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Design Aspects of Welding Fixture for Nozzle Casing Assembly by TIG Welding

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ABSTRACT

In aerospace application, most of the structural components made of aluminum, magnesium, stainless steel alloys, because of their low weight to high strength ratio. The quality and reliability requirements are stringent. Welding of this stainless steels is a challenging task. This topic deals with the design aspects of welding fixture for nozzle which is used in rocket motor case. The welding fixture consists of fourteen parts which are to be assembled and nozzle casing is welded over it without ovality, distortions and other weld defects. And Material used is Stainless steel For TIG Welding . This paper highlights the design aspects of welding fixtures considering the quality and reliability requirements it highlights various important features of the fixtures such as backup, purging arrangement, spider mechanism, heat sink, clamping arrangements and collapsible system for ovality This paper also discusses the difficulties faced during design and welding of stainless steel components which are made up of thin rolled sheets.

Keywords:
TIG Welding
Nozzle Casing
Fixture
Solid works
Weld Defects

1. Introduction

In aerospace application most of the structural sections are made of aluminum, magnesium and SS alloys because of low heat to high strength ratio. Nozzle casing assembly are made by welding of rolled SS sheets. The quality and reliable requirements are stringent. Hence weldments are subjected to 100% radiographic, dye penetrant, and ultrasonic inspection. Defects like ovality, distortion, porosity and cracks are not permitted. These tanks have to go for hydraulic test for dimensional checks. These stringent requirements are essential as these components have to support all working condition like vibration, high-G and high temperatures. The safety factor is used in the design of Fixture are of the order of 1.25 on proof strength and 1.5 ultimate strength against the general factors of safety of 4-10 in pressure vessel designs. Any defect on such a critically designed hardware can be very detrimental to the performance. The weld efficiency of 80% has been taken in designing the nozzle casing assembly. The weld efficiency figure is suitable for aluminum alloy only by exercising very close control on welding parameters and use of the proper welding fixture having heat sink arrangements.

2. Design and Manufacturing of Welding Fixture for Nozzle Casing Assembly

Nozzle casing assembly is a component used in rocket booster motor components in aerospace applications. The welding fixture of nozzle casing assembly consists of 14 parts where these all parts are to be welded each other. The assembled part of welding fixture is welded by nozzle casing over it with accuracy, quality and reliability. Avoidance of ovality, distortion and other weld defects is essential requirements for achieving product performance of required level. The modeling of all the parts are carried out in solid works 2015 and material used for the manufacturing is stainless steel alloy done by TIG welding (Fig. 1, Fig.2).

Fig. 1. Nozzle Fixture

Fig. 2. Nozzle Casing Assembly

2.1 Partlist of Welding Fixture

Table 1 shows partlis of welding fixture and 3D part diagrams for welding fixture shown in Fig. 3.

Table 1. Partlis of welding fixture

S.NO	NAME OF THE PART	QUANTITY	MATERIAL
1.	Shaft	1	S S
2.	Locking bush	2	S S
3.	Locating block	1	S S
4.	Bushes	3	S S
5.	Supporting bushes	2	S S
6.	Purging ring	2	S S
7.	Taper sleeve	1	S S
8.	Taper sleeve ring	1	S S
9.	End sleeve	1	S S

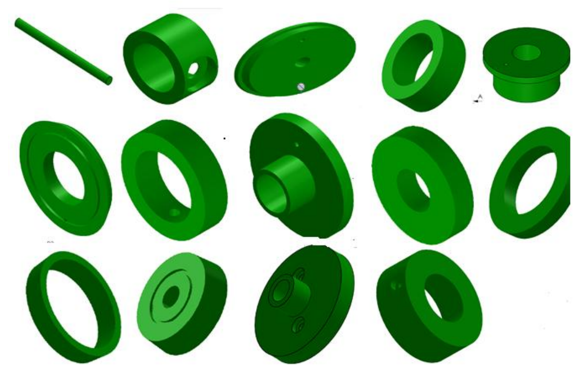

Fig. 3. 3D Part Diagrams for Welding Fixture

2.2 Stainless Steel Alloys

Stainless steel alloys contains the following:

(i) Stainless steel is alloy of iron with a minimum of 10.5% of chromium.

