# Some Aspects of Distortion Control

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## INTRODUCTION

Distortion of fabricated components poses problems to all equipment fabricators. The extent of problems encountered depends on the *rigidity of the component* and the dimensional accuracy needed on the finished product. Of the different manufacturing activities, welding poses the maximum problems of distortion.

Different steps involved in welding distortion control are :

(i) Following an appropriate technique/procedure
(ii) Obtaining feedback at different stages of welding, and
(iii) Analysis of the feed back to modify the technique/procedure as and when needed.

It is evident that the above increase the cost of fabrication, as it increases the unproductive work. All the above steps are to be rigorously followed on welding fabrication of critical components requiring final dimensional accuracies of high order and on components that are too complicated, wherein rectification of the distorted member is impossible without major rework.

For components, of simple nature such as longitudinal seams of pressure vessels, it is cost effective to follow a general procedure based on basic concepts to minimise distortion and to find an effective rectification procedure.

It is to be appreciated that there would be *no single optimum answer* to control distortion in all cases. Based on experience and the first hand feed back, fabricators tend to follow their own well proven methods.

In this paper, through some case studies, the techniques followed by us to control distortion are highlighted.

*Case 1 : Use of simple sequence to control distortion :*

A. **Job details :**

| | |
|---|---|
| Type of joint | : Long. seam of shell- 1.184 mtr. OD and 58 mm thk. |
| Material | : Low alloy steel |
| Edge Preparation | : Double Vee (see Table 1) |
| Welding processes | : SMAW seal run and rest by SAW |
| Method of backchip | : Gas gouging and grinding. |

It was required to weld this seam without the necessity to reroll. Otherwise hot/warm rerolling of the shell would be involved.

B. From an initial analysis of the feed back data from other shells of equivalent rigidity, it was realised that a simple sequence of welding would be sufficient to avoid rerolling. However, it was decided to monitor the distortion pattern at different stages and at three pre-determined locations as shown in *Sketch* 1. The shape at the weld joint, checked with a D/4 template, was the method used to monitor distortion.

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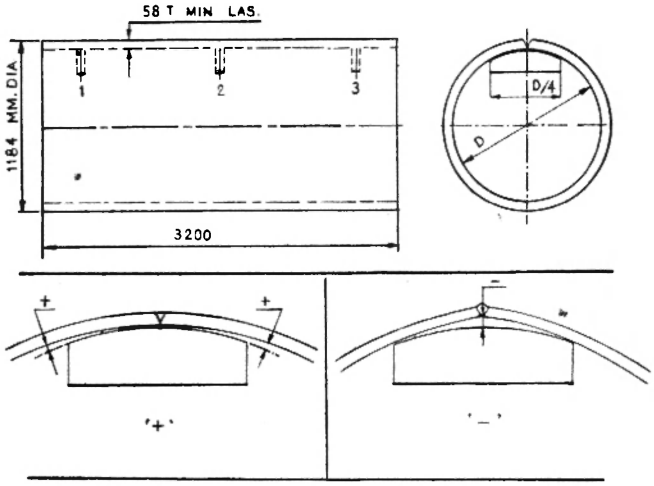
**TABLE 1**

**(D/4 Template Reading)**

| Stage | Location | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 1 Set-up Stage | +4 | +2 | +2 |
| 2 After Seal Run | +6 | +4 | +5 |
| 3 After O/S Welding | +8 | +6 | +8 |
| 4 After Back Gouging | +6 | +5 | +5 |
| 5 After I/S Welding | +4 | +2.5 | +4 |



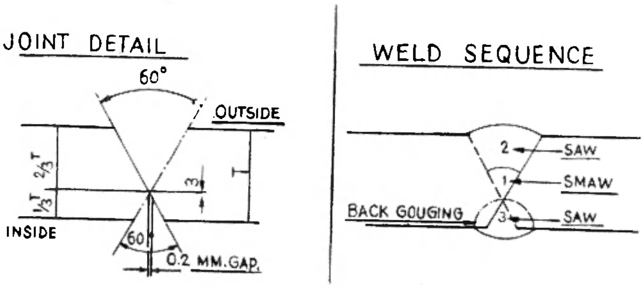

*Sketch 1.*

C.1. Adequate precautionary measures were taken at the rolling stage to get as near to perfect set up as possible. The shape and ovality were checked at the set up stage.

