Indian J. Fert., Vol. 9 (8), pp.78-82 (5pages)

Repairing and Extending the Cycles of HP Vessels by SMAW in Urea Plant

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Urea synthesis section requires quite a significant number of HP vessels (reactor, stripper, condenser and scrubber). Operating temperature is about 200°C and operating pressure about 20.0 ~200 kg/Km². Structural shell that is made of carbon steel is protected from being exposed to highly corrosive media by lining or cladding it with 316LUG (1.4435) or 25-22-2 (1.4466).

Perlitic steels that are used for structural shells are very sensitive to corrosive environment of the synthesis section. In case the leakage through the protective lining or cladding is discovered too late, the structural shell might be significantly damaged by corrosion (up to 50% of total wall thickness).

Such measures as heat treatment of perlitic steels before, during and after the welding are required in order to repair corroded areas using conventional welding technologies. Conditions at most urea plants are not suitable for such repair jobs that makes the restoration of HP vessel on site very difficult or almost impossible.

That's why NIIK developed a method to repair corrosive and erosive damages. It has been applied to renovate vessel shells made of perlitic steels by overlay welding using welding materials of high austenitic grade. This method does not require heat treatment before, after or during the welding. The paper highlights the results of research work done during the development of methodology and demonstrates the examples equipment repaired on site.

In 1981,specialists of NIIK which at that time was a state urea specialized company in USSR, were appointed to repair a synthesis reactor shell damaged by corrosion (50% wall thickness depth and 1000 cm² damage area). The shell was made of pearlitic steel (grade 30Mn5, chemical composition, %: C-0.3; Mn-1.45; Si-0.3; S-0.02; P-0.03). Application of standard shell recovery method with electrodes of the same grade with shell material required preheating and additional heating as well as post welding heat treatment. It was complicated to execute heat treatment because of closeness of the damage to a reactor concrete support.

Finally, an experimental repair method of carbon steel structural shell damaged by corrosion using SMAW welding with high austenitic electrodes was applied. Previously this method had been successfully used in power industry.

After repair, inspection of NIIK specialists didn't detect any deterioration of the reactor shell that had been in operation for about 30 years. In 2009 a technical diagnosis of shell was carried out during a planned relining of the reactor, no damage were uncovered in the repair area **(Figure 1)**.

Based on positive experience, it is decided to standardize and legalize repair welding procedure of carbon steel structural shell damaged by corrosion using SMAW welding with high austenitic electrodes without preheating, additional heating and post welding heat treatment at national level.