(ii) Other alloys like nickel, molybdenum, copper added to this alloys to enhance their structure and properties such as formability strength and toughness.

(iii) Non metal like carbon and nitrogen are also added

(iv) The main requirement of stainless steel alloys is they are non-corrosive in nature.

3. Methodology

3.1 Welding Fixture

The purpose of the welding fixture is support the parts to be welded in the proper relationship both before and after welding. Many times a fixture will maintain the good relationship during welding, but the part will distort itself largely determine product reliability.

3.2 Elements of Welding Fixyure

Generally, all fixtures consist of the following elements:

a) Locators
b) Clamps
c) Fixture Body
d) Supports

3.3 The Design Objectives of Welding Fixture

(i) To hold the part in the most convenient position for welding.
(ii) To provide proper heat control of the weld zone.
(iii) To provide suitable clamping to reduce distortion.
(iv) To provide the suitable purging arrangement for inert gas.
(v) To provide clearance for filler metal.
(vi) To provide for ease of operation and maximum accessibility to the point of weld.

3.4 Factors Governing the Fixture Design

(i) Cost of tool and size of production run and rates.
(ii) welding process used for it
(iii) Complexity of weld and quality required in the weldment.
(iv) Process to be employed and condition under which the welding swill be performed.
(v) Dimensional tolerances, material to be welded and smoothness required.
(vi) Coefficient of expansion and thermal conductivity of both work piece and tool materials.

3.5 Specific Design Features of Welding Fixture

Initially these are designed to use for manual TIG welding, subsequently these are modified for use on AUTO TIG welding machine. While designing for manual mode much care was not taken for mounting and run out of the fixtures.
The concentricity and run in the range of 10-20mm which was not acceptable in missile application. Due to the configuration of tanks i.e. circular and for obtaining accuracy to use these fixtures on AUTO TIG welding machine, which resulted in concentricity and runout within 1-1.5 mm. During welding on auto tig the mismatch between the rows mating components had to be maintained within in 0.5mm which was achieved by providing fixed middle spiders instead of floating.

3.6 Spider Mechanism (Extractable and Retractable)

As most of the components used in fuel tanks thickness is about 10-12 mm, so the fixture must exert enough force to correct the ovality. Our fixtures have been provided with spider type expandable and retractable system which facilitates the correction and exert the force radially. In the retractable position it facilitates the removal of the welded components.

Shows expandable and retractable system consist of number of segments attached with a bolt and guided in the annular groove in side ring. When the bolts are tightened the spider segments move outward direction radially which provide the necessary radial force in correcting the ovality of the component during the welding to avoid any distortion. This system also help in correcting mismatch between the two components to the acceptable limits. The segments were provided aluminum thin (2-3 mm) packing plates to avoid any damage on components.

3.7 Weld Board Control on Purging Arrangement

A groove was provided directly under the weld. The alloy complete penetration without pick up of the backup material but the molten metal. During final welding these segments are forced outwards against the part to make the weld root as air tight as possible.

The groove dimensions are important as these help in weld bead shape and height control. To ensure that an adequate penetration bead can be formed, it should not be shallow as the possibility of oxide entrapment and other unwanted foreign matter.

Will inherently accumulate at the root of the point and result in porosity and lack of fusion. Conversely a groove that is too deep can cause excessive penetration bead formation and slow up weld travel speed which can lead to lack of root fusion in the form of cold lapping. The thermal conductivity and coefficient of expansion of aluminum components may result in cracking adjacent to the weld when tightly clamped. By using fixture we can avoid it to produce uniform work pieces.

Show the purging arrangement for inner surface which was provided by making small holes in the segments having opening in common grove. This groove covered with a plate. The inert gas for purging was supplied through a nipple and PVC pipe.

