Failure analysis of AISI 321 stainless steel welded pipes in solar thermal power plants

Kamal Mankari, Swati Ghosh Acharyya
School of Engineering Sciences and Technology, University of Hyderabad, Gachibowli, Hyderabad, Telangana 500046, India

ABSTRACT
AISI 321 stainless steels (SS) pipes are commonly used in solar thermal power plants for transport of thermic fluid containing chloride ions at ~400 °C. Several of these SS pipes have failed while in service after very short exposure to service conditions leading to leakage of the thermic fluid. The present study aims to understand the root cause of failure of these pipes which were seam welded together with spot welds on the surface. The seam welding had been done either by a) laser beam welding (LBW) or by metal inert gas welding (MIG). Dye penetrant tests were applied to the pipes followed by microstructural analysis of the pipes using optical microscopy, and field emission scanning electron microscopy (FESEM). Subsequently, phase determination was carried out by X-ray diffraction. Stress corrosion cracking (SCC) susceptibility of the laser beam welded, MIG welded and spot welded joints were tested as per ASTM G36 in boiling MgCl₂. Detailed investigation revealed that leakage in each case occurred near spot welded joints due to chloride-induced SCC of AISI 321 SS. SCC susceptibility tests of the welds showed that both the seam welds and the spot welds had residual stresses beyond the threshold limit which resulted in early nucleation of cracks in presence of chloride ions. Improper post-weld heat treatment (for LBW, MIG and spot weld) was identified to be the root cause of failure of the pipes.

1. Introduction
Austenitic stainless steel (SS) finds enormous application in different industrial sectors due to its high strength, good weldability, and good corrosion resistance. However, these steels are susceptible to localized corrosion, like pitting, crevice corrosion and stress corrosion cracking (SCC) in aggressive environments like chloride ions which can lead to catastrophic failure events in chemical and petrochemical industries, power plants, civil structures etc. [1–7]. SCC is a phenomenon wherein cracking takes place under the synergistic action of tensile stresses and aggressive environment and a susceptible material. Stresses may either be in-service stresses or residual stresses. Tensile residual stresses arise in the material due to different steps involved in component fabrication like bulk deformation, surface finishing, welding etc. [8–15]. Welding in general results in the development of high magnitude of residual stresses due to the constrained weld geometry. The thermal expansion and contraction of the alloy during welding gets restricted due to the constraint geometry resulting in the development of high magnitude of tensile residual stresses [16,17]. The magnitude and nature of residual stress distribution in the component depend on the nature of welding and the welding parameters [17] such as welding speed, heat input, time for cooling, component thickness etc. Welding of austenitic stainless steel also leads to sensitization and the formation of the heat affected zone which makes it susceptible to intergranular corrosion [18,19]. As a control measure to the problem of sensitization, various low carbon grades of austenitic stainless steel such as 304L, 316L and stabilized grades of stainless
steel have been developed [19–21]. Welding of stabilized grades of stainless steel should be followed by appropriate post-weld heat treatment failing which corrosion issues like ‘stress corrosion cracking’. Moreover, the choice of the filler material plays a major role as it determines the ageing behavior of the austenitic stainless steels [22]. The present study gives a practical illustration of the various corrosion issues that can possibly emerge in welded austenitic stainless steel grade AISI 321 when in service in presence of chloride environment and explains the root cause behind each of the failures and the precautionary measures required.

2. Background of the failure

The present study investigated the failure of a number of welded stainless steel AISI 321 pipes used for transportation of hot thermic fluid (~400 °C) from the parabolic heat collectors to the heat exchangers in solar thermal power plants as shown in the schematic given in Fig. 1. The pipes were seam welded using either laser beam welding (LBW) or metal inert gas welding (MIG), together with spot welds at several locations. Fig. 2 shows the schematic of the pipes indicating the location of welds. The failure of the pipes had led to the leakage of hot thermic fluid while in service. The cause of such a failure should be understood in order to control such instances in future. Hence the aim of the present investigation is to understand the root cause failure and emphasize the precautionary measures required to be taken to avoid such failures in future.
دریافت فوری متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات