ANALYSIS AND OPTIMIZATION OF STRUCTURAL INTEGRITY OF WELDED JOINT

SANAP PRASAD S.[1], LAWANDE MAHESH B.[2], THORAT RAJENDRA R.[3], PATARE RUSHIKESH S.[4], PATHAN FARHAN A.[5]

Student of B.E. Mechanical, G .H. Raisoni C.O.E.M., Chas, Ahmednagar[1],[2],[3],[4]
Assistant professor, G. H. Raisoni C.O.E.M., Chas, Ahmednagar [5]

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Abstract - *Structural integrity includes tasks in many areas, such as failure analysis, structural analysis , non-destructive testing, corrosion, fatigue and creep analysis, metallurgy and materials, fracture mechanics, fatigue life assessment, development of repairing technologies, welding metallurgy, structural monitoring and instrumentation etc. Arc welding is a type of welding, in which the power supplies to create an electric arc between the base material to melt the metals at the welding zone and an electrode. The present analysis has been carried out on the welding parameters to achieve good quality of Arc welding. It has been explained in experiment, important of different welding parameters such as Different type of electrodes, Weld Current and Electrode Size on Mechanical properties of welded joint. Three dimensional FE model has been developed to simulate the arc welding process and validated by experimental results.*

Keywords: *Arc welding, Butt weld, Current, Electrodes, Structural integrity, etc.*

1. INTRODUCTION

Arc welding process is widely being used in industry for sheet joining purposes. There are wide applications of welding made of carbon steel such as Fencing or Railing done in Ghats, shipbuilding, bridge structure, pressure vessels etc. are subjected to various stresses such as compressive, tensile and thermal stresses etc. Structural integrity of large engineering structures gives a unique challenge in the production of safe and cost-effective means of analysis, rehabilitation and inspection Objectives of this research is to determine structural strength of welded structures, obtain results by FEA method and to obtain the good quality welding.

2. FINITE ELEMENT ANALYSIS

2.1. Thermo - Mechanical Analysis

In the mechanical analysis, the basic equations are the geometric compatibility equations, equilibrium equations and constitutive stress–strain relations. The change in the temperature distribution contributes to the deformation of the body through influences the material properties and thermal strains.

2.2. Calculation for Temperature

The temperature is being required for the Finite Element Analysis, so the temperature is calculated theoretically by using the formula of heat input.

$$Q = mc_p \Delta T \qquad \text{........ (a)}$$

Where,

Q	= heat input
m	= mass
C_P	= specific heat
ΔT	= temperature

$$Q = I \vee T \qquad \text{......... (b)}$$

Where,

I	= current (amp)
V	= voltage (v)
T	= time (sec)

$$I \vee T = mc_P \Delta T$$

.... From (a) & (b)

$$\boxed{\Delta T = \frac{Q}{mCp}} \text{.......... (c)}$$

Hence, by using above formula eq. (c) the temperature for each plate is calculated to get the simulation in finite element analysis and temperature for each plate is as follows:

- **Temp for E6013 Specimen**

Table - 1: Temp. for E6013 Specimen

Sr. No	Current	Voltage	Time	Temperature
1	100	20	33	528
2	105	20	33	553
3	110	20	33	581
4	115	20	33	604
5	120	20	33	631
6	125	20	33	658

- **Temp for E7016 Specimen**

Table - 2: Temp. for E7016 Specimen

Sr. No	Current	Voltage	Time	Temperature
1	115	20	30	551
2	120	20	30	575
3	125	20	30	603
4	130	20	30	623
5	135	20	30	644
6	140	20	30	671

- **Temp for E7018 Specimen**

Table - 3: Temp. for E7018 Specimen

Sr. No	Current	Voltage	Time	Temperature
1	150	20	30	721
2	155	20	30	743
3	160	20	30	771
4	165	20	30	793
5	170	20	30	819
6	175	20	30	841

3. SIMULATION RESULTS

3.1. Simulation Results for E6013

Table – 4: Simulation Results for E6013

Sr. No.	Plate Coding	Min. Shear Stress	Min. Equivalent Stress
1	A100	78.14	149.93
2	A105	95.57	174.63
3	A110	103.13	183.02
4	A115	96.61	170.07
5	A120	89.50	156.06
6	A125	82.61	143.42

