# ISSUES RELATED TO BIMETALLIC WELDS

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## ABSTRACT

*Bimetallic welds have been a necessity within the pressurized water reactor and boiling water reactor designs, where the heavy section low alloy steel components are connected to stainless steel primary piping systems. There are certain issues which need to be addressed while welding the bimetallic joints due to the variance in the properties of base metals. The present paper discusses these issues and the important investigations carried out by various researchers in the field of bimetallic welds.*

***Keywords: Bimetallic welds, ferritic low alloy steel, austenitic stainless steel, transition metal joint.***

## I. INTRODUCTION

Bimetallic welds (BMWs) between low alloy steel components and stainless steels are widely used in nuclear power plants [1]. For pressurised water reactor, the BMWs, which are of particular interest, are those attaching the piping system to the various nozzles of the reactor pressure vessel (RPV), steam generators and pressuriser [2]. A sketch of a Combustion Engineering hot-leg surge nozzle shown in Figure 1 depicts the bimetallic weld between the surge line and the hot-leg surge nozzle. The material of surge line is stainless steel while the hot-leg is made of carbon steel. Thermal sleeves are installed and hot-leg surge nozzles to protect the nozzle wall from thermal transients, which could develop high thermal stresses [3].

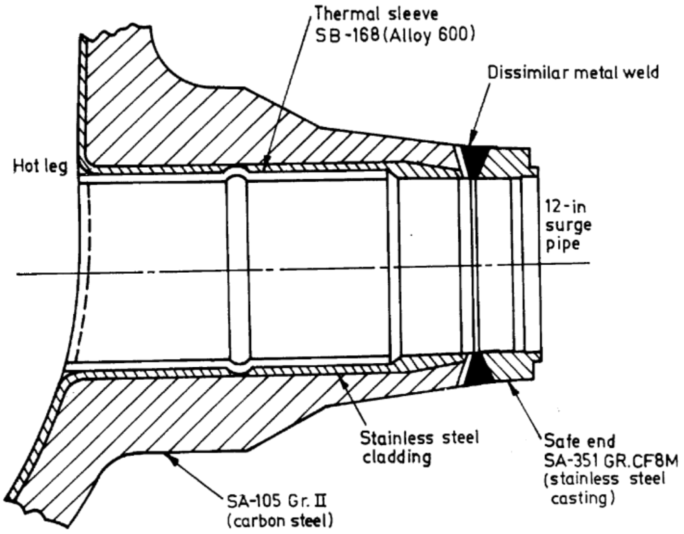


**Fig. 1 Typical combustion engineering surge nozzle at the hot leg [3]**

BMWs between ferritic low alloy steels such as SA 508 and austenitic stainless steels such as AISI types 304, 316, etc., as shown in Figure 2 are used widely in steam generators of the power plants. The requirement of high corrosion resistance, higher creep strength and suitable mechanical behavior at elevated temperatures such as in final stages of super heaters and reheaters, has led to the extensive use of austenitic stainless steels such as SS 304, SS 304L, 316L etc. in nuclear power plants. The use of carbon and low alloy steels due to their low cost and relatively good mechanical strength is preferred particularly in the construction of reactor pressure vessels and tubes for use in low temperature sections of nuclear power.

