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In-time monitoring of fatigue damage

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Abstract

In-time monitoring of the fatigue damage for a structure in a real operation is the complex problem, including :

- measurement of the operational loading and evaluation stress-strain state
- transformation of the loading into a critical section (notch)
- using the material properties for a corresponding material
- in-time calculation of the fatigue damage increase, etc.

This contribution includes the brief analysis of these steps and explains the processing of the measured deformation state without re-calculation the strain into stress in detail and presents the results from the installed in-time monitoring system of the fatigue damage in a real operation of gas pipelines.

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1. Introduction

In-time monitoring of fatigue damage lies in continuous sensing of stress i.e. strain with respect of time in critical place of the structure and its continuous processing into the form allowing calculation of the current fatigue damage increment using the known material properties [1]. The current value of the fatigue damage in the specific time t_i is given as an addition of the previous damage increments until the time t_{i-1} and current calculated increment D_i according

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the following expression

$$D_{akt} = \sum_{t_i=1}^{i-1} D_i + D_i \qquad (1)$$

where interval between t_i and t_{i-1} introduces the time length in which the loading process is processing and the fatigue damage is calculating.

Such increment monitoring system of the current fatigue damage in critical place of the structure safeguards as follows the continual sensing of the loading in critical place, continuous evaluation of stress-strain state, peaks detection of the extreme values, separation of the loading amplitudes and calculation of the fatigue damage increment using the known material parameters. The overall process must be justified in a way so that during the sensing of a loading in a time ti+1 must conduct all operations with the previous loading process. The performance of the monitoring system must have some reserve for visualization the behavior of the fatigue damage and archiving the loading process including archived the data of the previous time sections. Next, the data organization must be ensured and their history in order to avoid the stream interruption of the measuring data as well as losing the information i.e. overloading the recorded hard drives.

In the contribution, there is presented this attitude that is applied on the critical places installed on the gas pipeline system of the compressor station. The service of these pipelines is characteristic except the loading with and internal pressure also with addition vibrating which is induced by the dynamic during the operation of the compressors. The main objective of this monitoring system except the recording of the development of the fatigue damage is the registration and recording of the so called non-standard loading situations e.g. owing to the instability of the pipeline subsoil. Early registration and consideration of the effects these situations will allow to prevent the collapse of the pipeline. The emphasis is placed on the procedures which allow the solution and processing of all tasks in a real time.

2. Processing of strain signals

Continuous sensing of the loading in real operation is realized by strain gages possibly with other sensors for strain. Assignment of the corresponding stress to measuring strain is the step which can significantly affect the magnitude of the stress amplitudes what is documented by Fig.1 with measuring curves for material steel C55. From the strain value of 0,1% is possible to identify the significant difference in the recalculated value of the stress for individual material models represented by curves display on Fig. 1. Difference of corresponding stress value of 20 MPa and more is then projected into multiple difference of the fatigue lifetime value. For purpose of the continual monitoring is than suitable remain the measuring loading process in the form of the strain. That means processing the measuring strains into comprehensive process of maximum strain in the measuring cross-section. As an example we introduce the annular cross-section loaded with internal pressure including additional loading of bending and torsion. There is necessary to use minimum of 6 strain gages for distinct determination of the critical point in the cross-section area assuming the proportional loading for known direction of the transversal force [2]. Condition of loading proportionality in view of the loading source to which is the internal pressure and its pulsations well satisfied. For annular cross-section of the pipeline was used system of circumferentially deployment of the strain gages in order to allow separation of the individual components of the loading (Fig.2). Using of this system is possible to determine the most stressed point of the cross-section including the component of main strains. Deployment of the strain gages circumferentially along the annular cross-section in the spacing of 120^o (rosette in this point of action of the transversal force in the vertical direction) allowing separation of the individual components of loading (ε_N – strain from normal force, ε_{Mo} – strain from bending moment, γ_{Mk} – shear strain from torque moment, γ_{Mk} – shear strain from transversal force, ε_r – strain from internal pressure in radial direction, ε_t – strain from internal pressure in tangential direction).

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