to obtain their microstructures.

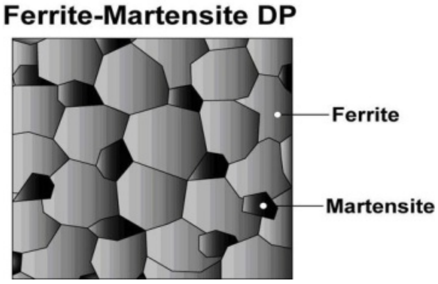

Fig. 1. Ferrite-Martensite DP

The microstructure indicates blocky ferrite regions (white) mixed with martensitic domains (black) having globular or plate morphology. The ferritic regions appear to remain enveloped by globular martensitic regions but dispersed with both globular and plate martensitic domains. In addition to the ferrite and martensite, it reveals some fine black dots dispersed in ferrite. These 'dots' represent undissolved carbide particles formed during the reversion of the initial martensitic structure to the ferrite austenite in the intercritical temperature via the path of tempered martensite state of ferrite plus carbine. Thus the amount of undissolved carbide in the ferritic regions bears a distinct relation with the temperature of intercritical treatments. This phenomenon can simply be explained by the time and temperature requirements for the definition for the diffusion of carbon and consequent dissolution of carbines to form austenite at intercritical temperatures.

III. FORMATION OF DUAL – PHASE MICROSTRUCTURES

The ferrite-martensite duplex structure can be formed by heating steel into a ferrite-austenite (α-γ) region of the Fe-C binary phase diagram [commonly referred as interstitial annealing] and then cooling it rapidly by quenching in a suitable media depending on the chemistry of the steel. Upon quenching, the austenite transforms to martensite. The level of Carbon and the selected inter critical temperature primarily governs the amount, type and the distribution of martensite in DP steel[1].

A Nature of ferrite

The design of Dual Phase steels demands maximum possible contribution of ductility to emerge from the ferrite matrix. This requires a clean ferrite, free from interstitial impurities and precipitates (Tanaka et al., 1979: Hayami et al., 1979). Lagneborg, 1978 has pointed out that ductility improvement of ferrite is usually associated with a reduction in strength, but Morrison, 1966 has considered that simultaneous improvement in strength and ductility of the ferrite phase in DP steels can be achieved by grain refinement. Davies, 1978 has compiled the above facts; and proposed that fine grained, clean ferrite is required for optimum ductility and strength combination of DP steels.

B Nature of martensite

The nature of martensite in DP steels is governed by the grain size and the solute (interstitial and substitutional) content of the austenite from which itforms. Cohen, 1978 has showed that yield strength of carbon free martensite is inversely proportional to the square root of the grain size. It is also well established (Chilton et al., 1968) that the strength of martensite varies linearly with the square root of the carbon content. This behavior has been explained (Fleischer et al., 1962) on the basis of tetragonal distortion of the ferrite lattice by carbon atoms during the phase transformation of austenite to martensite. The amount of such distortion increases with increasing in carbon content. Martensite with high carbon content is reported to posse's high residual stress (Kelly et al., 1961).

IV. MATERIAL

The chemical composition of the steel was ascertained with the help of a Baird Optical emission spectrometer and as shown in the Table 3.

TABLE.3 CHEMICAL COMPOSITIONS (WT. %) OF THE STEEL

C	Mn	S	P	Si	Cr	Mo	V	B	N
0.2	1.3	0.002	0.01	0.44	0.03	0.09	0.056	0.0019	0.4

V. HEAT TREATMENT

Varying the relative proportions of the micro constituents can change mechanical properties. It is in practice that the process known as Heat Treatment. This process consists of heating a metal or alloy to a specific pre-determined temperature, holding at this temperature for a required time and finally cooling from this temperature. Hence Heat treatment can be referred to both heating and cooling operations applied to alloys or metals in solid state so as to obtain the desired properties.

Heat treatment process can be under taken for the following purpose:

1. Improvement in Ductility.
2. Revealing internal stress.
3. Refinement of grain size.
4. Increase the hardness or tensile strength.
5. Achieving changes in the chemical composition of the metal as in the case of hardening.

HEAT TREATMENT PROCEDURE

To Obtain Dual Phase steel from the base material, an, Intermediate Quenching heat treatment process is followed. Specimen blanks of size 210 x 70 x 14 mm were cut from hot rolled plates in quenched and tempered condition. The IQ treatment consisted of double quench operation where the specimen was first soaked at 920°C for 30 minutes and was quenched in 9% iced brine solution (50°C). These were then held at different inter-critical temperatures of 730°C, 750°C, 780°C and 810°C for about 60 minutes and were finally quenched in oil at 25°C. From Fig.2, the microstructure indicates that composite mixture of ferrite (black) and martensite (white) having plate morphology.

