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INFLUENCE OF FILLER MATERIAL ON MECHANICAL PROPERTIES OF GAS TUNGSTEN ARC WELDMENTS

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Abstract:

Advancement in manufacturing process is in progress since very old age as the human needs go on increasing. The process of joining two metal pieces by the application of heat is defined as welding. Welding process is least expensive process and widely used in fabrication. Welding is the least expensive process and widely used now a days in fabrication. Welding is an essential part of everyday life. From high rise office buildings to cars, pipelines to high ways, airplanes to rockets, none of it would be possible without welding technology. There are various types of welding like, Gas welding, Arc welding, resistance welding, solid state welding and few more. In this report Tungsten Inert Gas welding has been covered in detail more specifically about the filler rods used in GTAW process. The projects objective is to study the influence of filler rods used in TIG welding process as it considerably effects the welded structure. Various testing like hardness, bending and Nondestructive testing (NDT) have been performed for different filler rods used and influences caused by filler rods have been studied and conclusions are noted.

Introduction:

The welding process is a fabrication process that joins materials, usually metals or thermoplastics, by causing coalescence. Manufacturing nearly any modern product involves joining various separate components. Welding is used were permanent joint is required. A weld is made by incorporating and joining of two separate meat pieces to form one piece when heated to a high temperature enough for softening or melting. The filler material is used to intensify the joint. Moreover, welding of aluminum and its alloys with shielded metal arc welding process can be realized using halide flux coated electodes by overcoming the problems associated with Al2O3.However, halides are very corrosive and therefore welding of aluminium is preferable carried out using inert shielding surrounds with the keep up of the processes like GTAW and GMAW. Despite of many developed Technology in the field of welding, TIG process is invariably suggested for joining of thin aluminum sheets of thickness less than 1mm.

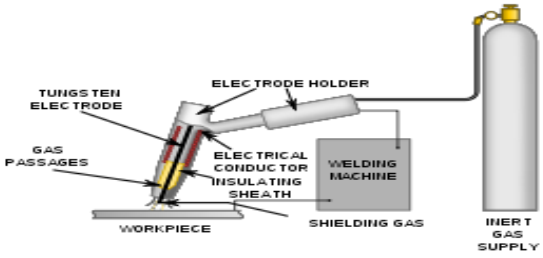

Figure 1: TIG welding

TIG Welding System:

There are four basic constituents of TIG welding system namely a) DC/AC power source to deliver the welding current as per needs, b) inert shielding gas (He, Ar or their mixture) for protecting the molten weld pool contamination from atmospheric gases c) welding torch (air/water cooled) with tungsten electrode and gas nozzle d) controls for moving the welding torch as per mode of operation (manual, semi-automatic and automatic). This process adopts the heat induced by an electric arc between the non-consumable tungsten electrode and work piece (mostly reactive metals like stainless steel, Al, Mg etc.) for melting of faying surfaces and inert gas is used for shielding the arc zone and weld pool from the climatic However, filler can be used in some cases, confide to the type of weld required. The arc produced is very intense and this essentially bonds one type of metal to another. Because filler isn't required, one can create high quality work with minimal seams.

Experimentation:

It is essential to have a roadmap before experimentation and this has been apprehended during the previous chapters like objectives, types of testing needed and procedure in this chapter.

Filler Materials:

Metal supplied in the form of a welding rod, sometimes flux coated, melted by an arc or a flame into ajoint between components to be joined is called as filer rod. Filer rod is responsible to provide the additional melts required while joining the base metals. It can also acts as shielded for base metals. It needs to be chosen properly otherwise it influences the mechanical and thermal properties considerably at microscopic as well as macroscopic levels.

Filler Rods: 1) Bare wire: It act as a of excess melts needed while welding. 2) Coated wire: Other than source of melt it also acts as shielding medium from atmospheric contamination.

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Every time you will have the awareness for selecting the type of rod to use in convinced technique by reading the manuals which usually encloses a list of acceptable welding rods. We have used two types of filler rods in course of project MS of 2.5 mm diameter and SS of 2mm diameter.

Edge preparation of Base Metal:

Firstly two mild steel materials of size 300 mm x 150 mm x 12 mm have been taken for cutting operation. During machining is shown in Fig. 2.