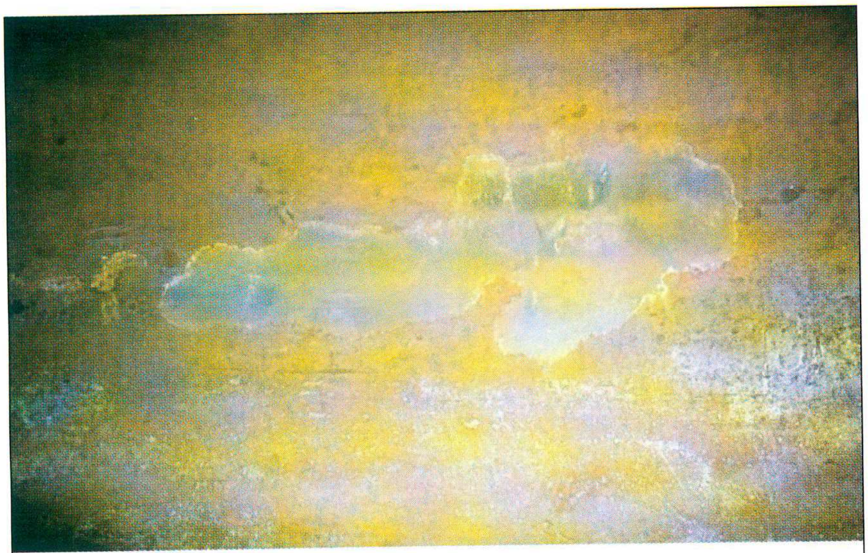


Figure 1 – Repaired damage of urea reactor shell after 28 years of operation

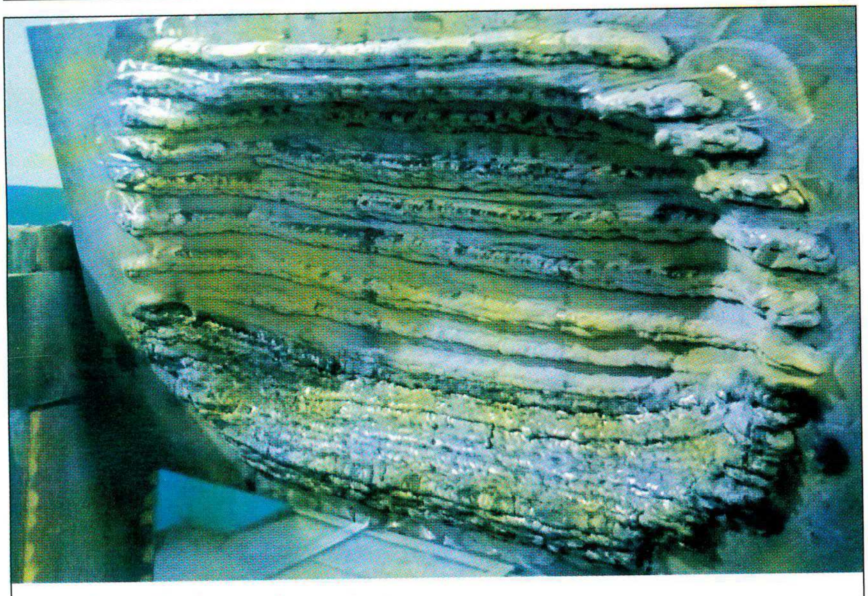


Figure 2 – Check sample overlaying

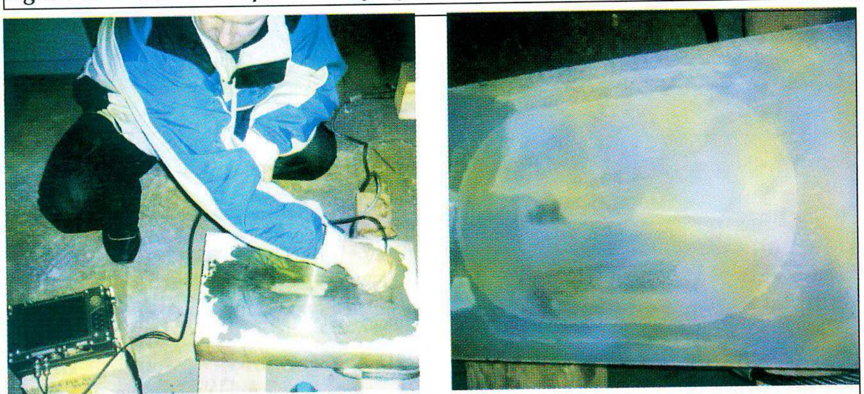


Figure 3 – Non-destructive testing (NDT) – ultrasonic inspection

Main features of the method are:

Damaged area is welded in 2 stages:

1. Grinded surface of the damaged area is faced by SMAW by electrodes with high nickel content (nickel content in overlay up to 60%) to inhibit the formation of diffusional layer. Facing follows a certain procedure to create a self-annealing effect in base metal adjacent to the welding seam during the process of welding thus improving material's ductility and increasing its crack resistance properties, at the same time facing on the grinded surface decreases residual welding stress by 50% for repair welding.

2. The rest of the damaged area that remains unfilled by the facing is filled by multilayer overlay SMAW by electrodes with moderate nickel content (around 40% in base metal) that assures high seam quality in all dimensions due to better welding properties of such electrodes compared to the ones with high nickel content.

