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Welding Distortion Control Technique

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Abstract — *This paper focuses on the distortion problem faced during the welding process of the divergent section of nozzle of High Speed Testing System. The High Speed Testing System is a system used to test the scaled models of rockets and missiles to determine how the actual model will perform in the atmospheric conditions of outer space at that speed. NOZZLE which helps the system in creating such conditions is considered the heart of the system and has to be manufactured with a great accuracy and care. As heat is involved in the welding process of nozzle, some distortions are caused due to it. This paper gives solution to one of such distortion which can be used not only for the welding of nozzle but also for any components which are to be welded to each other at an angle using the same logic.*

Keywords- *Nozzle, Flanges, Cone, Shielded metal arc welding, Cone angle, Blocks. Strip and tack weld*

I. INTRODUCTION

In the High Speed Testing system, the system creates the conditions in which the air at hypersonic speed enters the test section in which the tests are held. The scaled model is made to stand in this condition to observe its performance in that condition. To bring the air at that speed, nozzle is used. Nozzle is considered the HEART of the High Speed Testing System. So the manufacturing of nozzle is one of the most important part in the manufacturing of the entire system. Its physical properties like concentricity, geometry, axis alignment, ovality and surface alignment are of great importance because these properties of the nozzle affect the performance of the entire system.

Each of the section of the divergent section of the nozzle has one cone in the centre with two flange rings at its both ends. These flange rings are assembled with the cone by welding.

In the manufacturing of the divergent section of nozzle, the cone and the flanges are welded to each other. There are two types of welding involved in this process. First is long seam welding which is used to assemble the edges of the cone to complete it and the second is circ-seam welding which is used to assemble the flanges with the cone. These flange rings are also made up of three flanges which are assembled by welding. Due to the heat involvement the welding process, the metal at the weld surfaces melts and the metal bents. This changes the shape of the component. Considering the importance of the nozzle in the system, not even the slightest error is allowable in its manufacturing.

In this paper, the distortion control technique discussed is for the distortion problem caused during the welding of the flange ring with the cone has been discussed which will contain the problem, old solution used and the new proposed solution.

II. MANUFACTURING PROCESS

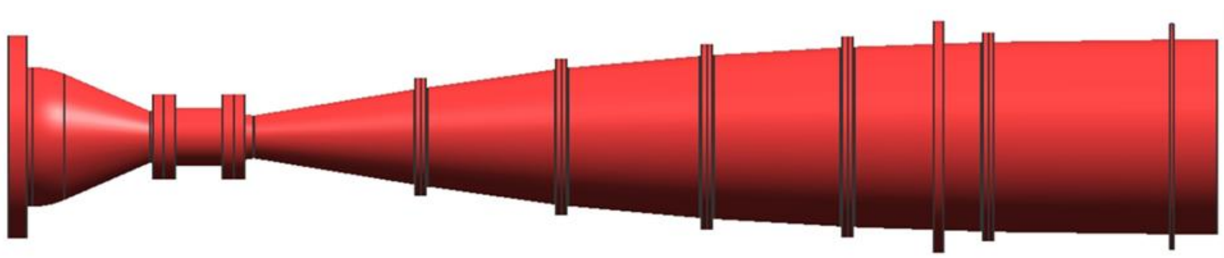

Figure 1: Nozzle

For the manufacturing of the divergent section of nozzle, the cone is cut from a plate. This part is pre-rolled, rolled, welded and then re-rolled which is the last step of the fabrication of the nozzle. These steps have been explained in short in the following section

2.1 Cutting of the plate

According the Plate Cutting Request (PCR), the Plate Cutting Layout (PCL) is made. Using this PCL, the plate is cut. The cutting of the plates is done by plasma arc cutting. After cutting the cones and the flanges from the plate, they inspected using the PCR.

2.2 Rolling of the cone

After the cutting of the cone and the flanges from the plate, the plate of the cone is rolled to make the cone. The process used for rolling is pyramid rolling. To start the rolling, the start part of the plate is pre-rolled according the minimum requiremnet of the roller so that it will start rolling. Otherwise it can't roll because it will not get support from the second base roller. The cone angle is priorly determined and using that angle the plate is inserted in the machine at that angle so that cone will have that angle after rolling. An exaple of this is shown in the figure below:

Figure 2: Pyramid rolling of the cone

This process is undertaken with special care baecause after rolling the opposite edges of the plate should connect each other without losing the ovality of the cone.