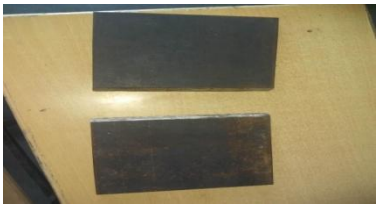
Figure 2: Metal Cutting Operation


Figure 3: During Grinding


Figure 4: After Grinding

After cutting we got two pairs of parent metals of size 150mmx 150mm x 12mm and V groove of angle 60^0 and level of 1.5 mm using grinding wheel and angle template for inclination verification as shown in fig 3 and 4.

Welding:

We have taken two pairs of mild steel plates on which welding have been done using mild steel and stainless steel as filler rods for each pair of plate. For first pair of plate: After doing machining operation, welding is done using filler rod of diameter 3.14 mm. using Tungsten as electrode of melting point 3500°C. Melting point of base metal is 1427°C and mild steel as filler rod. Refer figures. During welding we made butt joint in horizontal position with supply of 200 Amperes currents and 20 volts power. Finally we got the weld joints as shown in fig. The shielding is performed because in this welding the molten weld pool on the metal may have epidemic in the atmosphere or the condition of weld becomes poor. The supply of water, inert gas and welding current is put on. The gas is fed through the welding torch for shielding the tungsten electrode and molten weld pool.


Figure 5: Butt joint of first pairs

Welding is initiated by moving the torch, compelling the arc making it to impinge on the work piece metal and a molten weld pool is built. As the welding proceeds on the work piece and reaches the end, arc is developed to made to break by enhancing the arc length and the shielding gas is impinged on the solidifying weld pool for few seconds even after the arc is put back to avoid atmospheric contamination of the weld metal.

For Second Pair of Plate:

In the similar way welding of the second pair of plate has been done using stainless steel as filler rod of melting point 1400°C to 1450°C as shown in the figure below.


Figure 6: Welding of plates using SS as filler material

Finally after welding we will get two welded plates formed using mild steel and stainless steel as filler rods. As shown in fig. 7:


Figure 7: Plates ready for testing

Finally we have done the welding of plates and it would be further carried for testing those are non-destructive as well as destructive testing to understand and analyze its capability and suitability in real world applications.

Testing of Weldments:

Non Destructive Testing:

We have done NDT for the examine of materials and components in such a way that concedes materials to be examined without modifying or spoiling their usefulness. NDT or NDE can be used to find, size and locate surface and substrate flaws and defects. Liquid penetrate testing: The procedures would be common for both the pair of plates and their surface flaws and defects can be observed from their figures and that would be given directly. Following are the steps to be followed in this process. Below fig shows the requirements of penetration test and they are cleaner, penetrant and developer.

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Figure 8: Cleaner, Penetrate and Developer

Surface Preparation:

The Sample should also require impression if mechanical operations such as machining, sanding or grit blasting have been done. Any other properties can smear metal over the flaw opening and resist the penetrant from passing.

Figure 9: During surface cleaning

Penetrant Application:

Once the surface has been throughway cleaned and dried, the penetrant material is activated by spraying, brushing, or immersing the part in a penetrant bath.

Penetrant Dwell:

The penetrant is left on the surface for a acceptable time to allow as much penetrant as possible to be drawn from or to seep in to a defect. The total time is the penetrant dwell time that the penetrant is in contact with the part surface. The penetrant producers are usually recommended the dwell times or required by the specification being followed. Experimentation will determine the ideal dwell time and may be limited to a particular application.

Excess Penetrant Removal:

The excess penetrant must be removed from the surface of the sample. Depending on the penetrant system used, this step may involve purifying with a solvent, direct rinsing with water, or first treating the part with an emulsifier and then rinsing with water. Developer application: A thin layer of developer was applied to the sample to draw penetrant trapped in flaws back to the surface where it will be visible. Developers come in a variety of forms that may be applied by dusting (dry powdered), dipping, or spraying (wet developers).

Figure 10: Developer Application

Indication Development:

The developer is concede to stand on the part surface for a period of time tolerable to permit the extraction of the trapped penetrant of any surface flaws. 10 minutes is sufficient for the development time. Significantly longer times may be crucial for tight cracks.

Inspection:

To detect indications from any flaws which may be present is done under appropriate lighting.

Figure 11: Inspection of weld for MS as filler rod

Clean Surface:

The final step in the process is to thoroughly clean the part surface to remove the developer from the parts that were found to be acceptable.

