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An Investigation of Failure Reasons Of Relief Valves of LPG Gastanks

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ABSTRACT

Relife valve is critical part of an apparatus which has great importance to ensure security of life and property of those related. Using this part is necessary for systems which have the possibility of rising of internal pressure. One of these systems is gas tanks which can act as a mobile bomb and have explosion possibility when the relife valve operates improperly. In this study, failure reasons of a relife valve of a portable LPG gas cylinder have been investigated. For this, chemical analysis, metallography, mechanical properties and especially fractography experiments were carried out on the failed sample. Surface quality of the samples were also examined using stereo and scanning electron microscopies. Results showed occurrence of fatigue failure. The main factor contributing to this phenomenon was identified as reduction of surface quality due to pitting and improper machining.

KEYWORDS:

Safety Valve, Tank, Fracture, Fatigue, Quality of Surface.

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1- Introduction

Safety valve, a vital part in gas containers such as LPG or propane, is used to release excessive pressure when the container is overfilled or heated up. This research is focused on parameters responsible for the fracture of one of these safety valves [1]. Figure 1 shows the broken safety valve.

Figure 1. Fracture location in valve

Some factors causing failure of this safety valve could be pitting corrosion, poor surface condition, hydrogen embrittlement, as well as fatigue fracture. Besides factors mentioned above, fracture of a part might be took place in various aspects, one of which is fatigue fracture. This type of fracture covers 90 percent of fractures in parts. The fatigue fracture which is due to cyclic or alternative loadings has three steps in general, initiation of crack, propagation of crack, and final fracture [7,8]. In the pitting corrosion, initiation of fatigue corrosion is controlled by the speed of crack initiation and the growth of pits to a critical depth from the surface [7]. After initiation of cavities on discontinuities such as grain boundaries, dislocations, particle boundaries, and particles accumulation, cavities are growing, accumulating. Therefore, a continuous fracture surface is produced and a sudden fracture ensues. Size and number of these cavities are in accordance with the number and distribution of initiations sites [2,4].

2- Test Results

Samples are prepared from broken valve for chemical analysis, hardness and tensile tests, metallographic examinations, Fractography, as well as energy dispersive analysis.

The chemical composition revealed is compatible with stainless steel 304 (AISI).

Microstructure evaluation of polished surface of samples (before etch) reveals some amount of elongated gray sulfide particles in the longitudinal direction, a small quantity of nitride andoxide particles in golden yellow and black colors, respectively (Figure 2). Austenite grains with the size of ASTM 9.5 and some portion of transformed martensite produced by mechanical work were seen after etching samples by kalling solution (Figure 3). Fracture cross section of the failed valve was assessed by stereo and scanning electron microscopes (Figures 4-7). Thechemical analysis inside the crack (the crack is shown in Figure 7) was carried out by EDS analysis.