3.8 Backup Support and Heat Sink

The size of the back-up also depends on the thickness and material of components to be welded. Thin weldment requires large back up to promote heat transfer from weld.

The thickness of the back-up also depends on the conductivity of the material being used as back up.

4. Locating References Points and Clamping Arrangements

The problem of distortion is as inherent with SS as it is with other common metals they undergo welding. to avoid distortion on a weldment Although rigid clamping reduces distortion, the inability of weldment to contract caused by the restraint may induce residual stresses .To keep the distortion to the minimum, the joint should be designed with minimum separation between members and welding should be done at the higher conductive material has been used to make back up this will helps in maintaining cross section small Clamps and locators must be carefully placed to preclude interference with the welding tool. Prepare to prevent its fusion to the fixture or burn through by including slots, relief areas, or back up bars. Burn fusion resistant material must be used.

Secondly, unlike machining fixtures, where the size and shape of the workpieces remain essentially the same at loading and unloading, workpieces for welding fixtures generally are separately loaded, , welded together and finally removed as a single and often locaters should placed for easy removal of the finished workpiece, it can be difficult or even impossible, to remove the weldment from the fixture. And ensure no dislocation during welding. In our case, the existing holes and lugs in the components were utilized to locate the components with reference to each other by providing pins and brackets in the fixture indicated. For welding of final tank assembly the support rings at both the ends were provided reference holes and bar was used to locate both the ends of the tank with reference to each other.

5. Uniform Rotation of Job with Minimum Runout and Concentricity

As the welds rotate at uniform speed with minimum runout in order to have uniform and continuous weldment. DRDL fixtures were designed to meet these requirements. The whole assembly of components and fixture was mounted on automatic TIG welding machine. The fixtures were modified by providing the slots and guide rings for mounting the fixtures on AUTO TIG machine. The weight of fixtures was reduced by drilling the holes in fixture components at suitable places. The assembly was rotated on head stock and tail stock faceplates. The runout and concentricity between the back-up segments and other components was within 0.50 mm. During trail of fixtures it was noticed that the bed of the AUTO TIG machine was twisted and the head stock and tail stock the both ends. Subsequently, the machine was leveled and we could get the tanks within the acceptable limits. The components and tank assembly before and after the welding.

It is advantages to have flexibility in design i.e. wherever it is feasible, all locating devices should permit some adjustment should permit some adjustment for changing locating dimension required by design changes to compensate for expected weld distortion. In addition to this the fixture must be strong enough to withstand the mishandling the workpiece. They should be simply designed up stresses from welding within the workpieces. They should be simply designed to permit easy accessibility for components positioning and permit the welder to work from the most advantageous angle, generally down hand, with no part should be readily operated by welders of varying skill and should incorporate error proof elements to prevent wrong assembly of workpieces or other welder's errors. Most of the welding defects can be minimised by talking care in design of fixture and controlling the process parameters.

5.1 TIG Welding

TIG welding is also known as Gas Tungsten Arc Welding (GTAW), is an arc welding process that uses a non-consumable electrode to produce the weld metal vapors known as a plasma.

GTAW is used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grant the operator greater control than process such as shielded metal arc welding and GMAW, and gas metal arc welding allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore a related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as result is often automated (Fig. 4).

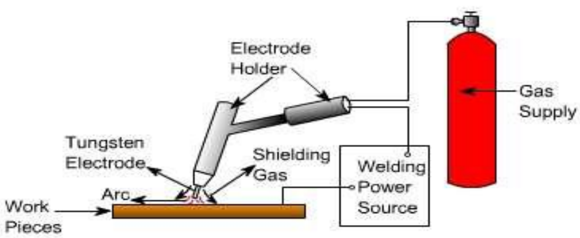

Fig. 4. TIG setup

Tungsten Preparation characteristics are shown in Table 2:

