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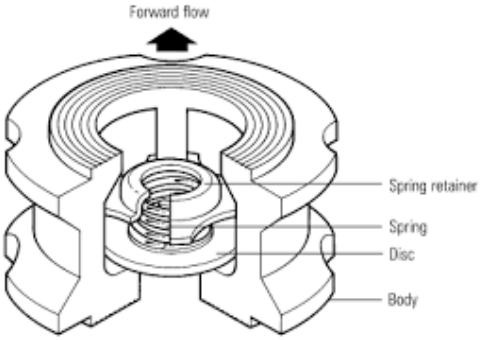
Failure Analysis Case Study

Failure Analysis of a Compressor Valve Disk due to Fatigue



Keywords: Compressor, Valve Disc, Fatigue

Material: Alloy Steel

Introduction

Two pairs of valve discs that failed, after an unknown period of service in an ammonia refrigeration compressor, were submitted for of failure analysis. The discs measured 5-11/16 inch outside diameter by 0.56 wide by 0.058 inch thick and were hardened to Rockwell C46/49. One pair was identified as "ARESCO (A)" while the second pair was marked "MIDWEST (M)". Visual examination, chemical, mechanical and metallographic analyses was performed on the submitted valve disc sections to look for root cause of the failure.

Visual Examination

All four of the discs were fractured. One of the ARESCO discs (designated "A") and one of the MIDWEST discs (designated "M") fractured in more than one place resulting in missing sections. Visual examination of all the exposed fracture surfaces revealed that the fractures were brittle in nature in that there was no evidence of plastic deformation in the material adjacent to the fractures. Moreover, all of the fracture surfaces were burnished indicating quite clearly that the fractures existed for a period of time during which rubbing of the surfaces took place.

Chemical Analysis

A chemical analysis conducted on the discs revealed the following results:

	ARESCO	MIDWEST
Carbon	0.52	0.33
Manganese	0.7	0.43
Phosphorus	0.01	0.005
Sulphur	0.02	0.014
Silicon	0.17	0.21
Chromium	0.87	0.98
Nickel	0.09	0.02
Molybdenum	0.02	0.17
Vanadium	0.18	0.01

The analyses showed that the 'ARESCO' disc was fabricated from a 6150 Alloy Steel while the MIDWEST' disc was fabricated from a 4130 Alloy Steel.

Mechanical Test

A hardness test conducted on the discs revealed the following results:

	ARESCO	MIDWEST	Required
Rockwell	C42	C49	C46/49

The ARESCO discs are below the specified range of C46/49.

Metallurgical Analysis

A metallurgical sample taken from an "A" disc was suitably prepared and examined. The structure found was tempered martensite which indicated that the disc was quenched and tempered. Presumably the tempering temperature used was too high resulting in the lower hardness. Figure 1 is a photomicrograph (500X) showing the observed microstructure. A sample containing fracture surface was cut from both "A" and "M" discs. The samples were

chosen from areas of fracture that where somewhat lees burnished in an attempt to find a fracture surface which was undamaged and thus determine failure mode using scanning electron microscopy (SEM). Figure 2 is a SEM micrograph taken at 100X showing a relatively undamaged fracture area on an "M" sample. The texture, suggestive of fatigue failure in that there are typical "beach marks" on the surface. Figure 3 is an SEM fractograph at higher magnification (800X) taken on an "M" sample. Here we see definite fatigue striations in paths of unburnished surface. In this fractograph the flat, featureless are smeared (burnished) surface and the horizontal striped areas are zones of fatigue striations. It should also be pointed out here that no evidence of intergranular and/or branched cracking was found on any of the fracture surfaces examined.

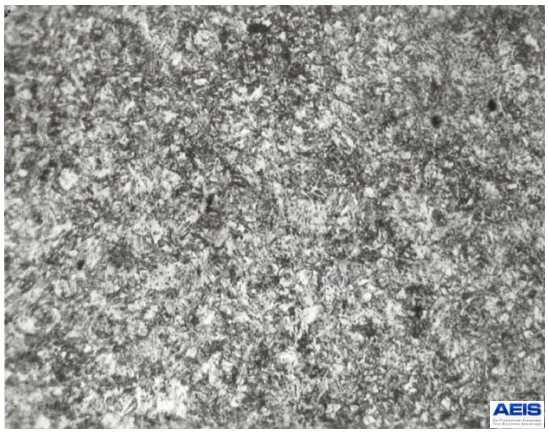


Fig 1 Microstructure of "ARESCO" disc shows a tempered Martensite structure X500

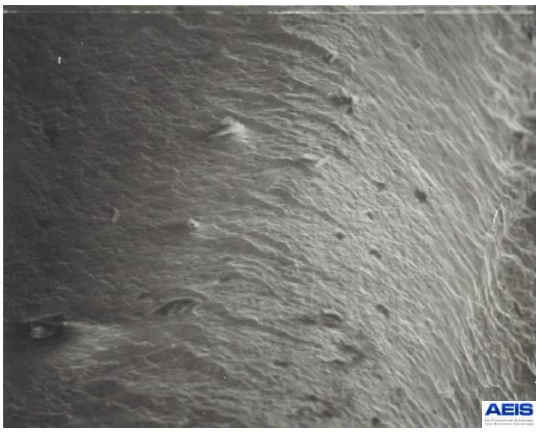


Fig 2 SEM of "MIDWEST" disc shows typical fatigue structure X100

Fig 3 SEM of "MIDWEST" disc shows typical fatigue structure X600

Conclusion

On the basis of the foregoing results it is concluded that failure of the discs took place progressively via the fatigue mechanism. Although the "A' discs were under specification with regard to hardness and would thus be more prone to fatigue failure, this is not considered

the main cause of failure since the "M" discs also failed by the same mechanism. The conditions of service must therefore be excessively severe for discs of this thickness and specified hardness. Inasmuch as we do not know the configuration of the discs in the system or the cyclic stress levels which they experience, it is not possible to make recommendations to reduce the frequency of these failures.