Improving Oxidation Resistance Wear Properties of Valves Trays Used in Oil Distillation Towers

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Abstract. Valve trays play an important role in the refinery crude oil distillation process. Valve trays are covered by lift able caps. The lifting cap positions vapor to flow horizontally into the liquid which providing better vapor/liquid contact and better separation at each tray. Corrosion and wear resistance are the most important properties should be found in the valve trays and caps. This research deals with increasing corrosion and wear resistance of valve trays and caps using thermal spray technique. (Ni Al Cr) powder was used to apply coating layer on the substrate surface. Some mechanical properties are evaluated for the coating layer. Oxidation test was performed using oxidation system. Data and results revealed that the coating layer with the thickness of 100 µm has slightly resistance against oxidation, while the thickness of 200 µm has excellent oxidation resistance and good peeling resistance. Thickness of 300 µm has excellent oxidation resistance but has poor peeling resistance.

1 Introduction

Valve trays are popular due to their low cost and efficiency. The tray openings are fitted with movable valves. The vapor pressure controls the entrance area for the vapor and thus the movement of the valve. When vapor pressure is little, the valves are totally locked. Increasing the vapor pressure leads to a broad entry of the valves. Some types of these valves are provided with extra sheet to add more heaviness. The lightest valves unlock when loading is small, at higher loadings weighty valves unlock too and start to work. This feature grants variability at differing loadings [1].

There is another type of valves, the fixed ones, which is lastingly open, despite the fact that liftable valves are more flexible, but fixed ones have better withstanding for operations troubles and more resistant to fouling (polymer deposition), they are designed so they don't sticks or pops or affect by corrosion and erosion products that are usually accompanied the liftable ones. The liftable valve are more subjected to fouling specially in harsh circumstances where corrosion products and contaminants are common. The motion of the valves makes part of the valve contacts the cavity ends and causes erosion and corrosion [2].

Severe environments of the valves tray require applying a protective coating on their surface to prevent them from hot corrosion and erosion especially at high temperatures. thermal spraying is an interesting technique that is hired due to its wide diversity for different temperatures appliances. the thermal spraying processes are different according to the source of heat, the kinetic of the process and particle velocity [3]. They can be classified to:

- Flame thermal spraying using wire or powder.
- Plasma spraying.
- Electric arc wire spraying.
- Cold spraying.
- Detonation flame spraying.
High velocity oxyfuel (HVOF).

Flame thermal spraying uses a fuel gas (usually acetylene) with oxygen to create a flame that melts the coating material and develop a protective coating with excellent wear and corrosion properties. Flame temperature rises up to 3300 °C which makes it suitable for coating different materials [4].

2 Experimental work

The experimental work was implemented by using samples of 304 stainless steel. Dimensions of each sample were (20×20×1.5 mm). Atomic absorption spectrophotometer technique was used to analyze sample materials. The chemical compositions are given in Table 1.

Table 1: analysis of 304 stainless steel

| Fe | N% | Ni% | Cr% | Si% | S%   | P%   | Mg%  | C% |
|----|----|-----|-----|-----|------|------|------|----|
| Bal. | 0.1 | 9.5 | 18.7 | 0.75 | 0.03Max | 0.045Max | 2 | 0.081 |

2.1 Powder used:
Ni-Cr-Al powder was applied on sample by thermal spray process. The chemical composition of such sample is given in Table 2.

Table 2: analysis of coating powder

| Al% | Si% | Ca% | Cr% | Fe% | Ni% |
|-----|-----|-----|-----|-----|-----|
| 0.21 | 5.33 | 0.05 | 14.94 | 3.95 | 75.52 |

Figure 1: scanning electron microscope (SEM) image of coating powder
2.2 Coating conditions:
Unlike the conventional work which applies thermal spray process manually, Thermal spray coating in this research was performed by using oxy acetylene thermal spray gun fixed on table provided with ball screw and stepper motor in order to make Spray gun can move left and right with smooth movement. The work sample fixed in front of spray gun on flat table. Sample fixture provided by ball screw with stepper motor which make it able to move up and down. Distance between spray gun and sample surface was maintain at 100 mm, and powder feeder regulated on 10g / min. coating thickness of all samples are maintain to 200 micron. The apparatus of thermal spray gun is illustrated in figure 2

Figure 2: Thermal spray apparatus

System of thermal spray was provided by powder automatic feeder. Surface roughness of all sample is (N8) according to DIN standard. Samples after coating were polished using cloth polisher, degreased and cleaned by alcohol and dried. Each sample was subjected to ceramic fixture which located in oxidation test system. Such system consists of electric furnace provided with air cooling system in order to implement thermal cycle test for each sample. Thermo couple was fixed inside the furnace for temperatures control purposes, as shown in figure 3.

Figure 3: Oxidation test system
In the oxidation test each sample was exposure to thermal cyclic condition, three samples were exposure to three ranges of temperature (600, 700, and 800°C), each sample kept at required temperature for 3 hrs and then cooled at room temperature for 30 minute. Cycle of heating and cooling was repeated for each sample up to 30 times. Sample was weighted after each cycle of heating and cooling.

3 Results and discussion

The weight gain of all sample surface after coating in the presence of oxidation air atmosphere at temperatures of (600, 700, and 800°C) have been shown in figures (4,5 and 6) respectively.

![Figure 4](image1.png)

Figure 4: Relationship between weight gain and No. of cycles at 600°C.

![Figure 5](image2.png)

Figure 5: Relationship between weight gain and No. of cycle.

![Figure 6](image3.png)

Figure 6: Relationship between weight gain and No. of cycle at 800°C.
Hot corrosion behavior of all samples at three ranges of temperatures, approximately linear, and weight gain was very low in all ranges of temperatures. This may have related to the homogeneous and precision spraying due to the use of automatic stepper motor movement. Surfaces of samples exhibit homogeneous texture, and no cracks and porosity visible, so hot corrosion does not occur beneath the coating as shown in figure 7.

![Figure 7: Samples after thermal cyclic tests a) at 600°C b) at 700°C c) at 800°C](image)

Resistance of coating layer against peeling was evaluated using samples with dimensions (50×20×1mm). Peeling test was performed by using bending fixture to bend sample with angle 180°. All samples exhibit excellent peeling resistance, as shown in figure 8.

![Figure 8: Samples after 180° bending](image)

4 Discussion

Thermal spray coating of 304 stainless steel was investigated in this research. Automatic spray with precision movement of spray gun and sample (X-Y movement) give homogeneous coating for all sample surface, no cracks and no visible porosity on the surface of all samples after thermal oxidation test have been given Coating layer excellent hot corrosion resistance at ranges of testing temperatures (600, 700, and 800 °C). The results of this study were applied by thermal spray coating with coating layer thickness 200 micron on some valve trays used in oil distillation tower, manufactured in state company for steel industries which exhibit excellent corrosion resistance at a temperature ranges of distillation process. figure 9 gives some valve tray after coating.
Figure 9: Some thermal sprayed valve tray used in distillation tower.

References
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