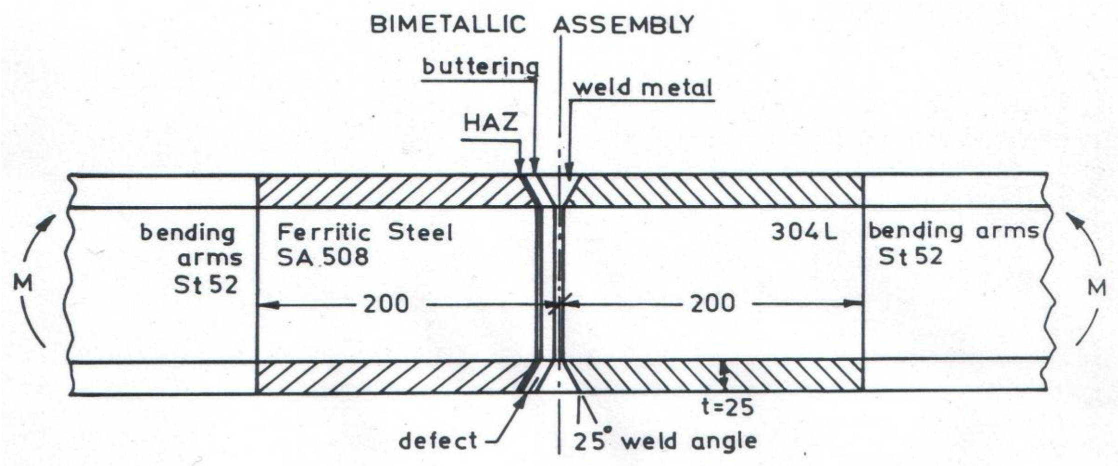


**Fig. 2 Ferritic- austentitc bimetallic weld configuration with a buttering layer and different zones [4].**

## II. VARIOUS PROBLEMS ASSOCIATED WITH BIMETALLIC WELDS

### 2.1 Metallurgical problems

The BMWs represent regions or zones with metallurgical discontinuities as shown in Figure 3. The regions critical for the performance of the BMWs are the coarse grained heat affected zone (CGHAZ), the fusion line and its immediate vicinity, and the first buttering layer. Degradation of fusion zone toughness is related to the formation of coarse upper-bainitic CGHAZ micro- structure, as well as a narrow martensitic layer as a result of carbon migration from the ferritic steel towards the austenitic material during welding. The other two zones are the carbon depleted zone and fully austenitic zone.

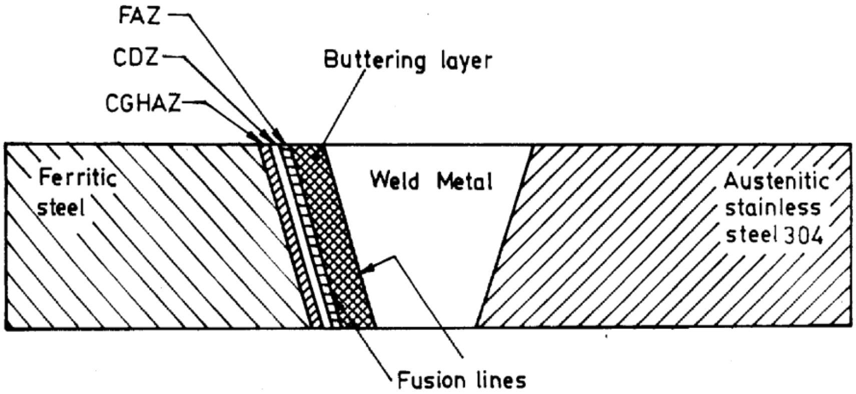


**Fig. 3 Bimetallic weld assembly [2].**

**2.2 Thermal fatigue**

The usual heat-up and cool-down cycles further impose thermal strain on the BMW having stainless steel as filler metal because the thermal expansion coefficients for stainless steel (SS) is about 30 percent higher than that for ferritic steel.

**2.3 Residual stresses**

BMWs between ferritic and austenitic steels exhibit a strong residual stress field, both as welded and after PWHT. Knowledge of the residual stress is an essential input to the structural integrity analysis of the joint, particularly where there is a locally embrittled region near the interface.

**2.4 Atmospheric corrosion**

In 1997, in France more than 1000 BMWs (using SS buttering and ferritic-SS weld) were analysed and 50 of them were found to be affected by intergranular degradation on the outer surface in the buttering and close to the ferritic to SS buttering interface.

**2.5 Solidification cracking (hot cracking)**

Hot cracking has been observed in the BMWs that join the hot leg pipes to the RPV nozzle. The hot leg pipes are large diameter, thick wall pipes. Typically, an Inconel weld metal is used to join the ferritic pressure vessel steel to the stainless steel pipe. The austenitic welds, which have 4–10 vol% delta ferrite and fine dendrites, are resistant to hot cracking, stress and severe impacts during service conditions [5].