Figure 12: Clean surface

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Here we observed that there are various undercuts and flaws on both the weld specimen due to various properties that we will see in observation section in more details.

Magnetic Particle Testing:

The following given steps we have followed common for both specimens for Magnetic particle testing. Surface has been cleaned that needs to be examined This may be accomplished using detergents, organic solvents, descaling solutions, paint removers, vapor degreasing, sand or grit blasting, sand or grit blasting or ultrasonic cleaning methods. See figure.

Figure 13: After surface cleaning in MPI

Magnetic field has been introduced into the part. Ferromagnetic medium has been applied while the part is still magnetized. Excess ferromagnetic medium has been removed with a light air stream from a bulb, syringe, or other source of low pressure dry air. Interpretation and evaluation of any indications has been carried out for the applicable acceptance standard. Yoke has been turned to 90 degree from the original position. And steps from 2-5 has been repeated, cleaning and demagnetization has been carried out. Finally defects has been observed within the surface up to 3mm depth. specimen with MS as filler rod.

Figure 14: Defects within surface for rod

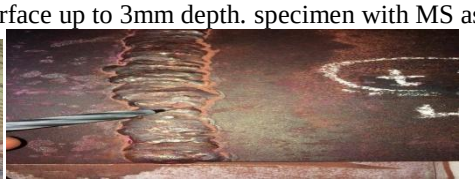

Figure 15: Defects within surface for SS as filler

Radiographic Testing:

In radiography testing the test-part is placed between the radiation source and film (or detector). The material density and thickness differences of the test-partr will attenuate (i.e. reduce) the penetrating radiation through interaction processes involving scattering and/or absorption. The differences in absorption are then recorded on films(s) or through an electric means. In industrial radiography there are several imaging methods available, techniques to display the final image, i.e. Film Radiography, Real time radiography (RTR), Computed tomography (CT), Digital Radiography (DR), And Radiography (CR). There are two different radioactive sources available for industrial use; X-ray and Gamma –ray. These radiation sources use higher energy level, i.e shorter wavelength, versions of the electromagnetic waves .Because of the radioactivity involved in radiography testing, it is of paramount importance to ensure that the Local Rules is strictly adhered during operation. We have finally got the report of testing.

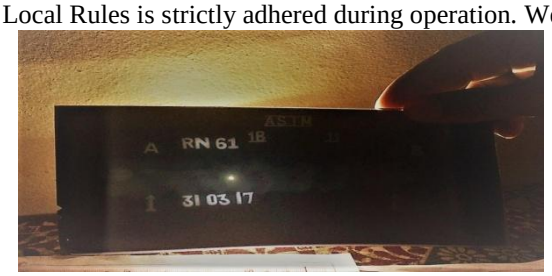

Figure 16: Image of weld defect on radiographic film

Destructive Testing:

Hardness Test:

Resistance of a material to deformation, indentation, or penetration by means such as abrasion, drilling, impact, scratching, and/or wear, measured by hardness tests such as Brinell, Knoop, Rockwell, or Vickers. In our test we have used Rockwell hardness test measured on C scale (HRC). And method is equally same for both specimens so the result of other is directly taken (for specimen with stainless steel as filler rod). The indenter is pressed with the test pre-force (also referred to as pre-force or preload) to a penetration depth of h_0 in the specimen to be tested. Defines the reference level (basis) for subsequent measurement of the residual indentation depth (h). Next, the additional test force is applied for a dwell period defined in accordance with the standard (several seconds), whereby the indenter penetrates into the specimen to a maximum indentation depth of h_1. The test pre-force plus the additional test force gives the total test force (also referred to as total force or main load).

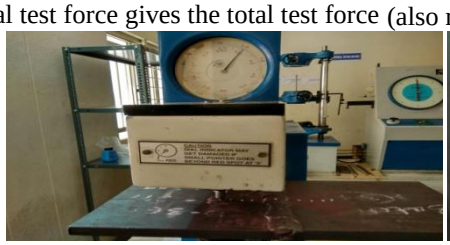

Figure 17: Dwell period

Figure 18: Final reading on dial

After the dwell period, the additional test force is removed, the indenter moves up by the elastic proportion of the penetration depth in the total test force and remains at the level of the residual indentation depth (h - expressed in units of 0.002 or

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0.001 mm). This is also referred to as the depth differential (difference in indentation depth before and after application of the total test force). Now the Rockwell hardness (HR) can be calculated, using the residual indentation depth (h) A formula defined in the standard, taking account of the applied Rockwell scale. Finally we got the Rockwell hardness for both specimens at various positions on and off the weld bead.