2. The sequence of operations adopted was as follows :

   (i) Complete the outside welding.
   (ii) Back chip with gas gouging and grind.
   (iii) Complete the welding of the gouged groove.

3. Distortion of the shell at the weld joint, as monitored at different stages is shown in Table 1. The legend of the sign, in the deviations from D/4 template column is explained in *Sketch 2.*




*Sketch 2.*

4. As could be seen from the readings in Table 1, the sequence followed did not distort the shell to any appreciable extent. On completion of welding, the shape and the ovality of the shell were checked and found within acceptable limits.

*Case 2 : Use of a changed welding technique to overcome distortion problems :*

A. **Job details :**

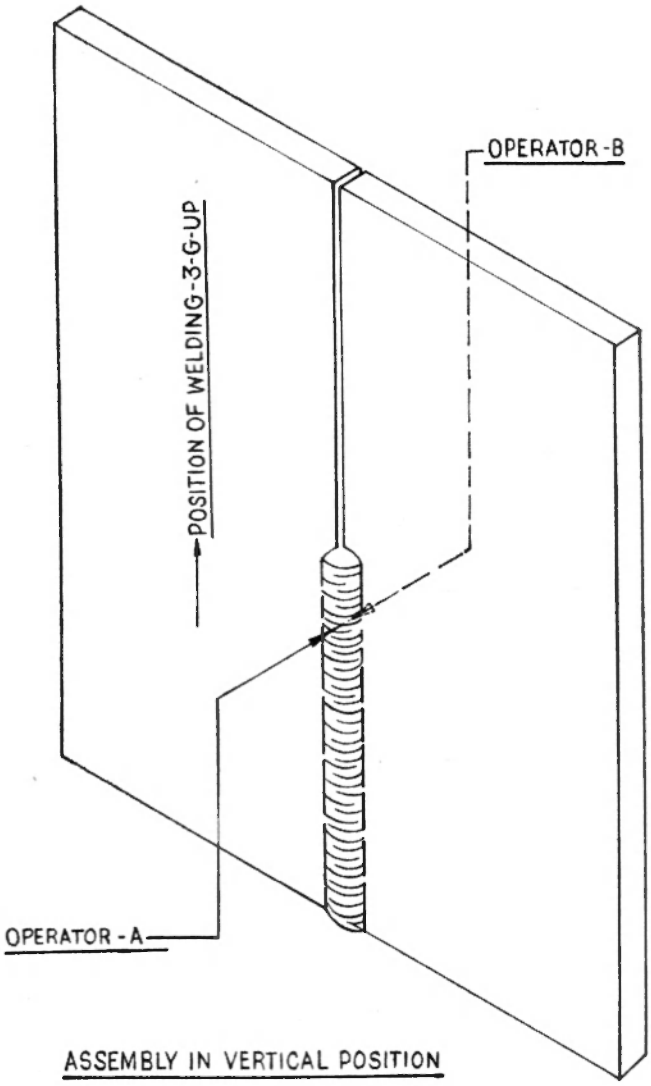
| | | |
|---|---|---|
| Type | : | Longitudinal and circumferential seams of 5 mm thk. 2.0 mtrs dia. vessel. |
| Material | : | Austenitic Stainless Steel |
| Edge preperation | : | Single Vee |
| Welding process | : | SMAW |
| Method of back chip | : | Grinding. |

B. Feed back information on previous jobs of similar rigidity revealed frequent problems of offset control after welding. Rectification of local offsets of thin shells is normally done by (i) cutting the seam locally, (ii) restraining the joint with the use of mood plates and screw jacks, and (iii) welding the joint under restraint. As could be seen, this rectification procedure is a time consuming and a costly method.

It was required to weld these joints by a method to avoid problems of offset.

C. Of the different methods visualised, welding of these seams with double operator GTA welding in vertical position was decided as the optimum method from an overall point. *Sketch 3* shows a typical double operator GTA welding in progress.

With the use of this welding technique in vertical position, the problems of offset was virtually eliminated.



