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ScienceDirect

Procedia Engineering 213 (2018) 58–68

Procedia Engineering

www.elsevier.com/locate/procedia

7th International Conference on Fatigue Design, Fatigue Design 2017, 29-30 November 2017, Senlis, France

Experimental tests and fatigue strength assessment of a scotch yoke valve actuator

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Abstract

Aim of this work is the fatigue assessment of a main component, termed scotch yoke, of a valve actuator used for oil & gas, power and chemical industries, in order to comply with its heavy-duty applications. To do this, full-scale specimens of the scotch yoke made of structural steel have been fatigue tested under nominal axial loading. All specimens have been tested under stress-relieved conditions by adopting a nominal load ratio R=-1. After experimental tests, the fatigue crack paths have been analysed by means of liquid penetrant inspections. The fatigue strength class of the considered scotch yoke has been determined by statistically re-analysing the experimental results, expressed in terms of range of the nominal applied load, and it has been compared with the design condition required by the relevant European Standard, EN 15714-3/4. Finally, two methodologies for fatigue strength assessment of the considered scotch yokes have been proposed, which are based on experimental fatigue data derived from smooth or sharp V-notched specimens, respectively, made of the same yoke material. The assessment capability of the proposed methodologies has been evaluated and discussed by comparing theoretical estimations with the experimental fatigue results of the scotch yokes.

Peer-review under responsibility of the scientific committee of the 7th International Conference on Fatigue Design.

Keywords: Valve actuator; structural steel; Experimental test; Fatigue assessment; Strain energy density (SED)

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1877-7058
Peer-review under responsibility of the scientific committee of the 7th International Conference on Fatigue Design.
10.1016/j.proeng.2018.02.007

1. Introduction

Pneumatic scotch yoke valve actuators are commonly used in many industrial sectors for different applications. High-cycle applications are among the most challenging scenarios for heavy-duty actuation, which impose high frequency of operation often at relatively high operating speed.

The LPS actuator series, see an example in Fig. 1, are mainly adopted in the Oil&Gas field and are able to provide a very high torque output. They are currently designed by FLOWSERVE – Limitorque according to the relevant European Standard, i.e. EN 15714-3/4 [1], which requires actuators to operate for a minimum number of cycles as a function of the nominal output torque. The required minimum number of cycle could be very different, even by some orders of magnitude. As an example, dealing with the Limitorque actuator model LPS-15, which is designed for a nominal output torque of 6000 Nm, the minimum number of cycles required by the Standard [1] is equal to 10^5. However, in high-cycle applications sometimes required also from chemical sector, customers frequently ask for actuators operating at least for 2 million cycles.

Accordingly, the adoption of standard actuator series for a wide range of applications inevitably leads to an oversize and an increase of the cost of the project, which corresponds to a decrease of the competitiveness on the global market. This issue can be addressed by adopting a validated design and by optimizing the actuator construction features, in order to guarantee the number of cycles required by Standards while avoiding an oversizing of the actuator.

To do this, experimental fatigue tests have been carried out on one of the main components of a valve actuator, that is the scotch yoke shown in Fig. 1. More in detail, the scotch yoke is located in the center-body assembly of LPS heavy-duty actuator series and it is responsible for the transmission of the actuation load from the cylinder to the valve. The experimental activity was aimed at deriving the design curve and at investigating the damage evolution of scotch yokes under fatigue loadings.

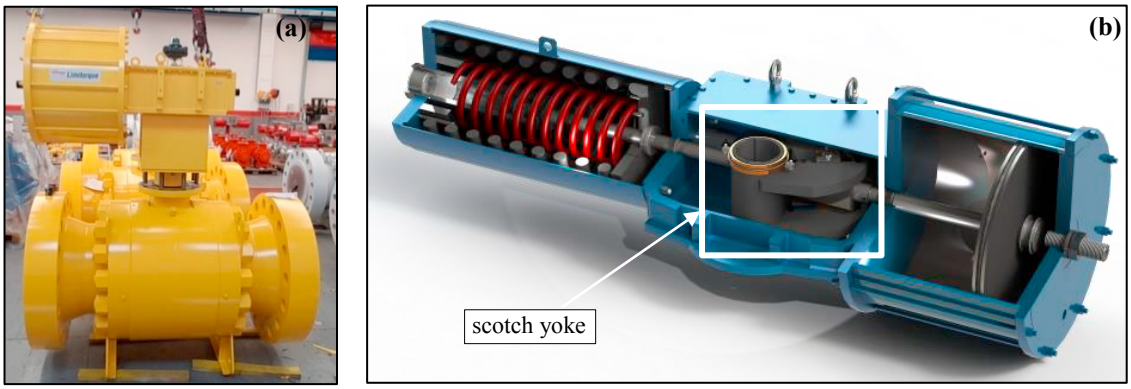

Figure 1: (a) LPS-30 actuator mounted on TMBCV Valbart valve, (b) Single acting fail close heavy-duty pneumatic actuator

Afterwards, methodologies for fatigue strength assessment of the considered scotch yokes have been proposed on the basis of experimental results obtained by fatigue testing simple specimen geometries made of the same material as the yoke. The adoption of either smooth or sharp V-notched specimens in the experimental tests aimed at defining the fatigue design curve has been investigated by comparing theoretical predictions with the experimental fatigue results of the scotch yokes.

The aims of the present contribution are:

- to fatigue test scotch yokes of valve actuators made of steel under nominal axial loading;
- to derive the fatigue strength class of the considered yoke;
- to convert the experimental results from a nominal to a local approach by means of FE analyses;
- to propose and discuss two methodologies for fatigue strength assessment of the scotch yokes based on experimental fatigue data derived from smooth or sharp V-notched specimens, respectively, made of the same yoke material.