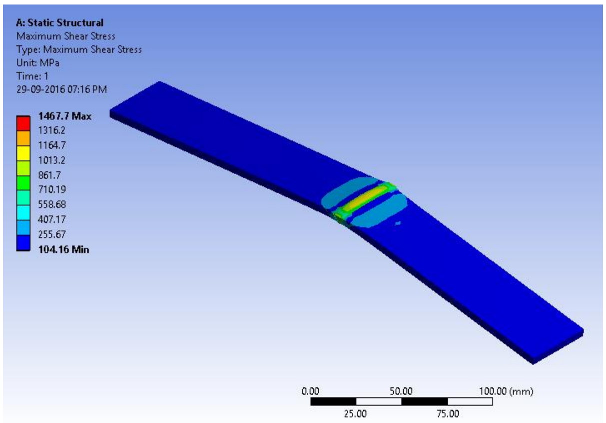

Fig. -1: Shear stress of A110

Hence, from the result table and the graph we can conclude that the specimen with current of 110 Amp i.e. A110 has the highest load bearing capacity

3.2. Simulation Results for E7016

Table – 5: Simulation Results for E7016

Sr. No.	Plate Coding	Min. Shear Stress	Min. Equivalent Stress
1	B115	94.26	172.71
2	B120	104.15	185.12
3	B125	97.37	171.63
4	B130	91.65	160.47
5	B135	86.21	150.15
6	B140	79.74	138.28

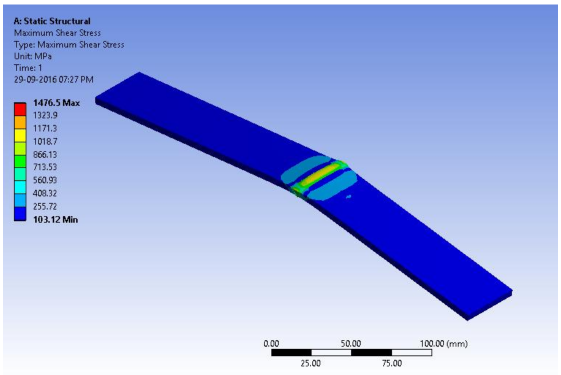

Fig. -2: Shear stress B120

Hence, from the result table and the graph we can conclude that the specimen with current of 120 Amp i.e. B120 has the highest load bearing capacity

3.3. Simulation Results for E7018

Table – 6: Simulation Results for E7018

Sr. No.	Plate Coding	Min. Shear Stress	Min. Equivalent Stress
1	C150	66.94	116.66
2	C155	61.35	108.37
3	C160	54.38	99.33
4	C165	48.48	93.23
5	C170	45.53	89.04
6	C175	46.51	86.98

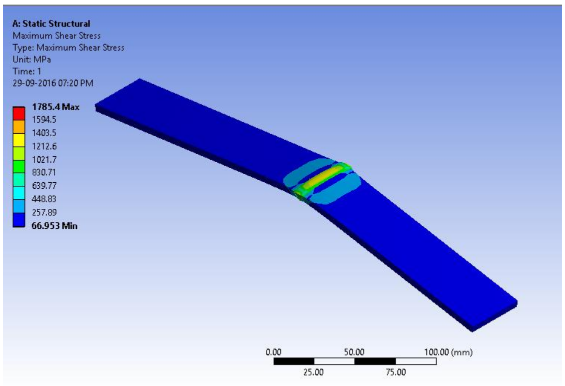

Fig. -3: Shear stress C150

Hence, from the result table and the graph we can conclude that the specimen with current of 150 Amp i.e. C150 has the highest load bearing capacity

4. EXPERIMENTAL VALIDATION

The Experimental results are for a Single-V butt weld joint of the dimensions (300 x 40 x 5 mm). The mechanical properties of the weld material and base material are shown in table above.