2.3 Edge Breaking

After the rolling these mating edges are welded to complete the cone. For the ease of welding and to ensure good strength, one phenomenon is used for welding which is called weld Edge Preparation. In this, the mating edges are cut at a particular angle with respect to each other as shown in the diagram below:

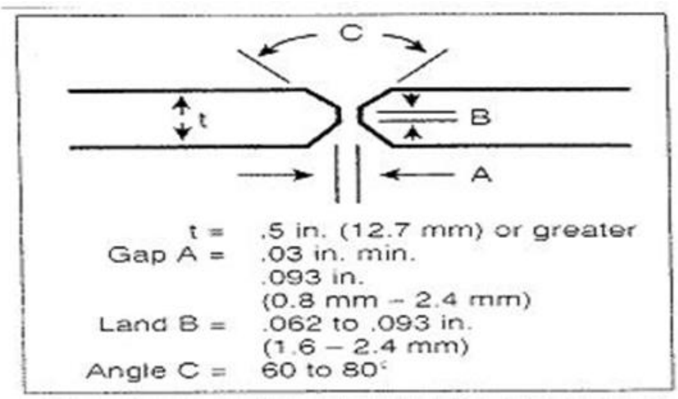

Figure 3: Weld Edge Preparation

The part in the centre is called the root gap. In the process the as the root gap is so small, it is welded with Tungsten Inert Gas Welding (TIG) and the part above and below is welded with Shielded Metal Arc Welding. The same combination of welding process is used at all the places. This combination ensures good strength and efficiency.
After the welding of the cone, it is re-rolled to ensure that its concentricity and ovality is not lost.

2.4 Welding process

There are total three places in the manufacturing of the divergent section where assembly is done and they are:

1. Joining of the cone edges
2. Assembling of the flanges to make flange ring
3. Assembly of the cone and the flanges.

The same combination of welding process mentioned above is used for the assembly of all the three parts mentioned above. TIG is used be at the root gap because the root gap is so small the other welding process guns can't penetrate in that gap. SMAW is with it though it is not very efficient because it cools down very quickly compared to other processes.

III. DISTORION PROBLEM

During the welding process of the cone, there are three distortions occurring. During the long seam welding of the cone, the WEP cut at the edges above the root gap to the one below the root gap are in the ratio 1:2. So when the cone is closed using rolling, the 2/3 side of the cut comes inside the inner surface. So more heat is involved on this side as compared to the outer one. Due to this the cone loses its ovality and bents inward. To avoid this, spiders are used from inward which are placed equidistant from weld on both sides. During the welding of the flanges, to avoid distortion, they are placed on a flat surface and clamped so that they don't move or bend during welding.

Finally, the last distortion problem occurs during the welding of the cone with the flanges. Considering the cone angle the flanges are welded to the cone at an angle which is the cone angle. When the filler material is inserted in the gap during the welding, it is very hot which transfer the heat tot the weld surfaces. Due to this heat, the edges expand and the flanges bend. A similar problem has been depicted in the figure below:

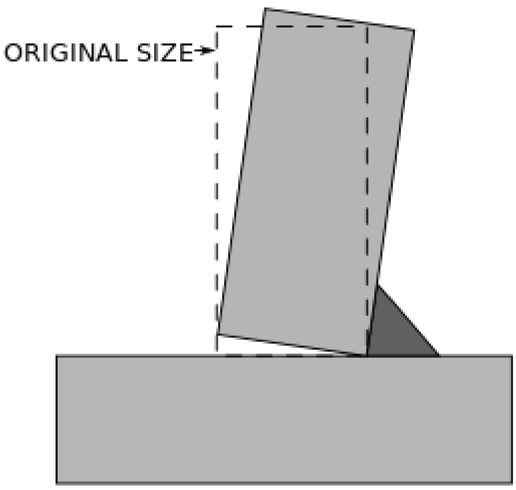

Figure 4: Distortion

IV. WELDING DISTORTION CONTROL TECHNIQUE

4.1 Fixture concept

The old solution for this is to make a disc of the diameter equal to that of the flange ring, tack weld it on the face of the flange and then continue with the welding process. After the welding, remove the disc from the flange. The disadvantage of using this method is as follows:

1. For each and every flange ring, new corresponding disc have to be made.
2. It is more time consuming as time is wasted in the manufacturing, welding and holding of new disc which will be also heavy because it will be thick so as to prevent the distortion.
3. This is an expensive method as more cost is involved in the material and manufacturing of the disc.