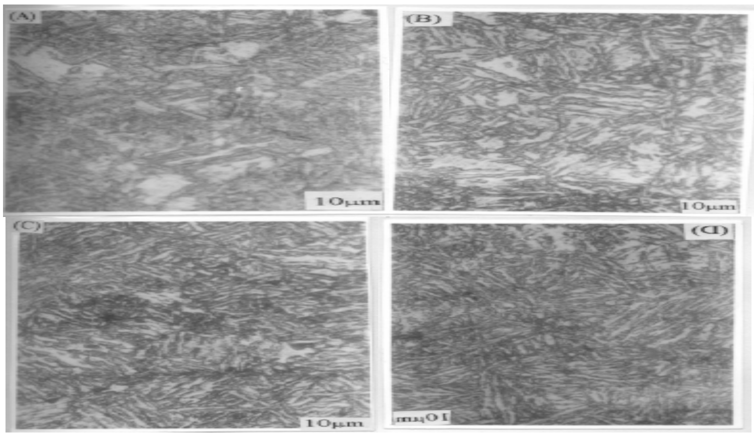

Fig. 2.Micro graphs corresponding to ICT at: (A) 730°C (B) 750°C (c) 780°C (D) 810°C

VI. VOLUME FRACTION DETERMINATION

To determine the volume fraction of the phases involved, by a systematic manual method, in which point-counting technique was employed by following the ASTM standard E562 and thereby estimating the volume fraction of an identifiable constituent of phase from sections through the microstructure. The four types of grids employed are as shown below[6].

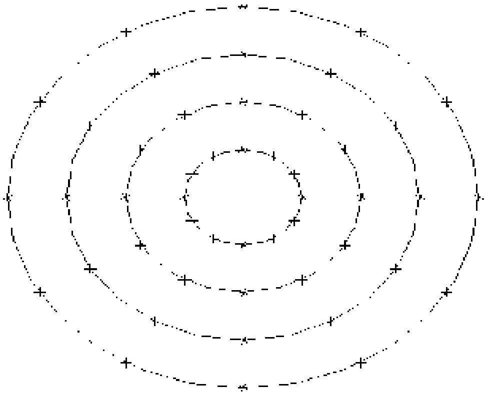

TABLE.4 RESULTS OF THE QUANTITATIVE MICRO STRUCTURAL ANALYSIS

Specimen code	Volume percentage		Retained austenite (%)
	Ferrite (%)	Martensite (%)	
A73	68.8	31.2	------
A75	54.78	43.05	2.17
A78	47.7	51.04	1.26
A81	39.29	59.07	1.34

According to the objectives above mentioned the mechanical properties of welded dual phase steel quenched at different temperature limits are tabulated below. The specimen which is quenched at the temperature 730°C, 750°C, 780°C and 810°C are named as A73, A75, A78 and A81 respectively. These names are used below to show the results.

VII. WELDING OF DUAL PHASE STEEL

A Pre Heating Process

Pre heat is the application of heat to the base metal before welding. This will reduce the danger of weld cracking, reduce the maximum hardness, minimize shrinkage, lessen distortion and help gases particularly hydrogen to escape from the metals [3]. Preheating is not a favored precaution in welding or Quenched and Tempered alloy steels because of its strong effects in recuing cooling rate. However if a satisfactory fast rate of cooling can be obtained in the heat affected zone with a given amount of preheat. There normally is no further objection to preheat. The customary practice in welding these steels is to start with the base metal at room temperature, lower temperature are avoided because they promote cracking. If the joints are heavy and restrained, then a moderate preheats is advisable [4].

Welding Parametric Values

1) Electrode Specification	-AWSE 9018G
2) Voltage	-22 to 27V
3) Current	-110 to 115 A
4) Welding Speed	-0.00228m /sec
5) Electrode diameter	-3.15 mm
6) Inter pass temperature	-100to150°C
7) Heat input	-0.4 to 0.7 K W

B Electrode specification

The mechanical properties of the above chosen electrode are:-

1) Ultimate Tensile strength	-625- 700 Mpa
2) Yield Strength	-550- 620 Mpa
3) Percentage of elongation	-24-30
4) Impact Strength	-35-75 joules

VIII. HARDNESS TEST RESULTS FOR WELDED DPS

Hardness of DPS specimens are measured by using many types of tests, but for our investigations we chosen Brinell hardness test[5]. The outcome is shown in below tables.

