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Effect of Rayleigh- Lumb Wave on AA2024 During the Static − Tensile test

Abstract: In the paper the results of ultrasonic technique utilizing Lamb waves for analysis of AA2024T3 specimen during tensile testing are presented. The three PZTs used as an actuator and two sensors were glued on the specimen surface using epoxy adhesive. Two frequencies of testing signals (50 kHz and 335 kHz) were used. The set of static tensile tests were performed. The recorded signals were processed to calculate the informative parameters to evaluate the changes of the stress-strain state of the specimen and its microstructure.

Key words: SHM, Ultrasonic testing, Rayleigh- Lumb Wave,

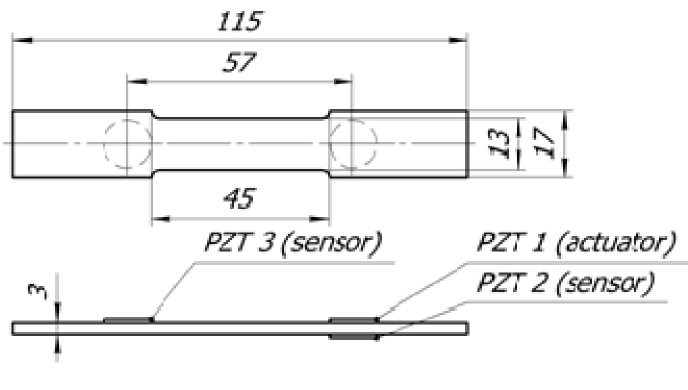
Introductions

Non-destructive testing played very important role in for industrial products. There are a lot of NDT methods based on flow detection and inspection of the part or equipment. To control the quality of the part, products & predilections for estimated life of component, now days NDT people are involving to development of Structural Health Monitoring (SHM) systems (1) to implement new structural change,

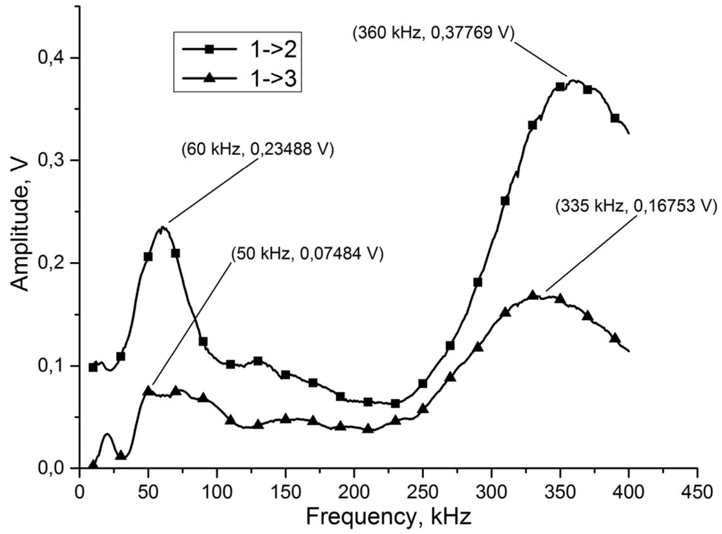
The SHM can be used to expand the inspection intervals if the system doesn't register the significant changes exceeding the defined threshold. There are different SHM principles proposed by different research groups, e.g. the strain sensing using optical fiber [2]. The obtained value is compared with the baseline of non-damaged structure thus revealing the damage. These systems should register the data during whole operation time (e.g. during aircraft take-off, flight, landing and taxiing). Another SHM approach [3] utilizes the network of ultrasonic transducers embedded in the structure being applied for direct detection of discrete damage (BVIDs and delaminating for CFRP, cracks in metal alloys, etc.). The online monitoring for such systems in unnecessary, moreover it can be distorted due to noise and vibration, so the initial data is obtained after defined lifetime intervals. These systems [4] are used for operational load monitoring and can expand the inspection periods. There are a lot of papers dealing with the research of ultrasonic systems utilizing Lamb wave principle and algorithms for damage detection. However in most of them the PZTs without substrate are used. Such PZTs will be inappropriate for cyclic loading during operation due to brittleness of piezoceramic. The aim of the present work is to assess the applicability of PZTs with steel substrate for fatigue evaluation. The experimental results of ultrasonic evaluation using Lamb waves of AA2024T3 specimens tested with static tension are presented in the paper.

