Design of Welds for Elevated Temperature SS 316 Components

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Concern expressed in nuclear Codes for weldments creep and fatigue behaviour is brought to the notice of the users of non-nuclear design codes. Guidelines are provided in the paper for improving the life of SS 316 welded components for elevated temperature service.

A. INTRODUCTION

Treatment to weld design for elevated temperature service in the non nuclear pressure vessel and piping codes like ASME Section[1], Section VIII Div 1[2] and Power Piping Code B31.1[3] is not complete. The nuclear code case N-47-28[4] for elevated temperature design does recognise the concern that weldments are inferior in creep and fatigue in comparison to the base material which forms the basic material properties data for design. The purpose of this note is to bring to the notice of users of the non-nuclear codes, the information availble in the literature on elevated temperature design of SS 316 grade components. Recommendations given below could enhance the reliability of components or provide life longer than design life which could derive advantage in life extension.

B. Weldment Creep Rupture Behaviour

Ratio of weld metal creep rupture strength to the base material creep rapture strength is a function of temperature and time. For 10^5 hours, the basis of design in the above mentioned non-nuclear codes, the weldment strength reduction factor in Code Case N-47-28 is as follows for SS 316 welded with E 316 electrodes and ER 316 welding rods.

Temperature deg. F (deg. C)	Factor
850 (454)	0.92
900 (482)	0.82
950 (510)	0.72
1000 (538)	0.62
1050 (566)	0.66
1100 (593)	0.68
1150 (621)	0.66
1200 (649)	0.64
1250 (677)	0.60
1300 (704)	0.56
1350 (732)	0.52
1400 (760)	0.47

Non-nuclear Codes do not call for any such reduction factor. If one wants to avoid usage of this factor, the solution lies in improving the specification of welding consumables. It is well established that carbon and nitrogen have a strong influence on creep resistance of both base and weld material. Nitrogen is not specified in ASME/AWS specification for SS 316 welding consumables. Specification of carbon and nitrogen in the weld deposit of minimum 0.11% will ensure weld creep rupture strength not lower than the base material upto 700^0 C[5]. Such electrodes for manual metal arc welding are not available in India. Indian welding industry needs to develop and encourage use of these welding consumables.

C. Weldability and Structural Stability

Non-nuclear Codes do not call for any specification on ferrite content. It is widely recognised that weld metal composition needs to be balanced to produce a small amount of ferrite to control cracking. One also needs to take care of the deleterious effect of ferrite on sigma phase formation in austenitic stainless steel and 316 grade in particular. ASME Code Case N-47-28 calls for FN 3-10 for SS 316 except that delta ferrite determination is not required for 16-8-2 electrode. Welding with 16-8-2 type welding consumables is to be preferred over 316 type as the weld is stronger in creep and has better structural stability but its commercial availability is poor.

D. Weldment Fatigue Behaviour

ASME Code Case N-47 calls for a reduction factor of two on cyclic life for the weldments. Fatigue analysis is not called for in ASME Section I and Section VIII Div. 1 Power Piping Code B31.1 has covered fatigue analysis by providing allowable stress range for expansion stress for piping flexibility design. Apart from weldment fatigue behaviour, weld left in the as welded state is likely to be poor in comparison to base material because of the geometric irregularities of the welded joint such as reinforcement, shrinkage, undercut erc. Solution to this lies in locating the weld joint at spool stage where piping flexibility stress is on the lower side.

E. Shell Nozzle Junction Welds

Nozzle to shell junction is of concern in the pressure vessel and pipping industry. For critical applications from thermal fatigue considerations, it is suggested to avoid weld directly at the junction. Instead one can either go for a forged nozzle or shell pull out.

References

1. ASME Boiler and Pressure Vessle Code Section I.
2. ASME Boiler and Pressure Vessel Code Section VIII Div. 1
3. ANSI/ASME B 31.1 Power Piping.
4. Class 1 components in elevated temperature service, Section III Division 1, Code Case N-47, ASME Boiler and Pressure Code.
5. Lefebvre, J, Daemon, R and Niset M; Welding Consumables for AISI 316 High Temperature Weldments, Stainless Steels, 84, The Institute of Metals, pp. 330-335.

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