- ✓ Specimen with MS material as filler rod: on the weld bead we found hardness as HRC 91 and HRC 79 and 78 on both left and right extreme region of observation.
- ✓ Specimen with SS material as filler rod on the weld bead we found hardness as HRC 60 and HRC 70 and 77 on both left and right region of observation.

Bend Test:

Test specimen of mild steel has been taken; method is same for both specimen so output of both will be taken directly and explanation for first one.

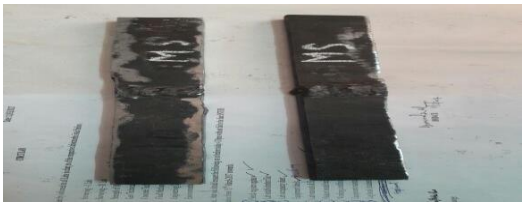

Figure 19: Specimens for bend test

Figure 20: During measurement of dimension for bend test

Dimension of first specimen (MS filler rod) is 305mmx 35mmx 12mm and of second specimen (SS as filler rod) is 304x 35 x 12 mm3. Now the test specimen has been in the bending table specimens have been kept in the bending table in such a way that the plane.

Figure 21: Specimen under bend test

Figure 22: Rod during bending

Intersecting the longitudinal ribs is parallel to the axis of the pin. Range of scale is 1 – 400 KN.4As load have been applied on beam they started to bend. Loads have been removed when bend angles have been reached 60^0 and 90^0 respectively. Specimens have been taken out and surface tensions and various mechanical properties have found.

Figure 23: After bend test of first specimen

Figure 24: After bend test of second specimen

Finally we Have Observed:

Flexural load F = 18 KN. Flexural stress σ = 39.56 MPa.

Flexural strain e = 1.88 x 10 ^-4 for first specimen and 1.95x10 ^--4.

Tensile Test:

First we have selected the both specimen for tensile testing, first specimen has effective length = 160mm and weld bead area = 204 mm x 2 mm and other specimen with effective length =200 mm and weld bead area = 180 mm x 2 mm.

Figure 25: Tensile testing specimens

Specimen under UTM machine setup for testing is made proper based on our requirement for testing like positioning the dial and load in limits.

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Figure 26: Specimen under UTM

A material is gripped at both ends by an apparatus, which slowly pulls lengthwise on the piece until it fractures. The pulling force is called a load, which is plotted against the material length change, or displacement. The load is converted to a stress value and the displacement is converted to a strain value. Finally we have found specimen has been fractured due to gradual increase in loads.

Figure 27: specimen fractured during tensile testing

We have observed maximum tensile stress and strain for first specimen as 512.8 MPa and 2.4x10 ^ -3. And for second specimen tensile stress = 427 MPa and strain = 1.9 x 10 ^-3.

Observations:

After doing the testing we have made the observations from both the destructive and nondestructive testing. And we refer first specimen as mild specimen welded with MS as filler rod and second specimen as specimen for the mild steel specimen welded with SS as filler rod.

Liquid Penetrate Testing:

Surface flaws have been observed on both specimens using Penetrant testing which includes porosity and undercuts and first specimen has more defect when compare to second specimen. And caused due to lack of fusion and more current fluctuations.

Figure 28: Observation of LPT

Magnetic Particles Testing:

It has been found various porosity and undercuts within the surfaces of both specimens. In defected portions ferromagnetic particles have been gathered as shown in figures.

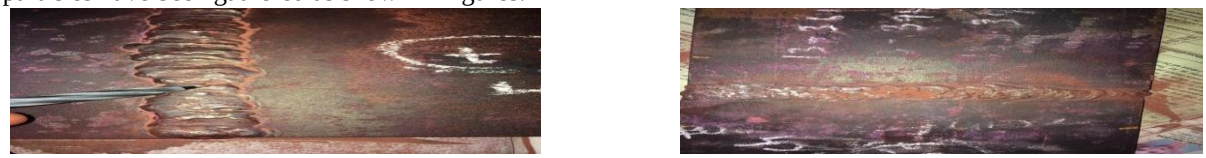

Figure 29: Observation of MPI

Radiographic Inspection:

Figure 30: Observation of Radiographic test

Various flaws have been observed in welding as we got the image on radiographic film and report caused due to lack of fusion.