Table 2. Tungsten Preparation characteristics

Base Metal Type	Thickness Range	Desired Results	Welding Current	Electrode Type	Shield Gas	Tungsten Performance Characteristics
Stainless steel Alloys	All	General Purpose	AC/HF	Pure (EW-P)	Argon	Balls easily, low cost, tends to spit at higher currents, used for non-critical welds only.
				Zirconiated (EW-Zr)	Argon	Balls well, takes higher current, with less spitting and with better arc starts and arc stability than pure tungsten.
				2% Thoriated (EW-Th2)	75 Argon 25 Helium	Higher current range and stability, better arc starts, with lower tendency to spit, medium erosion.
	Only thin sections	Control penetration	DCRP	2% Ceriated (EW-Ce2)	Argon Helium	Lowest erosion rate, widest current range, AC or DC, no spitting, best arc starts and stability.
	Only thick sections	Increase penetration or travel speed	DCSP	2% Thoriated (EW-Th2)	75 Argon 25 Helium	Best stability at medium currents, good arc starts, medium tendency to spit, medium erosion rate.
				2% Ceriated (EW-Ce2)	Helium	Low erosion rate, wide current range, AC or DC, no spitting, consistent arc starts, good stability.

Sheilding Gas Selection characteristics are shown in Table 3:

Table 3. Sheilding Gas Selection characteristics

Base Metal Type	Thickness Range	Weld Type	Shield Gas Type	Characteristics
Stainless steel Alloys	Thin	Manual	Pure Argon	Best arc starts, control of penetration, cleaning and appearance on thin gauges.
	Thick	Manual	75 Ar - 25 He	Increase heat input with good arc starts of argon, but with faster welding speeds.
	General Purpose	Manual	Pure Argon	Best overall for good arc starts, control of penetration, cleaning and appearance.
	Thin	Mechanised	50 Ar - 50 He	Higher weld speed under 20mm thick, with good arc stability and starting.
	Thick	Mechanised	Pure Helium	Highest weld speeds, deeper penetration with DCSP, demanding arc starting and fixturing requirements, high flow rates needed.

5.2 Welding Parameters

Welding Parameters characteristics are shown in Table 4:

Table 4. Welding Parameters characteristics

Metal Gauge	Joint Type	Tungsten size	Filler Rod Size	Cup Size	Shield Gas Flow			Welding Amperes	Travel Speed
					Type	CFH (L/Min)	PSI		
1.6 mm	Butt	1.6 mm	1.6 mm	4, 5, 6	Argon	11 (5.5)	20	80-100	307mm
	Fillet							90-100	256 mm
3.2 mm	Butt	1.6 mm	2.4 mm	4, 5, 6	Argon	11 (5.5)	20	120-140	307 mm
	Fillet							130-150	256 mm
4.8 mm	Butt	2.4 mm	3.2 mm	5, 6, 7	Argon	13 (6)	20	200-250	307 mm
	Fillet	2.4 mm 3.2 mm						225-275	256 mm
6.4 mm	Butt	3.2 mm	4.8 mm	8, 10	Argon	13 (6)	20	275-350	256 mm
	Fillet							300-375	205 mm

5.3 Welding Stainless Steel

In TIG welding of SS electrodes consists AWS-ASTM prefixes of E or ER can be used as filler rods. However, only bare uncoated rods should use. Stainless can be welded using ACHF, however recommendations for dcsp must be increased 25%. Light gauge metals less than 1.6mm thick should always be welded with DCSP using argon gas. Follow the normal precautions for welding stainless steel as: clean surfaces dry electrodes use only stainless steel tools and brushes, carefully remove soap from welds after testing.