TABLE.5 HARDNESS TEST RESULTS FOR WELDED DPS

PARAMETER	SPECIMEN DESCRIPTION			
	A73 (730°C)	A75 (750°C)	A78 (780°C)	A81 (810°C)
BALL DIA	2.5mm	2.5mm	2.5mm	2.5mm
APPLIED LOAD	187.5kg	187.5kg	187.5kg	187.5kg
AVG DIA OF INDENTATION	0.9	1.22	1.18	1.18
BRINELL HARDNESS	285	150	161	161

Fig. 3.Showing of hardness test Specimen for welded DPS

XI. IMPACT TOUGHNESS (CHARPY) TEST RESULTS

After preparing the standard specimen for charpytest, the test has to be carried to find the toughness of all specimens. The average results of 3 samples tested are tabulated in below tables.

Type of Notch: V NOTCH, Test temperature: Room (28°C), Size (mm):10X10X55

TABLE.6 IMPACT TOUGHNESS (CHARPY) TEST RESULTS

SAMPLE TRAIL REFERENCE	IMPACT TOUGHNESS(KJ)			
	A73 (730°C)	A75 (750°C)	A78 (780°C)	A81 (810°C)
1	124	118	174	32
2	89	100	60	94
3	112	96	178	46

Fig. 5.Showing impact toughness test Specimen welded dual phase steel

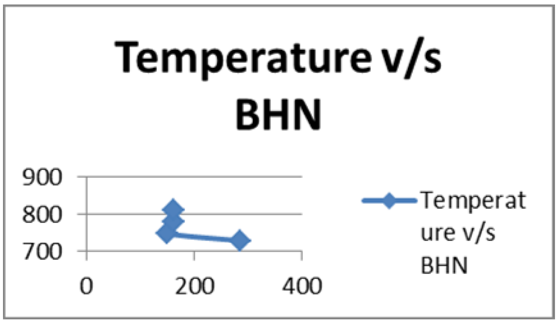

Fig. 4.Temperature v/s BRINELL HARDNESS

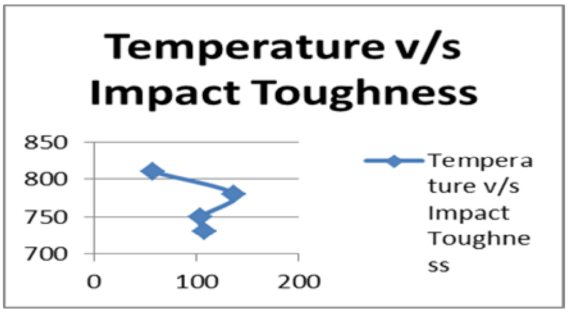

Fig. 6.Temperature v/s Impact Toughness(KJ)

X. TENSION TEST RESULTS

Tensile test is carried out in computerized Universal testing machine to find ultimate tensile strength of given specimen. Tensile stress-strain diagram of specimens tested for welded DPS specimen shown in Figs

A) Tensile test for A73 (730°C)

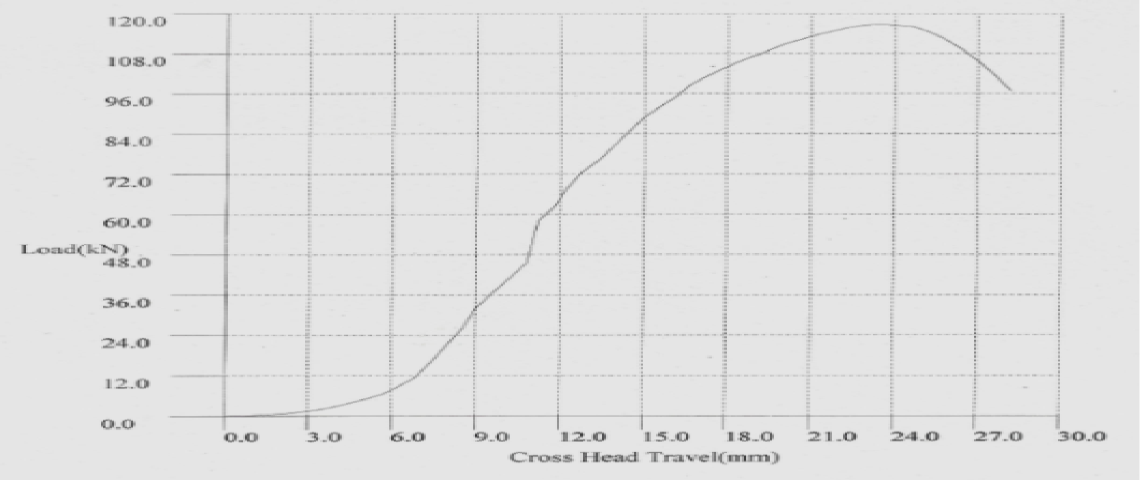

Fig. 7.Tensile stress v/s Strain response of A73 (730°C) specimen 1

The graph shown above gives the results which is tabulated in below table

TABLE.7 TENSILE TEST RESULTS FOR A73 (730°C)