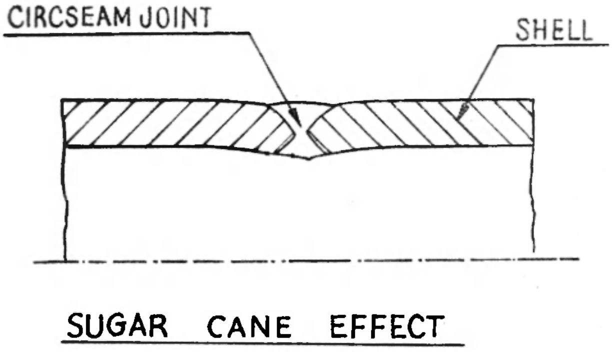

*Sketch 3. Double operator technique.*

*Case 3 : Use of changed joint design to overcome distortion problems :*

A. **Job details :**

| | | |
|---|---|---|
| Type | : | 3.5 mtrs. dia, 30 mm thk. carbon steel circumferential seams |
| Edge preparation | : | Single Vee (see Sketch 5) |
| Welding processes | : | SMAW seal run and subsequent SAW |
| Method of back chip | : | Gas gouging. |

Circumferential shrinkage of welding leads to 'sinking in' affecting the weld joint, commonly termed as "Sugar cane effect" (*see Sketch 4*). The extent is not of any significant concern for many of the equipments. However, in cases wherein, refractory lining is involved in the inside of the equipment, it is required to control this effect to as low an extent as possible.




*Sketch 4.*

B. As the distortion at the circumferential seam is mainly due to the longitudinal shrinkage of the weld, it was decided to minimise the extent of weld metal used and to use restricted heat input. Further, it was decided to monitor the extent of 'sinking-in' on two circumferential seams, one with inside Vee and the other with outside Vee, with the same welding procedure.

C. The straightness across the seam as checked with a straight edge of 1 mtr. in length at different points equally distributed along the circumference, was used to monitor the 'sinking-in' effect. Such measurements were taken at different stages of welding.

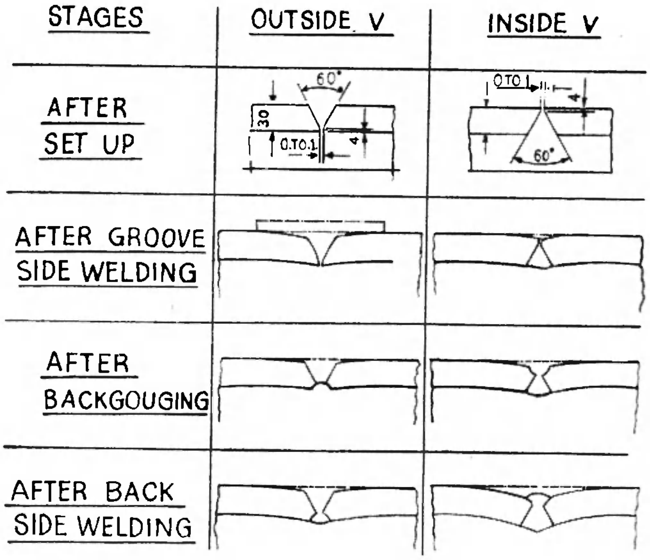
Although one expected the inside Vee joint to sink in to a lesser extent compared to the outside Vee joint, the final results were found to be to the contrary. The observations are schematically represented in *Sketch 5*. As could be seen from the sketch, the back gouging in the case of outside Vee joint has a slightly beneficial effect with respect to the sinking-in problem.

It was decided to adopt outside Vee edge preparation for circumferential seams, wherein the sinking-in effect had to be controlled to a minimum.

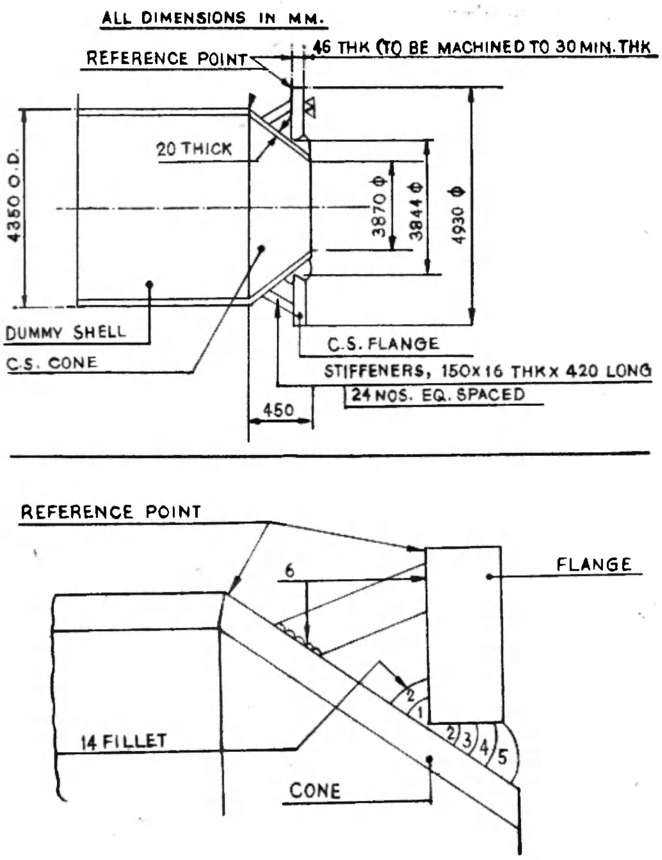
*Case 4 : Use of a change in welding position & sequence to control distortion :*