## III. WELDING OF BIMETALLIC JOINTS

In their study King et al. [6] proposed that joint stress could be reduced considerably by using a transition material Alloy 800H with an intermediate coefficient of thermal expansion between the 2-1/4 Cr-1Mo ferritic steel and the Type 316 austenitic stainless steel. Various filler metals corresponding to Types 309, 312, 347 and 16-8-2 were evaluated for joining alloy 800H to Type 316 stainless steel and their relative merits/demerits were highlighted. Weldability studies showed that Type 16-8-2 weld metal was the least fissure sensitive while Type 347 was the most susceptible to hot cracking. Although Type 312 showed little cracking but it contained a relatively large amount of delta ferrite which could transform to sigma phases during high-temperature service.

Bhaduri et al. [7] carried out the investigations on transition metal joints between chromium-molybdenum (Cr-Mo) ferritic steel and austenitic stainless steel widely used in the steam generators of power plants. The investigators highlighted the various failure causes of bimetallic joints using Ni-base weld metals and instead of austenitic SS weld metals. They proposed an improved trimetallic transition metal configuration of austenitic stainless steel (SS 304)/ Alloy 800/ ferritic steel (2.25Cr-lMo). For the type 304 SS/Alloy 800 joint, a comparative evaluation of Inconel 182 and 16-8-2 welding consumables has been carried by the authors. 16-8-2 consumable was declared better over Inconel 182 for welding the joint between SS304 and Alloy 800 due to its various advantages which includes its lower tendency for micro fissuring along with the reduced mismatch in the coefficient of thermal expansion across the joint. Also the choice of 16-8-2 welding consumable, involve only a marginal penalty on the elevated temperature mechanical properties of the joint.

Sireesha et al. [8] presented a comparative evaluation of welding consumables for dissimilar welds between 316LN austenitic stainless steel and Alloy 800. Four consumables examined were 316, 16-8-2, Inconel 82 and Inconel 182. The comparative evaluation was made on the basis of hot cracking tests; estimation of mechanical properties and coefficient of thermal expansion. The weld samples were prepared using shielded arc welding with Inconel 182 and 316 consumables and gas tungsten arc welding with 16-8-2 and Inconel 82 filler wires. The coefficient of thermal expansion coefficients of Inconel 182 lies in between the both base metals and therefore it is better suited than the other welding consumables. The 16-8-2 filler material resulted in the lowest susceptibility to solidification cracking while the other Inconel welding consumables were superior from the mechanical property view point.

Sudha et al. [9] discussed about the dissimilar weldments between low-Cr and high-Cr ferritic steel used in a number of steam generator circuits. Weldments of 9Cr-1Mo and 2¼Cr-1Mo steel were prepared using plates of 12.5mm thickness by shielded metal arc welding process using 9Cr-1Mo as the electrodes. Carbon migration occurs across the weld interface from low-alloy ferritic steel to high-alloy ferritic steel during exposure to high temperature. Diffusion of carbon driven by the activity gradient across the weld interface resulted in the formation of a soft zone in the low-Cr side and a carbide-rich hard zone in the high-Cr side of the weld interface. The authors also discussed the width of these zones and the effect of post weld heat treatment. It was suggested that hardness and width of both soft as well as hard zone decreases with increasing the time of heat treatment.

Srinivasan et al. [10] investigated the use of autogenous gas tungsten arc welding to produce a dissimilar weld between ferritic and austenitic stainless steels and carried out a mechanical property evaluation of these welds.

Rathod et al. [10] suggested a Ni-Fe alloy buffer layer in buttering the ferritic steel for the dissimilar welds between SA508Gr.3Cl.1 and SS304LN. The joints (with and without buffer layer in buttering) were fabricated using gas tungsten arc welding and shielded arc welding processes. The metallurgical and mechanical investigations of four dissimilar welds were carried out. The carbon did not migrate from the ferritic steel to the Ni-Fe alloy (buffer layered buttering) due to the absence of chromium.

## IV. CONCLUSION

The present paper introduces the bimetallic welds and highlights the key problems associated with these joints. It also shows the important research findings of some the researchers who investigated the bimetallic joints by introducing the transition metal joints in between the base materials.

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