Case study 011
Turbine runner weld repair

1 Project background

Chen Welding Integrity Services (CWI) has recently completed a turbine runner for the Ramu 1 hydropower plant that owned by the PNG Power Limited (PPL). The turbine repair was sponsored by the Australia Government via the Economic and Social Infrastructure Program (ESIP). The turbine repair contract was awarded to AG Investment Limited (AGI), a PNG based energy contractor. CWI was contracted by AGI to provide welding engineering support to repair the runner.

2 Problem statement

The repaired runner was from the Unit 4 turbine of the Ramu 1 hydropower plant where it was commissioned in 1983 and constructed from grade GX4CrNi13-4 (equivalent to A/SA-487-CA6NM Class A) martensitic stainless steel. The runner suffered cavitation damage at the shroud and blades. The cavitation was especially severe at the leading edge of the shroud and blade, where severe metal loss occurred on blades and a large volume of cavitation on the shroud with the pit depth ranged between 19mm and 25mm.

If under continuous operation, the cavitation on the leading edge of blades would potentially result to brokage of runner blades and the deep pit of cavitation on shroud would result to through wall pin hole on the shroud. In this context, the weld repair was focused on restoring the thickness of the cavitated areas on the leading edge of blades and shroud.

3 Challenges

The runner weld repair conducted at the power station entailed to the challenges resulted from the issues of material, weldability, distortion, location and limited facilities.

Material challenges:

- The first material challenge was to avoid cold cracking as the runner material is highly susceptible to cold cracking on the weld metal and heat affected zone.
- The second material challenge was to avoid the detrimental effects to the corrosion resistance and mechanical properties due to surface oxidation and grain coarsening.

Distortion control challenges:

- The distortion challenge was to avoid significant change of runner geometry under the heating and colling cycles developed from welding process.

Facility challenges:

- The facility challenge was due to lack of bend test facility and service in PNG which also lead to compliance issue to the weld overlay welding procedure qualified to ASME Section IX.

4 Solutions

4.1 Overall solution

In the context of solving the challenges for the runner weld repair, a qualified and experienced welding engineer and four specialist welders were deployed to perform the welding repair. The welding engineer deployed is experienced in dealing with various types of exotic materials and certified as international welding engineer. The welders deployed are experienced and skilful in welding high safety and integrity critical facility for oil and gas industry. Deploying the right resources was the first approach taken by AGI to ensure success of the weld repair.

Furthermore, in view of the damage condition, restriction of accessibility and confirming the welding techniques to be applied, AGI also initiated the development of a site and condition specific welding procedure specification (WPS) for this weld repair. With respect to this, the welding engineer of CWI designed a preliminary weld overlay WPS prior to mobilisation to Ramu 1. The welding parameters and techniques were then tested via procedure qualification test at the power station in accordance with the requirements of ASME Section IX. The welding parameters and techniques were finalised and given in the WPS for weld repair reference.

4.2 Solutions to material challenges:

In the context of avoiding the possibility of cold cracking, high preheat, low heat input and multi-pass welding techniques were adopted.

The preheat temperature and welding parameters were developed and tested via welding procedure qualification test. High preheat technique was adopted by preheating the area to be repaired to 100ºc, in order to induce slow cooling after welding and to avoid quenching effect that will result to transformation to excessive hard microstructure. Preheat was also adopted to remove the source of hydrogen to remove the primary factor of cold cracking. The preheat temperature was maintained at above 100ºc until the completion of welding for a repair area and interruption (e.g lunch break) that will cause the preheat temperature drops below 100ºc was avoided. This method was applied to avoid start of transformation to hard microstructure during the welding repair process.

The second measure taken to avoid cold cracking was by applying low heat inputs, multi-pass and narrow weld beads techniques. The heat input was controlled at between 0.60 and 0.80kJ/mm by depositing narrow and stringer weld beads. The cavitated areas were filled by multi-pass and multi-layer small weld beads. The multi-pass and multi-layer welding technique also brings beneficial effects of grain refinement and temper to the weld metal and heat affected zone. Hence, reduce the possibility of forming excessive hard microstructure which is another contributing factor for cold cracking. The welding parameters and heat inputs were constantly monitored using digital clamp meter by the welding engineer of CWI to ensure weld beads were deposited based on the qualified heat inputs.

Control of interpass temperature was taken to avoid excessive surface oxidation and grain coarsening. The interpass temperature was controlled at maximum 200ºc to avoid excessive surface oxidation and grain coarsening effect. In the condition when the material surface is over oxidised, the corrosion resistance film on the surface will be damaged and the corrosion resistance will be unrestorable. Control of interpass temperature was also adopted to avoid the material expose to high interpass temperature for a prolong period. If this condition is happened, the grains of the material will be coarsened and resulting reduction of toughness. In order to ensure welding is not performed at the interpass temperature higher than 200ºc, the interpass temperature was constantly monitored by a welder helper.

4.3 Solutions to distortion challenges:

The low heat input narrow weld bead technique adopted for solving the material challenges is also a method uses to reduce distortion. This is because low heat input produces lower tensile residual stress and narrow weld bead produces lower shrinkage stress during solidification weld metal. Hence, distortion will be reduced when these two stresses are reduced.

The second approach applied to control distortion was to minimise the thermal gradient between the repair area and surrounding areas as low thermal gradient create less thermal stress during cooling. This approach was executed by preheating the weld metal and the surrounding areas (within two blades, shroud and hub areas) to the preheat temperature and maintain the temperature throughout the welding repair process. During cooling the areas adjacent to the repair area were also heated up to introduce an even temperature distribution over the repaired weldment and the surrounding areas to reduce thermal gradient during cooling.