A. Job details : Refer to *Sketch 6*.

The flange and the cone are fabricated out of six segments, butt welded together.




*Sketch 5.*




*Sketch 6.*

The flange to cone joint is of partial penetration type.

After welding, the face of the flange is required to be machined with a minimum thickness of 30 mm.

B. Previous experience had indicated that problems of inadequate machining allowance on the flange thickness were frequently encountered leading to costly rework.

It was found that the flange thickness could not be increased in the above job due to non-availability of the material. The assembly of the job had to be welded with a method to avoid rework.

C. After detailed discussions, the following procedure was adopted on the job.

(i) Utmost care was taken in the fabrication of the cone and the flange so as to have the setup with a max. gap of 3 mm.

(ii) Heat correction of the fabricated flange was done at the setup stage, to obtain the level of the flange face within 3 mm.

(iii) Tacks of about 100 mm length approximately 600 mm apart were given on the face side of the groove.

(iv) The assembly was tacked to a dummy shell and kept horizontally on a tank rotator.

(v) 24 Nos. of reference points were punched on the dummy shell and the flange at a distance of 700 mm. The distances between the reference points were measured at different stages of welding to monitor the distortion. Typical observations are shown in Table 2.

**TABLE 2**

**Typical readings of reference points at various stages**

| *Reference Point No .* | *Bead No* | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | —2.5 | —1.0 | —1.0 | —1.0 | 0 | —4.0 |
| 5 | —3.5 | —1.0 | 0 | —1.0 | 0 | —4.0 |
| 3 | —3.5 | —4.0 | —5.0 | —5.0 | —3.0 | —6.0 |
| 13 | 0 | —1.0 | 0 | +1.0 | +1.0 | —2.0 |
| 17 | —1.5 | 0 | —3.0 | —1.0 | —1.0 | —4.0 |
| 21 | —2.0 | 0 | —3.0 | —1.0 | 0 | —1.0 |

(vi) The sequence of weld deposition is shown in *Sketch 7.*

(vii) Beads 1, 3, and 4 were welded in vertical position with 2 welders employed in diametrically opposite position.

(viii) Bead 2 was deposited simultaneously on both sides of the flange with two pairs of welders, each working in diametrically opposite positions.

(ix) 24 Nos. of gussets were setup between flange and cone and were welded in 3 F position. No specific sequence was followed.

(x) On completion of welding, the cone was separated from the dummy shell and kept with the cone axis in vertical condition. The out of flatness of the flange face was checked with monometer and the level was found o be within 6 mm.

(xi) The assembly was subsequently machined without any problem.

## CONCLUSION

Through some of the case studies, we have tried to highlight how a simple sequence of welding, a change of welding process & technique, a change in joint design, and a change in welding position and sequence, could be successfully made to control distortion within the desired limits.

## ACKNOWLEDGEMENT

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# Welding Spatter

"It has always been recognised that it is impossible to grade electrodes on the basis of mechanical results which relate directly to practice since the very many different ways in which the electrodes are used, e.g. welding position, electrode size, run sequence, welding current and the great variety of parent material upon which the electrodes are deposited, would create an impossible task. At best, therefore, an electrode standard can provide a system by which various types of electrodes can be graded in accordance with a specified manner of weld deposition and testing which is free from the effects of variations present in practical welding. By this means, electrodes of different types or manufacture can be compared. Whilst such grading of electrodes can never indicate the results which will be obtained in any given welding procedure test, in practice they form a useful guide to the welding engineer as to what type of electrode he will need to adopt to achieve satisfactory mechanical test results".

—Chairman, BSI Committee for revision of BS 639 : 1976