Hardness Test:

In this test we observed hardness in the weld zone of first specimen has been increased as mild steel has been used as filler rod and for the second specimen hardness has been decreased as SS used as filler which has less hardness than the parent joining plates. It can be observed from graph and tables.

Distance in Cm	0	1	2	3	4	5	6
HRC for MS as filler	79	85	89	91	88	85	78

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HRC for SS as filler	70	79	80	60	83	80	77

Table 1: Rockwell hardness values

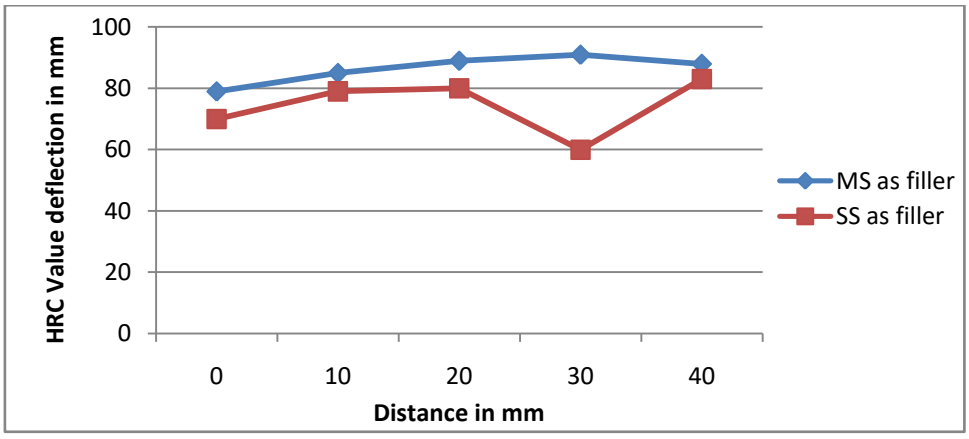

Figure 31: Rockwell hardness test graph

Bend Test:

We observed that as steel is less hard and malleable than mild steel. First specimen MS (MS) sustains bending load whereas second specimen MS (SS) broken off during bending .In graph blue color line represents first specimen and orange color represents second specimen. As shown in graph and tables.

Load (KN)	5	7	10	12	13	13.5	14.5	15	16
Deflection(mm)	5	7.5	10	17.5	25	35	42.5	60	70

Table 2: Bend test of first specimen

Load (KN)	5	8	10	10..5	11	12	13	13.5	15
Deflection(mm)	5	10	20	27.5	32.5	40	47	52.5	70

Table 3: Bend test of second specimen Deflection

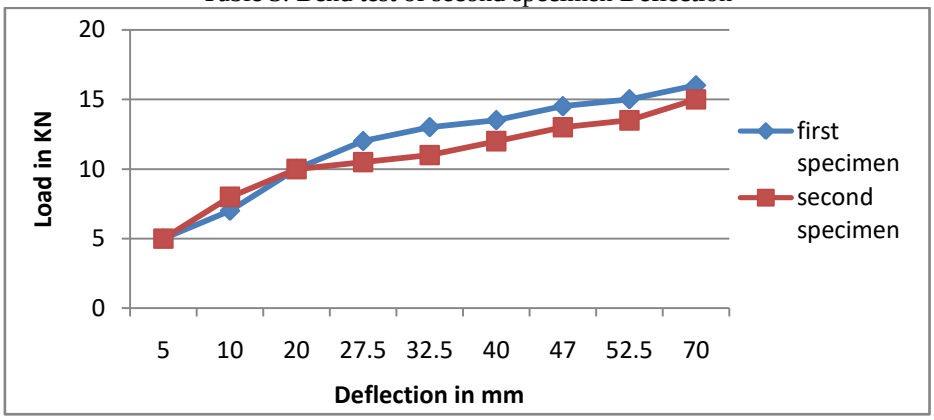

Figure 32: Specimen deflection with load

From graph it is to be noted that blue color line represents the first specimen and orange color represents second specimen bending curve.

Tensile Test:

It is observed that first specimen MS (MS) has been broken at the point near to edge of base metal as weld bead is stronger, whereas for second specimen MS (SS) it has found that it has been broken at weld bead as it is weaker than parent metal. It has been shown in tables and graph.