4.4 Solutions to facility challenges

Due to unavailability of bending test service in PNG, the bend test as specified in the ASME Section IX for welding procedure qualification could not be conducted. Bend test is required to be conducted to examine the fusion quality between the base metal and weld metal.

In order to ensure the fusion quality of the weld metal of the procedure qualification test specimen and fulfil the purpose of fusion examination specified in the ASME Section IX, the welding engineer of CWI adopt ultrasonic test to examine the fusion quality between weld metal and base metal. The ability of examining the quality of the fusion boundary of ultrasonic test method allows the fusion quality to be verified at the power plant. The knowledge of examination techniques and purpose of tests of the welding engineer was the main contributor to solve the facility challenge and avoiding negative impact to the work schedule.

5 Weld repair process and quality control

Prior to start of the weld repair activity, preliminary activities including damage condition and site assessment and method statement development were conducted.

The preliminary damage condition and site visit was conducted for the purpose to understand the condition of damage and the repair viability so that a specific welding repair procedure and method statement for controlling the welding repair activities and welding quality can be developed. The flow chart given in the Figure 1 elaborates the weld repair process and was developed based on the site assessment observations.

The weld repair process from removing cavitated areas until the final grinding of excess weld metal to regain the geometry of the repaired area are illustrated in the Figure 2. The control measures applied to solve the material and distortion challenges are illustrated in the Figure 3.

Flow chart of weld overlay repair of turbine runner

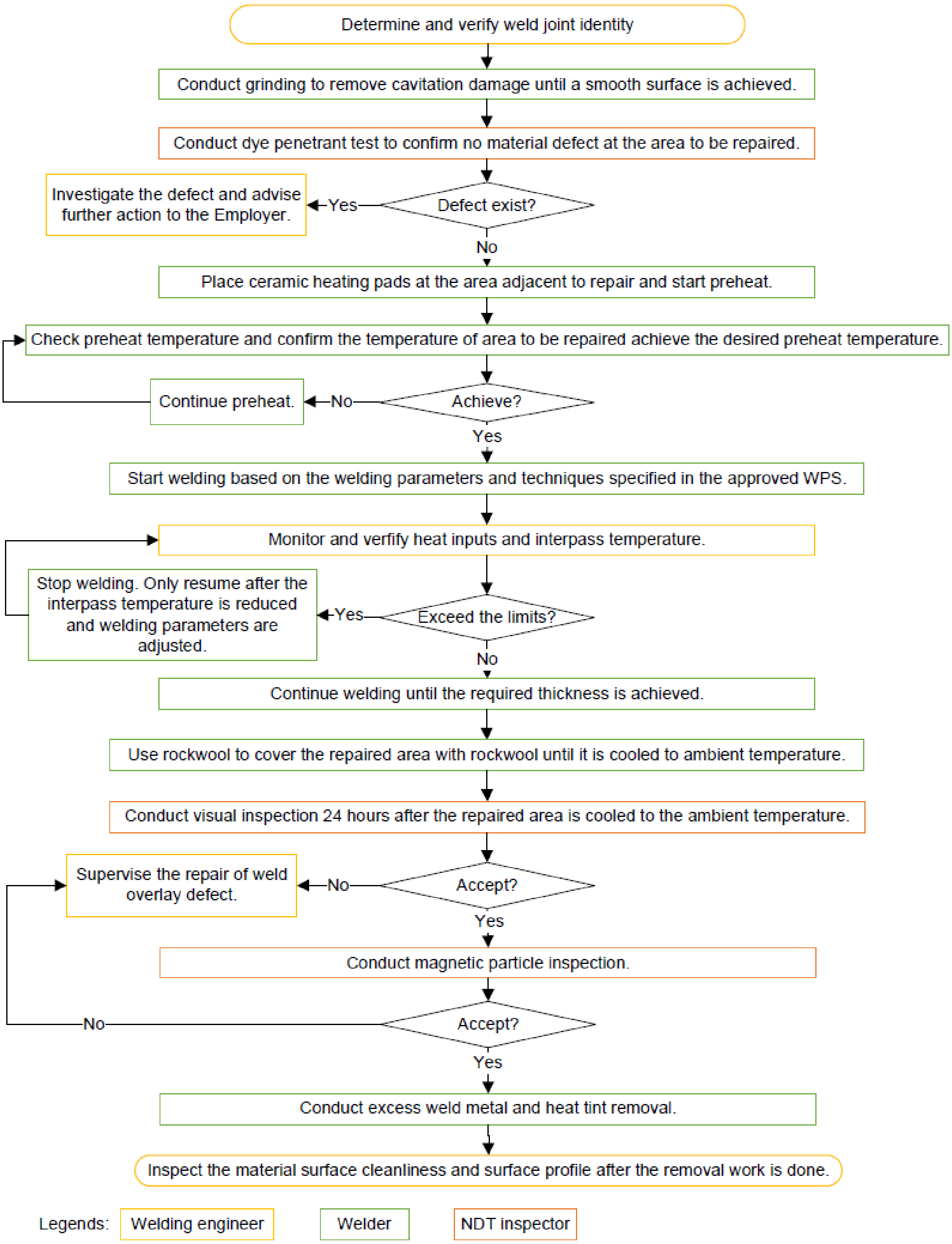

Figure 1 Weld overlay repair flow chart

Legends: 1 – Cavitation damage; 2 – Ground cavitation; 3 – Completely repaired cavitation; 4 – Ground surface after excess weld metal removal.

Figure 2 Overview of the outcomes of weld overlay repair process

Weld overlay repair process and quality control

Legends: 1 – Preheating; 2 – Welding; 3 – Welding parameter monitoring; 4 – Interpass temperature monitoring' 5 – Slow cooling of weldment; 6 – Magnetic particle inspection.

Figure 3 Weld overlay repair process and quality control