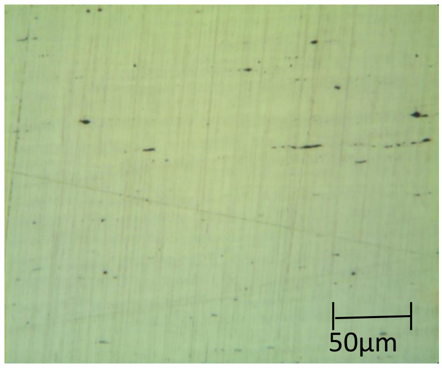

Figure 2. Microstructure after polishing

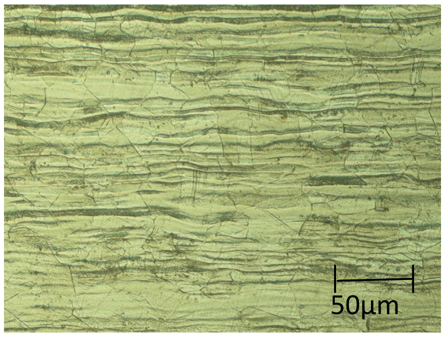

Figure 3. Microstructure after etching

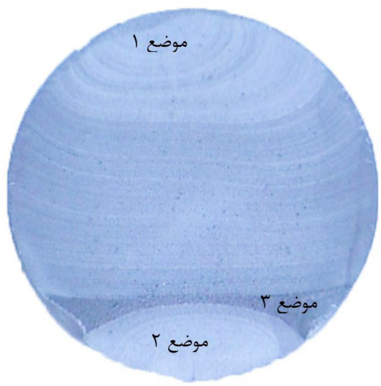

Figure 4. Stereomicroscope image of the fracture surface

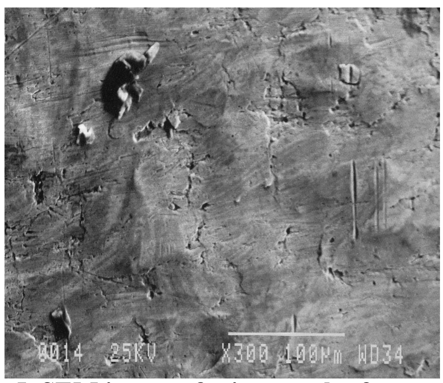

Figure 5. SEM image of microcracks & corrosion voids on surface

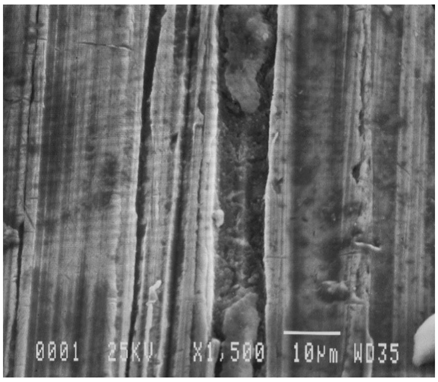

Figure 6. SEM image of coarse machining lines & cavities

Figure 7. SEM image of ratchet markon the fracture surface

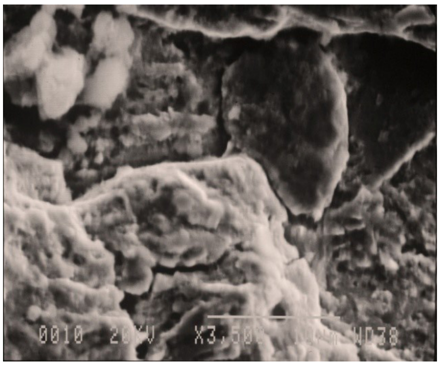

Figure 8. grain boundary cracks on fracture surface

3- Discussion

Inappropriate machining may causecoarse lines/ marks, roughness of surface, micro-cracks, and gouges on the valve surface. These imperfections on the surface are the main evidences which could prove sudden fracture is mainly because of lower fatigue resistance in valves. Furthermore, pits from the corrosion on the surface exacerbate this phenomenon, and finally the valve encounter with fatigue corrosion. Moreover, the presence of a great number of micro-cracks is a confirmation for tensile stresses on the surface. The origin of these stresses is in coarse machining or hydrogen embrittlement.

As it may be seemed in Figure 8, high content of carbon is seen at point A. This high amount of carbon is concluded from pitting corrosion products.

Martensite in the microstructure could be responsible for the appearance of hydrogen embrittlement. This assumption may be verified by the observation of micro-cracks on the surface (Figure 5) and in grain boundaries in the fracture surface (Figure 9).

4- Conclusion

Course marks from machining, especially gouges, and pits from corrosion and micro-cracks are factors which worsen surface conditions, increase surface tension and chance of hydrogen embrittlement. Therefore, simultaneous existence of these factors will cause initiation of fatigue cracks in two positions, and consequently the fatigue life of valve will be decreased.

Sulfide particles in the surface along with the roughness of the surface will increase the suitable sites for initiation of corrosion pits; therefore, reduce the fatigue life of the valve.

Removing martensite from microstructure could be done by annealing process on specimens. By this process the probability of hydrogen embrittlement will decrease or eliminate.

5- References

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