Figure 33: Specimen after tensile test

Stress σ1 of first Specimen (MPa)	Strain e1 of first Specimen X 10^-3	Stress σ2 of second specimen (MPa)	Strain e2 of second specimen X10^-3
31.5	1.15	37.7	1.3
50	2.06	55.55	2.64
200	6.67	155.5	7.4
289	9.89	250	10

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236.3	11.03	200	10.5
231.6	11.38	195	11.12
250	12.05	235	12.22
277.3	13.4	250	13.35
301.1	14.12	300	14.7
374.09	15.51	350	15.2
425.06	16.8	375	16.08
505.67	20.27	400	17.2
538	22.13	425	19.13
512.8	24.19		

Table 4: Readings of tensile test

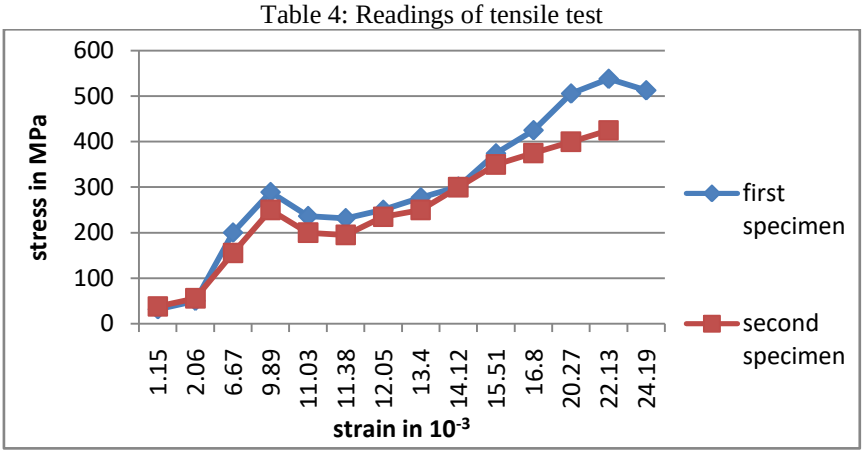

Figure 34: Graph of Tensile test

It has been observed that first specimen break at 512.8 MPa and second specimen break at 425 MPa, as hardness and strength of former is more than of later.

Results:

From non-destructive testing we have found that there have been various flaws like porosity, lack of fusion and undercuts in the weld joints of both the specimen due to:

Low heat input, incorrect voltage and inductance, Improper welding positions, wrong weld bead orientations.

Presence of moisture in gas, Weld nozzle has been held too far from work piece, improper torch angle.

Presence of grease oil on base metal surface.

From destructive testing we have found various considerable mechanical parameters which defines the strength of specimens:

1) Hardness Number:

For first specimen MS (MS)

1) At weld bead HRC =91
2) At HAZ, HRC = 89
3) At parent metal HRC=79

for second specimen MS (SS)

at weld bead HRC =60
at HAZ, HRC =83
at Parent metal HRC =77

2) Bend Test:

For Root Bend:

For Specimen 1: Bending stress σ (b) = 27.47 MPa, Load P = 12.5 KN,
Deflection δ = 76mm, Strain e = 1.3 X10 ^ -4, span length L= 205mm

For Specimen 2: Bending stress σ (b) = 41.0 MPa, Load = 16 KN
Deflection δ = 70 mm, Strain e = 1.95x10 ^ -4, span length L =204 mm

For Face Bend:

For Specimen 1: Bending stress σ (b) = 39.56 MPa, Load p = 18KN,
Deflection σ =95 mm, strain e = 1.88 x 10^ -4, span length L= 204 mm

For Specimen 2: Bending stress σ (b) = 35.89 MPa, Load = 14 KN,
Deflection δ =70 mm, strain e = 1.7 x 10^ -4, span length L = 205mm

3) Tensile Test:

For Specimen 1:

1) Upper yield stress σ (y) = 289 mPa, 2) Lowe Yield stress σ (y) = 236.3 MPa
3) Ultimate stress σ (u) = 538.23 MPa, 4) Point of rupture σ (u) = 538.23 MPa 5) Strain e = 2.44x10 ^ -3.

For Specimen 2:

1) Upper yield stress σ (y) = 250 MPa, 2) Lowe Yield stress σ (y) = 200 MPa
3) Point of rupture σ (u) = 427 MPa 5) Strain e = 1.9 X 10 ^-3

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