According to the new method, support has to be given to the flange from behind. A combination of two blocks and one strip is used for this. Eight such pairs are to be used for this which will be equidistant from each other around the cone's outer surface. The strip is attached to the flange and it is pushed ahead with the help of blocks tack welded on the cone.
All the attachments i.e. the strip to the flange, strip and the block and the block to the cone are done by tack welding. Material of flanges and the blocks is the same as that of the component. The blocks are equidistant from the centre of the strip. So the one end of the block is connected to the strip and the other end of the block is connected to the cone surface.

4.2 Block and Strip dimensions and properties

Same material of which the component is made can be used of the blocks and strips so that extra cost is not invested for the new material purchase. While deciding the dimensions for the blocks, important objective is that the block surface touching the strip should cover maximum area of the strip without touching anywhere else. Since the cone and the flanges are welded at an angle to each other, the same angle has to be used for the block. Consider the cone angle measured w.r.t. the centre axis of the cone. Add the 90 degrees to it. Whatever the we get give that angle to the inner corner touching the strip and the outer bottom corner. For the other two corners, subtract 90 degrees from it and use it. For the dimension of the strip, the thickness should be minimum 30mm. considering the load on it. The distance between each pair should be minimum 100mm. along the pitch circumference. The flange should be curved so that maximum face of the flange can be covered. To explain this, consider a example in which the cone angle is 3 degrees w.r.t. to the centre axis. Flange radius is 532mm. leaving a 10mm. gap from the flange edge the strip placed will have major radius as 522mm. considering the 30mm. thick strip, its minor radius will be 492mm. (522-30 = 492). Lets consider the lengthwise thickness for both flange and strip be 40mm. considering the dimensions the block and the strip will look as following:

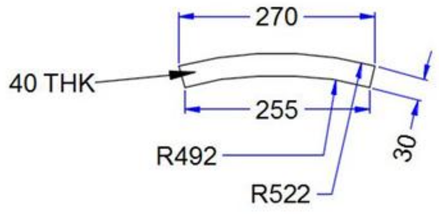

Figure 5: Strip

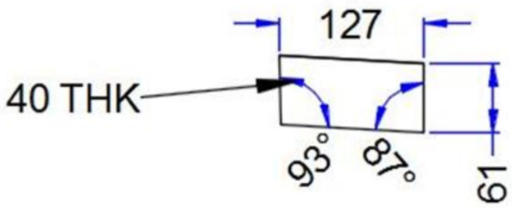

Figure 6: Block

4.3 Actual application and advantages

Figure 7: Welding Distortion Control Technique

Above figure shows the application of the Welding distortion control technique. As my final year project this concept was introduced in my report and tested actually. It worked properly and the results were within the tolerance limit. The advantages of this technique are as follows:

a. The same block can be used for other sections by just grinding. There is no change in the strips. There no need to make new sets again and again
b. It is less time consuming because in the old case such a heavy disc had to be properly aligned with the flanges before welding them together. There is alignment problem in this case. The blocks and strips are cut from the plate so there is no waste of time in their manufacturing.
c. They are small in size as well as they are not manufactured which makes this technique cost effective.
d. The surface doesn't need to be finished as in the case of the disc which has to be finished properly as it will be touching and holding the flange on its face.

e. They are light in weight hence safer on the shop-floor.
f. The distortion caused after using this technique is less than 40 microns.

V. SUMMARY & CONCLUSIONS

The Welding Distortion Control Technique is an improvement technique over the old technique. It is a cost effective and less time consuming technique. It is more efficient than the older method. It can be used for other components also. In our case we had considered the angle with respect to the centre axis. Same idea has to be used for components of any geometry. The standard procedure for manufacturing of the divergent section has been discussed in the paper. Different types of distortions have been discussed along with their solutions.

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