Table -7: Chemical composition of base material

Element	C	Cu	Fe	Mn	P	Si	S
Weight Max. %	0.25 - 0.290	0.20	98.0	1.03	0.040	0.280	0.050

Fig. – 4: Actual specimen

4.1. EXPERIMENTATION

As we know there are many welding parameter affects the strength of welding. We are finding the best suitable current for each electrode so we tested on three electrodes. There are 18 numbers of specimens were prepared from testing with arc welding process. The first six specimens of E6013 electrode at six different values of welding current (specimen code A100 at 100 amps., A105 at 105 amps., A110 at 110 amperes, A115 at 115 amperes, A120 at 120 amperes, A125 at 125 amperes) similarly another 6 specimen of E7016 electrode (specimen code B115, B120, B125, B130, B135, B140) and remaining 6 specimen of E7018 electrode (specimen code C150, C155, C160, C165,C170, C175) were prepared for testing.

4.1.1. Electrode – 6013 (E-6013)

6013 is a high titanic coated electrode.
Working Current Range : 100 Amp – 140 Amp.

Table – 8: Chemical Composition of E-6013

Element	C	Mn	Si	P	S
Weight Max. %	0.08 0.05-0.10	0.45 0.3-0.60	0.25 0.30 max	0.03 max	0.03 max

Table – 9: Results for E-6013 conducted on UTM

Sr. No.	Specimen code	Breaking Load (KN)	Tensile stress	Remark
1	A100	68.5	342.5	Breaks at weld
2	A105	72	360	Breaks at weld
3	A110	78	390	Breaks at weld
4	A115	75.5	377.5	Breaks at weld
5	A120	73	365	Breaks at weld
6	A125	71	355	Breaks at weld

4.1.2. Electrode – 7016 (E-7016)

for welding heavy structures , high tensile strength jobs where impact strength are required the E 7016 ,a basic coated low hydrogen electrode is suitable.
Working Current Range : 110 Amp - 150 Amp.

Table – 10: Chemical Composition of E-7016

Element	C	Mn	Si	P	S
Weight Max. %	0.09 max	1.10 0.8 - 1.5	0.54 0.25-0.65	0.03 max	0.03 max

Table – 11: Results for E-7016 conducted on UTM

Sr. No.	Specimen Code	Breaking Load (KN)	Tensile stress	Remark
1	B115	82	410	Breaks at weld
2	B120	93	465	Breaks at weld
3	B125	77.5	387.5	Breaks at weld
4	B130	76	385	Breaks at weld
5	B135	72	360	Breaks at weld
6	B140	68	340	Breaks at weld

4.1.3. Electrode – 7018 (E-7018)

E7018 stick electrodes are a good choice for structural steel applications due to their smooth, stable and quiet arc, and their low spatter levels.
Working Current Range: 140 Amp – 180 Amp

Table – 12: Chemical Composition of E-7018

Element	C	Mn	Si	P	S
Weight Max. %	0.10 max	0.90 – 1.40	0.75 max	0.03 max	0.03 max

Table – 13: Results for E-7018 conducted on UTM

Sr. No.	Specimen code	Breaking Load (KN)	Tensile stress	Remark
1	C150	78	390	Breaks at weld
2	C155	76.5	382.5	Breaks at weld
3	C160	70	350	Breaks at weld
4	C165	68.5	342.5	Breaks at weld
5	C170	65	325	Breaks at weld
6	C175	66.5	332.5	Breaks at weld

5. RESULTS

5.1. FOR SPECIMEN of E6013

Table – 14: FEA results for E6013

SPECIMEN	A100	A105	A110	A115	A120	A125
FEA (shear stress)	78.15	95.56	103.12	96.60	89.59	82.60
FEA (Equivalent Stress)	149.94	174.64	183..01	170.08	156.05	146.43
Tensile stress	342.5	360	390	377.5	365	355

