METALLURGICAL INVESTIGATION OF AN EXPLOSION BONDED PLATE THAT CRACKED DURING FORMING FOR NOZZLES FOR AUTOCLAVES

1. Background
Moody International South Africa and Moody International China are jointly involved with inspection of new autoclaves destined for the mining industry in Southern Africa. Problems were encountered in the fabrication process with rolled nozzles.

2. Introduction
Nozzles manufactured from explosion bonded normalized carbon steel plate cracked after final forming and welding of the components. The carbon steel was a Chinese equivalent to ASTM A516 GRADE 70. The carbon steel nozzles were internally clad with INCONEL Alloy C-276 through explosion bonding. The surface of the steel had been damaged in certain areas during the explosion bonding process and the damaged areas were repaired with welding as shown in Figure 1. A metallurgical failure investigation was done to determine the cause of the failures.

3. Experimental
The surfaces of the welded areas (including cross sections) were studied microscopically as were the flame cut surfaces. The following was determined:

The base plate consisted of normalized ferrite/pearlite microstructure (Figure 2) and had high toughness values as would be expected from normalized material. In the heat affected zone of the welded areas, the material had formed hard, brittle microstructures that were susceptible to cracking (Figure 3). Cracks had already initiated in some of these areas and propagated into the parent metal. The cracks were fine hydrogen embrittlement cracks and would be very difficult to detect with any NDT method. The hardness values of the material increased from ±180HV30 in the parent metal to ±420HV30 in the heat affected zones.

In the flame cut areas the material had formed a hard, brittle martensitic microstructure that was very susceptible to cracking. These areas had already cracked and the cracks had the typical morphology of hydrogen cracks (Figure 4). The hardness values of the material increased from ±180HV30 in the parent metal to ±440HV30 in the heat affected zones. Although the toughness of the material in the heat affected zones could not be determined, the microstructures indicated that the toughness values in these areas would be much lower than in the parent metal.

4. Discussion
The investigation showed that the material was highly hardenable and exposure to the wrong heat treatment before and after welding had caused the formation of hard microstructures which were susceptible to cracking. During the bending of the material, cracks had initiated in the hard, brittle zones and in some instances had also propagated into the parent metal.

5. Recommendation
The hydrogen cracks must be removed. Fluorescent MPI is required after removal to ensure complete removal. The non -conforming welds must be removed to ensure no cracking during operation. These areas must be cleared by macro-etching to ensure all welds are removed.

Figure 1. Visual appearance of the explosion bonded plate that shows the weld repair on the top of the plate.

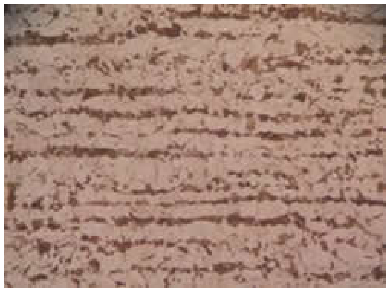

Figure 2. Micrograph of a cross section of the parent metal of the plate below the welded area.

Figure 3. Micrograph of the heat affected zone of one of the welded areas.

Figure 4. Micrograph of the hydrogen crack.