S.NO		SPECIMEN1	SPECIMEN2	SPECIMEN3
1	Initial width	18.98mm	18.96mm	18.94mm
2	Initial thickness	12.45mm	12.31mm	12.29mm
3	Intial gauge length	50mm	50mm	50mm
4	Peak load	116.76KN	115.44KN	116.40KN
5	C.H Travel at peak	23.4mm	20.4mm	22.8mm
6	Ultimate tensile strength	494.12N/mm2	494.61N/mm2	500.06N/mm2
7	% of elongation	31.88	28.97	31.31

B) Tensile test for A75 (750°C)

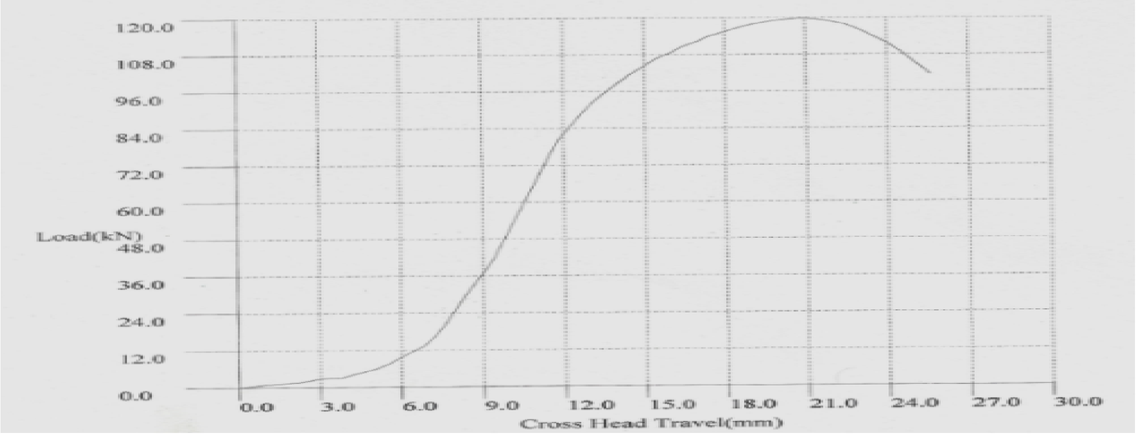

Fig. 8.Tensile stress v/s Strain response of A75 (750°C)

TABLE.8 TENSILE TEST RESULTS FOR A75 (750°C)

S.NO		SPECIMEN1	SPECIMEN2	SPECIMEN3
1	Initial width	19.05mm	19.08mm	18.94mm
2	Initial thickness	12.23mm	12.2mm	12.21mm
3	Intial gauge length	50mm	50mm	50mm
4	Peak load	119.64KN	120.06KN	122.52KN
5	C.H Travel at peak	20.8mm	20.8mm	25.7mm
6	Ultimate tensile strength	513.52N/mm2	515.77N/mm2	529.80N/mm2
7	% of elongation	29.37	29.37	33.94

C) Tensile test for A78 (780°C)

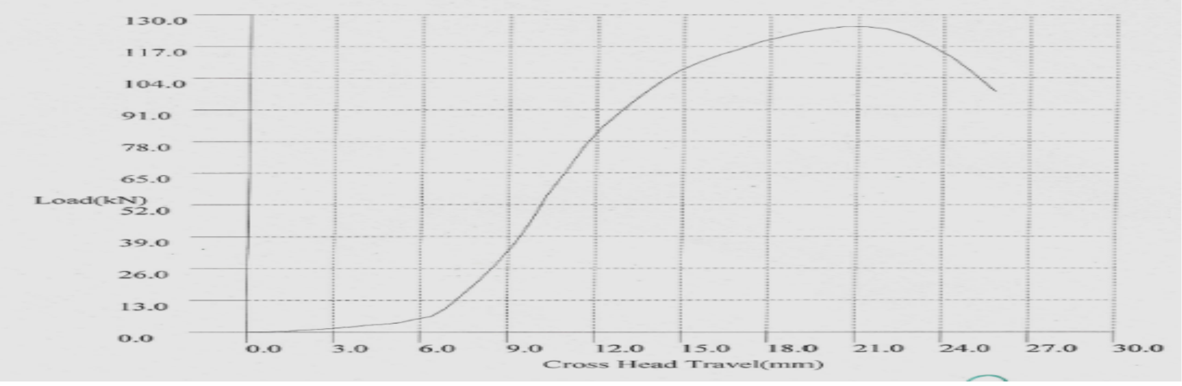

Fig. 9.Tensile stress v/s Strain response of A78 (780°C) specimen 1

TABLE.9 TENSILE TEST RESULTS FOR A78 (780°C)