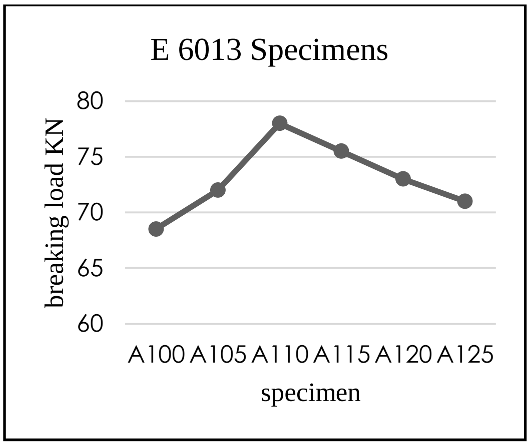

Chart -1: breaking loads on E6013 specimen

Hence, from the result table and the graph above we can conclude that the specimen with current of 110 Amp i.e. A110 specimen has the highest load bearing capacity

5.2. FOR SPECIMEN of E7016

Table – 15: FEA results for E7016

SPECIMEN	B115	B120	B125	B130	B135	B140
FEA (shear stress)	94.27	104.16	97.38	91.66	86.22	79.76
FEA (Equivalent Stress)	172.73	185.11	171.62	160.48	150.14	138.29
Tensile stress	410	465	387.5	385	360	340

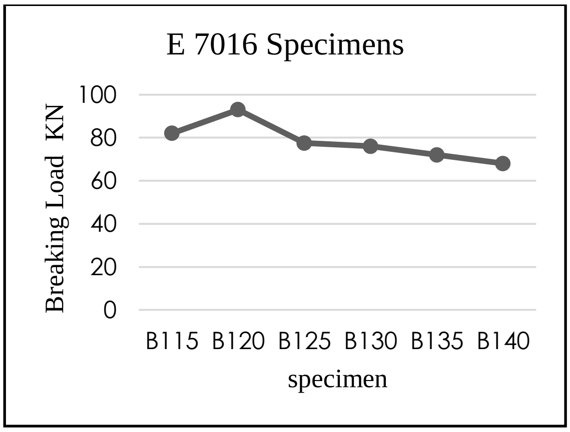

Chart -2: breaking loads on E7016 specimen

Hence, from the result table and the graph above we can conclude that the specimen with current of 120 Amp i.e. B120 has the highest load bearing capacity

5.3. FOR SPECIMEN of E7018

Table – 16: FEA results for E7018

SPECIMEN	C150	C155	C160	C165	C170	C175
FEA (shear stress)	66.95	61.37	54.36	48.44	45.52	46.56
FEA (Equivalent Stress)	116.67	108.38	99.32	93.24	89.05	86.99
Tensile stress	390	382.5	350	342.5	325	332.5

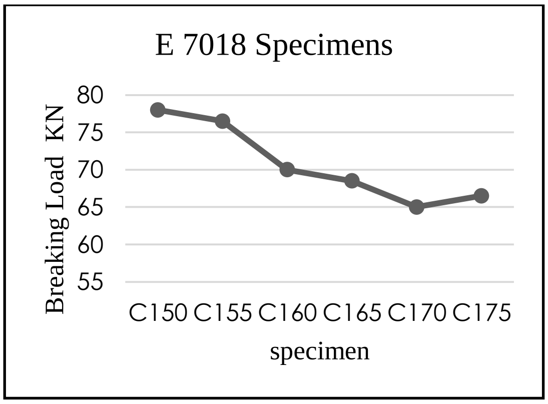

Chart -3: breaking loads on E7018 specimen

Hence, from the result table and the graph above we can conclude that the specimen with current of 150 Amp i.e. C150 has the highest load bearing capacity

CONCLUSION

From observation table and result analysis conclusion obtained are as follows:

1. Analytically found the ideal current for the particular electrode which can give better appearance to a weld with minimum efforts in minimum time.
2. Optimized result are been obtained for the three different electrode i.e. E6013, E7016, E7018. And for each electrode a fixed value of current is been found on which high strength achieved.
3. 3D FE model has been developed to simulate the arc welding process to find the optimized specimen for a specific current by using FEA software and validated the results by experimental procedure.
4. The specimens whose results were obtained by Finite Element Analysis are same as that of the results obtained by experimental procedure.
5. Hence by using proper parameters we can achieve good quality of welding with a high strength. And rather than doing actual experiment we can get the results by FEA software.

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