Pilot lot of forgings (steel 30G2, analog 30Mn5, chemical composition, %: C-0.31; Mn-1.58; Si-0.34; S-0.033; P-0.028) was manufactured for repair welding procedure development and required tests. Check samples with openings imitating shell damage were made of same forgings. **(Figure 4)**

A number of tests of heat affected zones were carried out after check sample over laying from base metal and overlay side and deposited weld metal **(Figure 2)**.

♦ **Non-destructive testing (NDT):** visual inspection, liquid penetrant (dye penetrant inspection), ultrasonic, radio-graphic **(Figure 3)**;

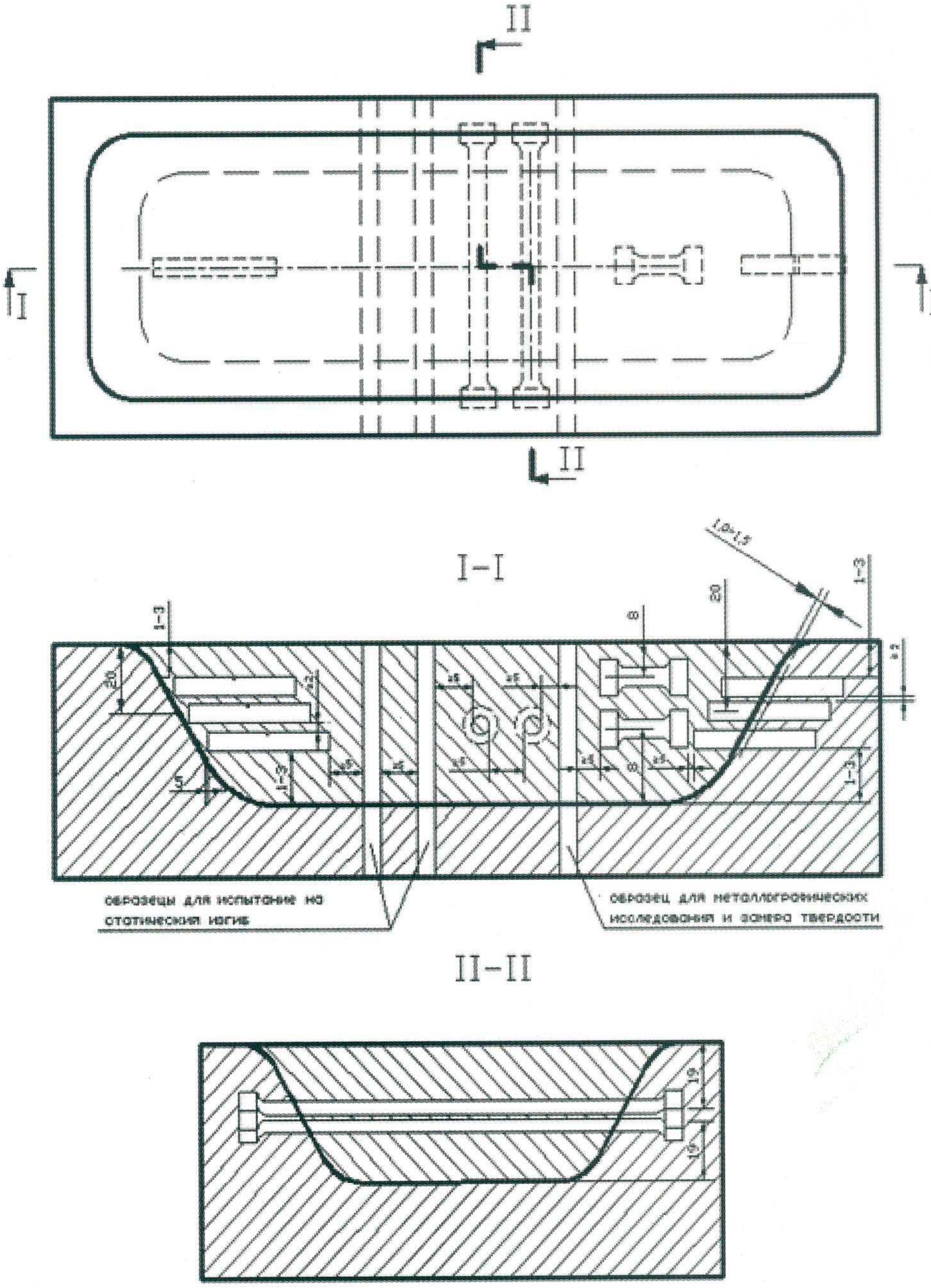


Figure 4 – Check sample. Cut up sketch for mechanical tests