S.NO		SPECIMEN1	SPECIMEN2	SPECIMEN3
1	Initial width	19.05mm	19.05mm	19.06mm
2	Initial thickness	12.54mm	12.54mm	12.41mm
3	Intial gauge length	50mm	50mm	50mm
4	Peak load	123.9KN	125.16KN	125.70KN
5	C.H Travel at peak	18.9mm	21.2mm	20.3mm
6	Ultimate tensile strength	518.66N/mm2	523.93N/mm2	531.42N/mm2
7	% of elongation	27.43	29.77	28.87

D) Tensile test for A78 (780°C)

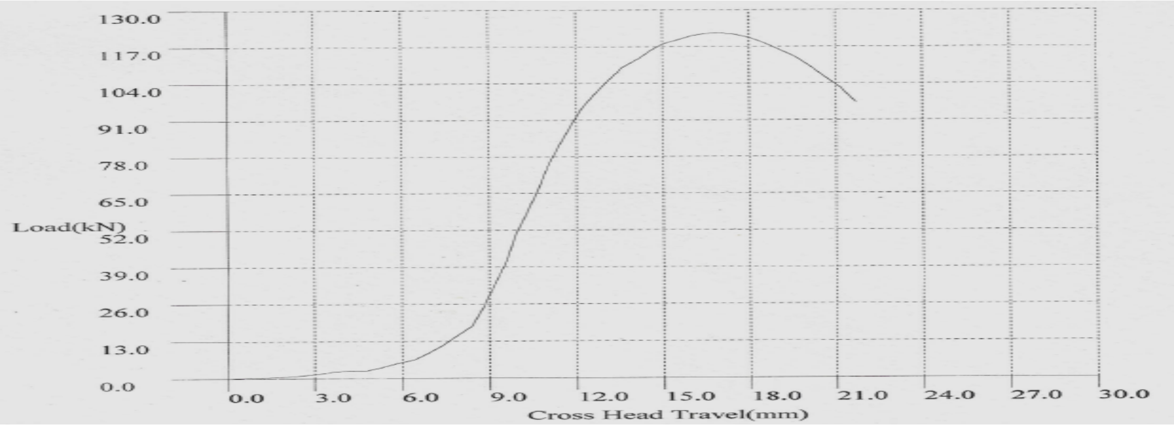

Fig. 10.Tensile stress v/s Strain response of A81 (810°C) specimen 1

TABLE.10 TEST RESULTS FOR A81 (781°C)

S.NO		SPECIMEN1	SPECIMEN2	SPECIMEN3
1	Initial width	19.01mm	18.99mm	18.96mm
2	Initial thickness	12.16mm	12.06mm	12.07mm
3	Intial gauge length	50mm	50mm	50mm
4	Peak load	121.74KN	119.88KN	123.54KN
5	C.H Travel at peak	17.00mm	17.4mm	18.2mm
6	Ultimate tensile strength	526.64N/mm2	523.45N/mm2	539.84N/mm2
7	% of elongation	25.37	25.81	26.68

CONCLUSION

The welded dual phase steel of 780°C exhibited higher combined properties of ultimate tensile strength and percentage of elongation as compared to other.ie interfacial bonding strength between atoms very effectively cling and occurs of slip is very difficult. Other major factor is energy observing capacity within the fracture higher value as compared to other grade. The 780°C welded dual phase steel exhibited higher impact strength. From the observation all above properties dual phase of 780°C is better as compared to other temperature heat treated.

TABLE.11 FINAL RESULTS OF DIFFERENT TEMPERATURE OF DPS STEELS

S.No	Temperature (°C)	Brinells hardness number	Impact Toughness (KJ)	Ultimate Tensile Strength N/ mm2	% of Elongation
1	730	285	108.33	496.26	30.72
2	750	150	104.66	519.69	30.89
3	780	161	137.33	524.67	28.69
4	810	161	57.33	529.97	25.95

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