Engineering Failure Analysis 27 (2013) 141–149

Contents lists available at SciVerse ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Influence of the residual stresses induced by tool wear on the failure of brass electro-valves

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ARTICLE INFO

Article history:
Received 27 March 2012
Received in revised form 29 May 2012
Accepted 6 July 2012
Available online 15 September 2012

Keywords:
Brass electro-valves
Dezincification
Residual stresses
Roughness
Tool wear

ABSTRACT

Failure analysis was performed on different brass electro-valves body affected by unexpected phenomena of cracking. Through the application of optical and scanning electron microscopy, micro hardness Vickers test and X-ray diffraction, the causes of damage were identified. The study showed the dependence between roughness and residual stress associated to the tool wear. A solution to avoid the failure is finally proposed, based on the use combination of a tool with controlled wear and stress relieving heat treatment.

1. Introduction

Solenoid valves find application in several specific fields, such as little steam generator, steam iron and coffee machines. A solenoid valve, or electro-valve, is a combination of two essential parts, a solenoid (electromagnet) and a valve body with several ways (flow passages) for opening and closing a fluid path controlled by an electrical or electronic circuit.

Depending on the minimum pressure that has to be intercepted, equal or more than 0 MPa, the operative modalities are ruled by two different working principles: direct acting modality and servo-piloted modality. Direct acting means that the fluid passage is opened or closed by a sealing mounted directly on the magnetic plunger actuated by the coil. The minimum working pressure is 0 MPa and this parameter is directly connected to the orifice diameter and to the coil power. On the other hand, in servo-piloted configuration both pilot orifice and master orifice are present, the magnetic unit opens and closes only the pilot orifice, so the maximum and minimum working pressure does not depend on the coil power but from the sealing constructive features on the master orifice (piston, etc.). For this type of valve the minimum working pressure is fundamental and it is always different and greater than 0 MPa. Fig. 1 shows the sketch of solenoid valve models similar to the ones that have been damaged.

Valves body is made of brass (UNI EN 12165CW 617N, Table 1) and the magnetic part in contact with the fluid is made of stainless steel AISI 430 F.

Brass is one of the most widely used materials for taps and fittings in the piping and sanitary industry. This is mainly based on two properties: excellent processability and good corrosion resistance to drinking and industrial water. Despite its corrosion resistance to these agents being good in principle, in the past many brass parts have failed by stress corrosion cracking (SCC) and selective corrosion. However, the probability of failure per component is low [1].

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1350-6307/$ - see front matter
http://dx.doi.org/10.1016/j.engfailanal.2012.07.017

Nomenclatures

Ψ	incident X-ray beam angle (°)
$\varepsilon_{\psi\varphi}$	deformation of lattice crystal
v	Poisson coefficient
E	Young modulus (MPa)
σ_1	first principle stress (MPa)
σ_2	second principle stress (MPa)
d_ψ	diffracted crystalline plane distance (nm)
d_0	undeformed interplanar distance (nm)
R_a	average roughness (m)
R_z	average maximum profile height (m)
R_{max}	maximum roughness depth (m)

Solenoid valves bodies were realized by close die forging or injection molding of brass, followed by machining operations needed to achieve geometrical features, dimensional tolerances and surface quality (roughness) requested by the specifications. The brass alloy selected to produce the valves is employed commonly in this application field and it is biphasic α/β alloy featured by 40% α-phase and by a 60% β-phase. Such an alloy is characterized by an excellent workability but very limited cold ductility if compared with other copper alloys, because it contains 2% Pb to improve the tool cutting and so it is not recommended for seawater use also because it is sensitive to dezincification [2].

These brass valves usually work in air, water or steam in an average thermal range of 140–150 °C associated with an applied pressure from 0.01 MPa to 0.5 MPa. The working environment is drinking tap water free from ammonia (NH_3) accordingly with the strict limits imposed by the Italian law (D. Lgs. 31/2001 and 98/83/CE directive).

All the produced valves have undergone the shakedown and some of these failed during the test.

The observed failures interest the valve body base (Fig. 1, position 8) in correspondence to the section near the thread where tube top is installed. The liquid penetrant test revealed several cracks parallel to the axis of tube top handler (also defined as sleeve) featured by perpendicular branches (Fig. 2).

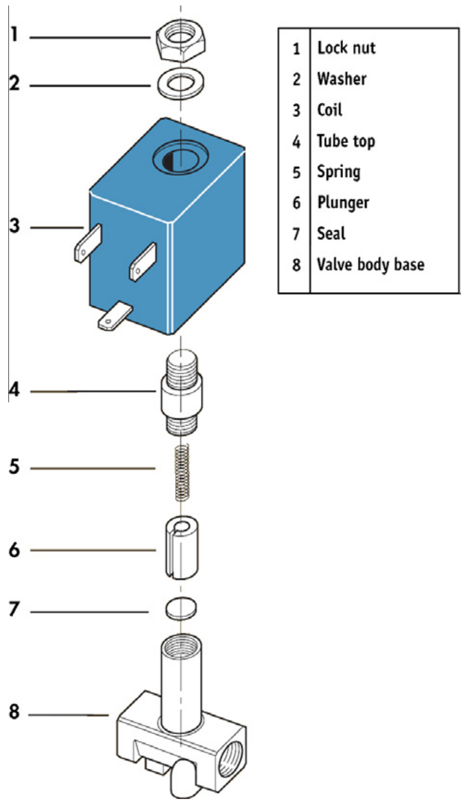

Fig. 1. Arrangement scheme of electro valves.