root. The structures in which such joints are used are often subjected to fatigue loading. This may result in the initiation of fatigue cracks at the LOP tip as well as from the toe region which depends on the LOP size, fillet geometry, leg length and the cyclic stress applied. This investigation has been carried out to study the influence of cryogenic treatment on the fatigue life of cruciform joints failing from root LOP.

Cryogenics is the treatment of materials at extremely low temperatures. For ferritic steels, sub-zero treatment at temperatures of approximately −80 °C transforms retained austenite left by the heat treatment process to martensite [5] enhances the material properties.

Cryogenic processing uses temperatures around −185 °C because this is a temperature easily obtainable with liquid nitrogen. Liquid nitrogen is a relatively inexpensive means of cooling. There is some evidence to indicate that some of the desirable changes are happening very near this temperature, because these changes do not happen when higher temperatures are used. There is also some evidence to indicate that some of the changes happen as the component is within certain temperature ranges on the way down to low temperature and some on the way back to room temperature. This makes the ramp up and ramp down parts of the cryogenic process important.

2. Experimental

2.1. Sample preparation

Load-carrying cruciform joints with LOP were prepared using 6-mm thickness AISI 304L austenitic stainless steel cold rolled plate. The initial joint configuration in the case of the cruciform joint was obtained by securing the long plates (300×100 mm^2) and stem plate (300×50 mm^2) in a cruciform position by tack welding in a fixture. Subsequently, fillets were made between the long plate and stem plate using semiautomatic gas metal-arc welding process, argon shielding gas and 308L electrode. Great care was taken to obtain the best possible joint alignment. After welding, the fatigue samples were cut into required sizes (20 mm) using power saw. The cut samples were again machined for better surface finishing. The dimensions of the cruciform joint (see Fig. 1) as follows: $2a$ (LOP size) = 4 mm, $2w$ = 14 mm, L = 4 mm, t_p = 6 mm and $\theta = 60^\circ$ (convex fillet). Welds were tested by X-ray radiography for their soundness.

2.2. Cryogenic process

Cryogenic treatments were given to half of the specimens prepared. Cryogenic processing must be done correctly in order for it to be successful. The basic steps in a cryogenic process are as follows:

1. Ramp down: The ramp down in temperature to −185 °C is an important part of the process. Too quick a ramp down can induce residual stresses. Typical ramp-down times are in the 4 to 10 h range.
2. Hold: This is part of the treatment in which the micro-structural changes are realized. Once down to −185 °C, the material is soaked at this temperature for 20–30 h. This depends on the volume of the part.
3. Ramp up: The typical ramp up times can be anywhere from ten to twenty hours. The chamber is then warmed to + 150 °C to temper the primary martensite, after which it is returned slowly back to room temperature.

The equipment used is also important. Different manufacturers use different means of cooling. Some spray liquid nitrogen into the chamber. Others introduce it into a false floor and hope the cold goes up to the parts. It is our opinion that the best machines use a heat exchanger to assure that liquid nitrogen does not hit warm parts.