

Failure Analysis of a Pulsation Dampener Using Statistical Fractography

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ABSTRACT

A cold-worked carbon steel pulsation dampener in glycol service failed catastrophically necessitating investigation of the underlying causes. This paper describes the methodology followed to determine the most probable root causes of the failure. In addition to more traditional metallurgical investigation approaches, a new fractographic approach (referred to as statistical fractography) from which fracture mechanics parameters are extracted from the statistical analysis of the fracture roughness was used.

Statistical fractography provides the fracture properties of the failed material as well as the local mechanical conditions driving crack growth. It revealed here that failure had occurred in three stages: (1) an internal explosion or similar event resulting in shell buckling, overloading the deformed wall (2) initiation and slow crack propagation likely due to an environmentally assisted cracking mechanism and (3) ultimate failure through the rapid growth of a through-wall crack separating the dampener in two parts.

In addition to the fractographic investigations, an initial series of slow strain rate mechanical tests were conducted in glycol bearing environments to understand the susceptibility of the material constituting the dampener to environmentally assisted cracking and controlling parameters. Whilst not conclusive at this stage, a susceptibility to EAC has been evidenced from the failure strain coming to support the scenario inferred from the fractographic analysis of the failed dampener.

Key words: Stress corrosion cracking, statistical fractography, cold work, glycol, failure analysis

INTRODUCTION

A cold-worked carbon steel pulsation dampener located on a glycol circulation pump failed catastrophically in service. The two parts of the failed dampener were projected several tens of meters across the offshore facility. The failure was investigated initially using traditional metallurgical techniques, but this failed to reach a conclusive failure mechanism. Statistical fractography, the focus of this paper and newly developed technique of failure analysis that relies on the measurement from the statistical analysis of the fracture roughness of mechanical quantities like the material toughness and the local stress levels, was then employed. In this study, we show how this approach enables to identify and quantify the different steps that led to the failure of the part from which a most likely scenario of failure can be inferred.

BACKGROUND INFORMATION

The pulsation dampener had the following fabrication details:

- Design code : ASME VIII Division 1
- Material: ASTM A372 Grade E Class 70, cold worked, seamless construction
- Design pressure: 132 bar (hydrostatic test pressure 198 bar)
- Operating pressure at time of incident: 72bar with spikes to 105bar
- Operating temperature: Ambient, 25°C
- Corrosion allowance: 0mm
- Inventory: Lean tri-ethylene glycol (TEG) with approximately 10% water
- Bladder: FKM
- Charging medium: Nitrogen

The basic design of the dampener is shown in Figure 1, whilst the location where the dampener was located is shown in Figure 2. The site is situated offshore in the Gulf of Guinea. Figure 3 shows the retrieved fractured part.

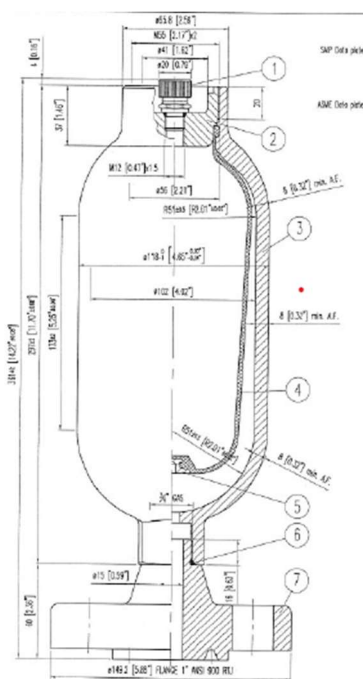


Figure 1: Dampener design



Figure 2: Location of dampener on site



Figure 3: Retrieved part of dampener showing high degree of deformation

The internal elastomeric (FKM) bladder was not retrieved from the site.

The plant design consists of 2 pumps set up in a N+1 configuration. At the time of the incident the pumps were being switched over, however no indications of abnormally high pressures were detected immediately prior to the incident. The dampener had been in use for close to 4000 hours at the time of incident.

The design premise of the dampener is for the nitrogen charged internal bladder to act as a cushion for pressure pulsations exerted by the pump, and to prevent these from being transmitted to the pipework system.

Review of the glycol stream sampling records highlighted the following points:

- The pH tended to be maintained in a high range and above the specified range. The average value was between pH 10 and 12, however there were periods of missing data. The increased pH is due to an over-doing of pH buffer (sodium bicarbonate).
- The glycol had a very low water content at the time of sampling with approximately 1% present. There were no historical records for water content available.
- The in-situ glycol had a high level of organic acids present likely due to oxygen entries to the system.

