Hardfacing Alloys

Cracking and Disbonding in Steam Valves

A Guide for AEGIS Members

P91 Evolution

The steam leaving the superheater of a modern large capacity boiler is approximately 1,050 °F to 1,126 °F and at operating pressures ranging from 2,400 PSI to 3,850 PSI. These operating conditions require the materials to have very high strength properties, not to deteriorate with time, and to be creep resistant.

SA 335 P22 was a widely used material for high-energy piping; however, the creep behavior at higher temperatures led to the advent of SA 335 P91, which is a ferritic alloy steel that meets these conditions. The material has been successfully used in power plants for the last two decades. It is also called 9Cr1Mo steel, based on its composition.

Grade 91 material exhibits high strength to temperatures approaching 1,140 °F, when compared to its predecessor, Grade 22. The Grade 91 material has tensile strength over 30% higher than Grade P22, allowing the use of components with less wall thickness such as tubes, headers, steam piping and valves. Grade 91 also has an increased thermal fatigue life allowing for elevated operating temperatures with corresponding efficiency gains. These properties make Grade 91 ideally suitable for power plants such as combined cycle facilities that operate on a cyclical basis.

Hardfacing

Hardfacing is a process where harder or tougher material is applied to base surfaces to provide wear resistance to components such as boiler tubes and valves.

Hardfacing is directly weld-applied to the base material of a valve body or disc and then machined to a smooth finish. In power generating facilities, hardfaced gate valves are typically used for isolating steam lines between the HRSG/boiler and turbine. Stellite, a common hardfacing material, has been successfully weld-applied to Grade 22 (2.25% chrome) and Grade 11 (1.25% chrome) valve components for more than 25 years.

Stellite Hardfacing to Grade 91

Many newer facilities are now designed to use Grade 91 (9% chrome) valve materials, due to higher operating pressures and temperatures in power plant operations.

The valve industry has responded to the demand for Grade 91 materials and provided similar valve designs using the same hardfacing materials and application methods that have been proven for years in lower alloy steel materials. Based on industry experience and EPRI studies, it is now apparent that these methods are inadequate for Grade 91 valve bodies and Stellite hardfacing.

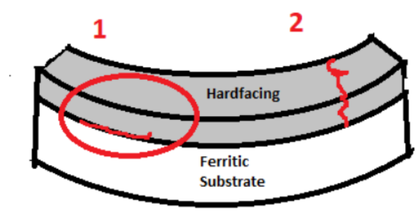
Stellite delamination was first publicly discussed at the 2009 7F Users Group Conference, where the liberated material from a 20-inch HRH block valve was displayed. General Electric made the industry aware of Stellite liberation earlier that year when they issued TIL 1629 (*Combined Stop and Control Valve Seat Stellite Liberation*) advising steam-turbine owners to check the condition of the Stellite inlay sections used in fabricating seats for the OEM's combined stop and control valves.

Revision 1 of TIL 1629, published at the end of 2011, recommended a "one-time seat Stellite inlay UT inspection during valve installation or the next planned maintenance inspection" to identify any lack of bonding between the inlay and base metal on units with fewer than 50 starts.

Disbonding of Stellite hardfacing in power plants has occurred primarily in parallel-slide gate valves and non-return globe valves. Hardfacing material has been liberated from valve seats, guide rails and discs. Tight shutoff of valves have been compromised in some cases.

The issue with applying Stellite directly to Grade 91 material lies in the intermixing of the materials during welding, which forms a brittle layer of diluted cobalt and iron. Various studies show cracks tend to form initially during welding, during stress-relieving activities, or after installation while experiencing thermal cycling from the steam process.

Types of Disbonding



Type 1 Disbonding between Substrate and Hardfacing

Type 2 Transverse (Through Hardfacing) cracking

Over time, cracks in the dilution layer propagate to create disbonded pieces of hardfacing that completely delaminate from the body of the valve or disc resulting in a valve that no longer isolates and allows loose material to flow downstream at high velocities and damage other equipment, including the steam turbine.

There are two common types of disbonding:

1. Cracking at the interface between the Grade 91 material and the hardface coating
2. Cracking of the hardface coating itself

Multiple cases of disbonded hardfacing of Grade 91 materials in valves have occurred throughout the power industry. For the majority of the reported disbonded hardfacing incidents, the Stellite material traveled no further than the screens located upstream of the HP and IP turbine; however, in one notable recent case the Stellite advanced through the screens downstream of the HP isolation valve.

Detail regarding the disbonding mechanism can be found in the EPRI report *Experience in Valve Hardfacing and Disbonding* (EPRI product #3002004991). A detailed analysis for avoiding this issue can be found in *Proposed Solutions for Hardfacing Disbonding in High-Temperature Valves* (EPRI product #3002004992).

Recommendations

It is suggested that valves with Grade 91 bodies with Stellite hardfacing located in HP and HRH steam lines upstream of the turbine be replaced as soon as reasonably possible.

A new more reliable method of applying the hardfacing identified in recent years includes applying a welded, "butter layer" of Inconel between the valve base material and Stellite hardfacing. The Inconel reduces the dilution that occurs between the Grade 91 and Stellite and has excellent bonding strength with both materials.

Details on the "butter layer" process and manufacturing technique can be found in the 2015 EPRI report, *Guidelines and Specifications for High-Reliability Fossil Power Plants: Recommendations for the Application of Hardfacing Alloys for Elevated-Temperature Service* (EPRI product #3002004990).

While the Inconel "butter layer" can be applied in existing valves, it is a very expensive repair option due to specialized field machining/welding required to remove and reinstall valve seats. Challenges that exist with the field repairs include access to the welds and working in a confined area with elevated temperatures to meet preheat requirements. In the majority of cases, field valve seat replacement will require specialized machine tooling and robotic welding equipment to complete the task. Valve replacement is a suitable option to remove the risk of hardfacing disbanding, noting that early planning may be needed due to sourcing challenges.

For further information on the subject matter in this paper please contact:

Ian Cowen, Senior Machinery Engineer, Loss Control

AEGIS Insurance Services Inc.

1 Meadowlands Plaza

East Rutherford, NJ,07073

iancowen@aegislimited.com