♦ **Destructive test:** Static tension test of overlay metal and heat affected zone, slow bend test, impact bending test of overlay metal and heat affected zones, metallography and hardness measurement test of base metal, overlay metal and heat affected zones, low cycle fatigue strength test **(Figure 4)**.

Main Test Results

♦ Based on results of non-destructive tests no damages were observed in overlaid check sample;

♦ Mechanical tests of overlay metal and heat affected zones showed no decrease of mechanical properties compared to original ones;

♦ Metallography and hardness tests of base metal, overlay metal and heat affected zones showed no critical hardness change and no hard brittle layers in contact zone **(Figure 5)**.

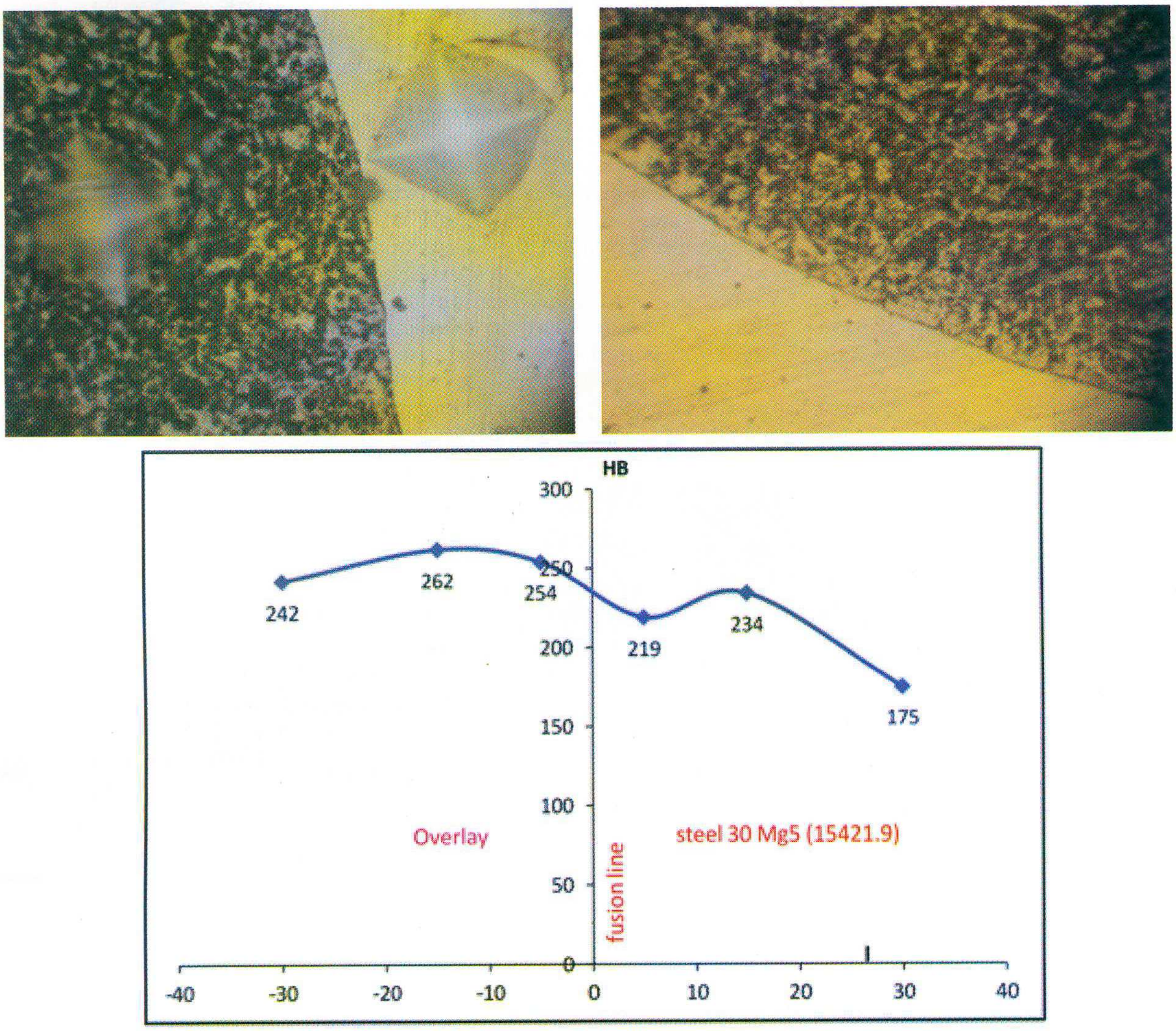
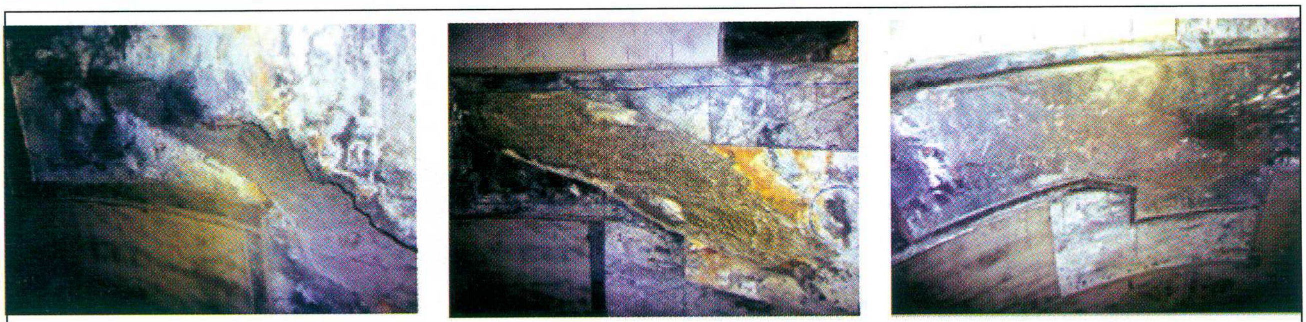