INITIAL METALLURGICAL INVESTIGATION FINDINGS

Findings from the metallurgical investigation are summarized as follows:

- No mechanical property anomalies against material certification were present.
- Chemical analysis was seen to meet specification.
- The microstructure was typical of a quenched and tempered low alloy steel and as expected for the given material grade. Refer Figure 4.
- There was no evidence of fatigue with an absence of striations and other typical features. See Figure 5.
- The hardness was seen to be higher on the highly deformed side (321 to 360 HV_{0.5}) as opposed to other lesser deformed side (321 to 339 HV_{0.5}). It is noted that the singular 360 HV_{0.5} value on the deformed side was located within 0.4mm of the outer edge (not exposed to internal fluids), whilst lower values (< 321 to 339 HV_{0.5}) were found closer to the inner edge. See Figure 6.

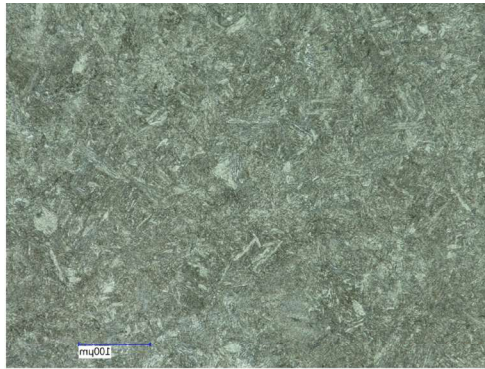


Figure 4: Microstructure of failed dampener.

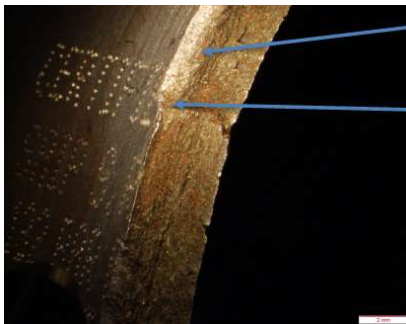


Figure 5: Suspected area of fatigue initiation at component marking area confirmed to be free of typical striations by SEM.

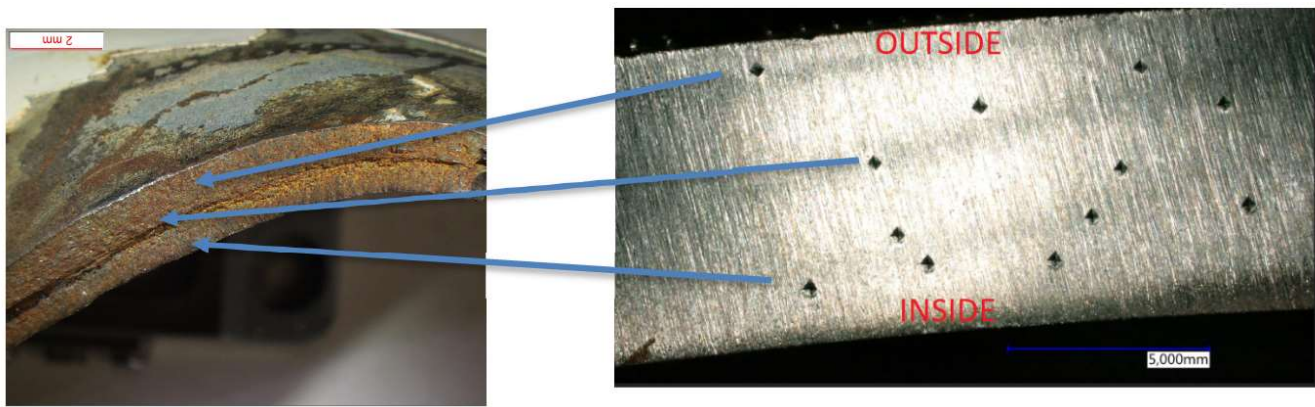


Figure 6: Representation of fracture surface and hardness indentations.

The fracture surface of the bulged region displayed two distinct regions running linearly along its length. In addition, there was some evidence of the failure proceeding in multiple stages by the presence of curved 'steps' on the inner facet. Refer Figure 6.



Figure 6: Fracture surface with stepped appearance and curved steps on inner facet

As seen in Figure 6, there was no evidence of thread stripping, suggesting that the dampener did in fact fracture then proceed to be propelled from its location.

There was evidence of very shallow pitting ($<0.5\text{mm}$) on the inner surface. However, this was not considered to have contributed to a direct loss of mechanical integrity. See Figure 7.