5.4 Guide for Shield Gas Flows, Current Settings and Cup Selection

Shield Gas Flows, Current Settings and Cup Selection characteristics are shown in Table 5:

Table 5. Shield Gas Flows, Current Settings and Cup Selection characteristics

Electrode Diameter (mm)	Cup Size	Welding Current (Amps) - Tungsten Type		Argon Flow - Ferrous Metals		Argon Flow - Aluminium	
		AC Zirconiated	DCSP Thoriated	Standard Body CFH (L/min)	Gas Lens Body CFH (L/min)	Standard Body CFH (L/min)	Gas Lens Body CFH (L/min)
0.50	3, 4 or 5	5 - 20	5 - 20	5-8 (3-4)	5-8 (3-4)	5-8 (3-4)	5-8 (3-4)
1.00	4 or 5	15 - 80	20 - 80	5-10 (3-5)	5-8 (3-4)	5-12 (3-6)	5-10 (3-5)
1.60	4, 5 or 6	70 - 150	50 - 150	7-12 (4-6)	5-10 (3-5)	8-15 (4-7)	7-12 (4-6)
2.40	6, 7 or 8	140 - 235	135 - 235	10-15 (5-7)	8-10 (4-5)	10-20 (5-10)	10-15 (5-7)
3.20	7, 8 or 10	220 - 325	240 - 350	10-18 (5-9)	8-12 (4-6)	12-25 (6-12)	10-20 (5-10)
4.00	8 or 10	300 - 425	350 - 500	15-27 (7-12)	10-15 (5-7)	15-30 (7-14)	12-25 (6-12)
4.80	8 or 10	400 - 525	475 - 800	20-35 (10-17)	12-25 (6-12)	25-40 (12-19)	15-30 (7-14)
6.40	10	500 - 700	700 - 1100	25-50 (12-24)	20-35 (10-17)	30-55 (14-26)	25-45 (12-21)

5.5 TIG Welding Trouble Shooting Guide

A. Problems:

(i) Excessive electrode consumption
(ii) Cracking in welds
(iii) In adequate shielding
(iv) Short parts life

B. Causes:

(i) In adequate gas flow
(ii) Improper size of electrode
(iii) Filler material is dusty
(iv) Gas flow leak in torch

C. Solutions:

(i) Increase gas flow
(ii) Use larger electrode
(iii) Replace filler metal
(iv) Locate and eliminate leakage

In this study, we discuss the influence of the power source, type of current, gas flow rate, electrodes, filer wire, TIG Machines settings, and shielding gases which are most important To do these analyzation is done various aspects of the proposed topic, in various peer-reviewed journals, patents, books and other research resources. The prominent results of the present study are summarized below. All the necessary TIG welding principles, equipment's, parameters, Shielding gases and tungsten electrodes for welding similar and dissimilar metals work have been explained.

6. Conclusion

Quality of the weld mainly depends ON design of fixture. Necessary care has to take about factors for good quality edge preparation, cleanliness, purging gas pressure and purging gas flow electrode filler material, welding torch.

It is advantages to have flexibility in design and some adjustment should permit some adjustment for changing locating dimension necessitated by changes to compensate for expected weld distortion. In addition to this the fixture must be strong enough to withstand the mishandling during loading and unloading may form stresses from welding within the workpiece. They should be simply designed up stresses from welding within the workpieces. They should be simply designed to permit easy accessibility for components to work from the most advantageous angle. Most of the welding defects can be minimized by talking care in design of fixture and controlling the process parameters.

In this work, we also discuss the influence of the power source, type of current, gas flow rate, electrodes, filer wire, TIG Machines settings, and shielding gases which are most important in determine arc stability, penetration and defect free components.

7. Future Scope

This work is only a first stop on the road before reaching the end station, i.e. a monitoring system that classifies an ongoing welding process as good or bad weld. Other stops before reaching it could be:

a. This study providing this theoretical Knowledge in to practices to get required quality of weld.
b. To design automated TIG welding machine to reduce weld quality.
c. Further experiments with TIG welding parameters, using the correct Tungsten electrode that UE uses, the adaptive change of arc length capability turned on and using different surfaces as in this thesis.
d. To get the required weld, special designed features of welding fixtures are to be designed.
e. Most of the welding defects can be minimized by taking care in design of fixture and controlling the process parameters.

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