Figure 5 – Fusion line and heat affected zone, scaling x500 Hardness measurement diagram



a) depth of single-layer reactor wall damage is up to 30mm (32%)

b) damage after welding

c) damage after grinding flat with shell surface

Figure 6 – Repair of Snamprogetti reactor shell, capacity 1500 MTPD

♦ Fatigue tests carried out at 200±5°C, which similar to operation temperature of process media. Samples were subjected to continuous stressing to destruction with 14 Hz frequency and 0.2 stress ratio. The following results were obtained: with stressing equal to 180 MPa (which similar to wall stress of equipment, appearing while in operation) the samples bore more than 2000×10^3 of cycles. With increasing of stress up to 500 MPa the samples bore about 40×10^3 of cycles fracture point at base metal. Cyclicity under actual operating conditions is less than 1×10^3 of cycles, i.e. there is a safety margin of fatigue strength.

Obtained test results proved that NIIK method can be used to repair carbon steel structural shell of equipment damaged by corrosion in urea plants. Without preheating, additional heating and post welding heat treatment execution period and ultimate cost of repair can be reduced considerably.

Recently, the method has been successfully used for a repair of 5 reactors with damage depth ranging from 20 mm to 50 mm.

Typical example of repaired damage is presented in **Figure 6**.

High pressure equipment renovated using this method operates stably at present. ■

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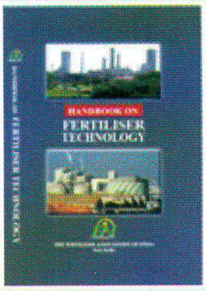

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