Procedure: The investigation of proposed ultrasonic technique was performed during static uniaxial tensile testing of the AA2024T3 specimens. The drawing of the dogbone-shaped specimen used for testing is presented in fig. 1. The static tensile testing was carried out using electromechanical machine Instron 5582 with the load rate of 0.3 mm/min. The piezoelectric transducers used as actuators and receivers are piezoceramic discs with diameter of 9 mm and thickness of 0.19 mm on steel substrate AW1E12G-190EFL1Z by

Audio well Corp. The PZTs were glued on the specimen's surface using 3M Scotch-Weld DP490 epoxy adhesive (the tests were carried out after full polymerization of the adhesive during 7 days). The 1st PZT was used as an actuator; the 2nd (to characterize the changes outside the highly stressed gage length of the



specimen) and the 3rd (to evaluate the changes in the gage length) were used as receivers. The ultrasonic signals were generated using arbitrary waveform generator AWG-4105 with the amplitude of 10 V and the frequency in the range from 10 to 500 kHz. The 5-cycle sine modulated by Hanning-window was used as a testing signal (fig. 2). The signals were recorded using USB oscilloscope Handyscope HS4 with the sampling rate of 5 MHz and 12 bit resolution. To increase the S/N ratio the averaging of 100 recorded signals was performed. The signal recorded straightly from the generator by the 3rd channel of HS4 was used as the timing reference. The registered signals were processed using band-pass 10–800 kHz filtering. The signal acquisition from sensor PZTs was triggered by the reference signal. The recorded acoustic signals were processes to calculate two parameters in order to characterize fatigue state on different specimen lifetime: maximum envelope and variance of two envelopes difference (or second central moment). The calculation of the maximum envelope of received ultrasonic signal was carried out using Hilbert transform procedure in the frequency domain [5]. The signal amplitude is calculated as the maximum its envelope – MaxEnv or Amplitude. There are two experiments performed for the uniaxial static tension. In the first the step mode loading was used and the signals were recorded when the specimen was fixed in grips but the load was withdrawn. Thus the influence of the adhesive layer deformation and residual strain of the specimen were assessed using ultrasonic evaluation. In the second the static uniaxial tensile loading was applied continuously with the stops in defined points for data acquisition (the specimen was fixed in grips and subjected to tensile load). So the dependence of the recoded signal amplitude on the stress-strain state was investigated. The main goal of the static tests is to investigate the response of the actuator-receiver pairs during loading and to ensure the possibility of PZTs and epoxy adhesive application for further fatigue evaluation of the AA2024T3 specimens



Results & Analysis: The choice of the frequency for ultrasonic tests was based on the results of preliminary study of the response of the actuator-sensor pairs glued on the specimen's surface in the range from 10 to 400 kHz. The signal registration was performed with the frequency step of 1 kHz, the sensed signal amplitude was calculated and thus the two graphs were obtained (fig. 2). They represent the signal sensed by the 2nd and the 3rd PZTs. First of all, this dependence was plotted to characterize the amplitude-frequency response of the PZTs used in the investigation. It is easily seen that the curves are similar to each other with respect to the decrease of the amplitude due to attenuation of the signal propagated through the gage length

This work deals with the investigation of the possibility of ultrasonic technique to characterize the changes of the specimen dimensions due to the deformation as well as microstructure changes of the material in the highly stressed gage length. Thus the frequency was chosen from the second curve (1→3): for the static testing the values of frequency corresponding to the peaks of 50 and 335 kHz were used.

Discussion & Conclusions: This work deals with the investigation of the possibility of ultrasonic technique to characterize the changes of the specimen dimensions due to the deformation as well as microstructure changes of the material in the highly stressed gage length. Thus the frequency was chosen from the second curve (1→3): for the static testing the values of frequency corresponding to the peaks of 50 and 335 kHz were used.,

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