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Simulation studies of fatigue degradation process with reference to composite pipes

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Analysis and modelling

ABSTRACT

Purpose: The work deals with the principle of utilization of simulation models of fatigue degradation processes of composite materials as well as acoustic wave propagation for diagnostics of state of exhaustion carrying capacity of composite pipes.
Design/methodology/approach: The basic aim of the assignment is working out the model of the propagation of the acoustic waves in inhomogeneous resilient resort representing the composite material, in the condition of acoustic diagnostic signal stimulation.
Findings: The modelled analysis of the results of the process of the acoustic wave propagation with the use of material of thin-walled coating of pipe made of epoxy-glass, confirms the possibility the parameters of physical model of fatigue degradation process to be identified.
Research limitations/implications: The dynamic load by course and distribution of surface corresponds to the cycle of the diagnostic impulse of the acoustic wave.
Practical implications: The application of the procedure of simulation with reference to propagation of acoustic wave with identical period to models of various degradation level, allowed to seize the impact of structural features of the model on the speed of the wave propagation.
Originality/value: Paper is representing simulation models of fatigue degradation processes of composite materials.
Keywords: Composite pipes; Simulation models; Fatigue degradation processes; Acoustic wave; Diagnostics

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1. Introduction

The study of ultrasonics [1] and numerical methods of simulation of research processes have its tradition in the literature of the subject [2-7]. As a result of the research carried on fatigue degradation of samples of composite materials conducted within the projects [8,9] the possibility of identification of diagnostic relation of fatigue residual strength and acoustic characteristic of diagnostic signal, particularly the speed of sound wave propagation was found. This qualitative relation requires individual identification of quantitative parameters for particular form and structure of the composite material [10,11,12,13].

The attempt of utilitarian identity was undertaken for pipes made of polyester-glass composite. The numerical model of composite material subjected to identification facilitated sequential numerical simulation of the processes [14,15]:

- acoustic wave propagation
- fatigue degradation of the material

2. Numerical simulations of propagation of acoustic waves in the centre

The basic aim of the assignment is working out the model of the propagation of the acoustic waves in inhomogenous resilient resort representing the composite material, in the condition of acoustic diagnostic signal stimulation. For building the model of the centre and simulation of the wave propagation, the method of finite elements was applied. The research thesis indicates the possibility of widening the methodology of classical ultrasonic diagnostics on the research on diffuse changes in fatigue of polymer composites.

Methodological simplifications assumed in computational modelling mean replacing axisymmetric geometry with a disc model (thin-walled tube) with homogenized structure. Rectangular area of the centre was assumed (Fig. 1), one dimension of which (length) corresponds to thickness of modelled composite layer. It is most frequently established measuring direction of diagnostic ultrasonic signal. The second dimension (height) results from conventionally accepted limits establishing the dimension of the task - have a disturbing impact on the full picture in the area of influence of waves reflected from these accepted borders of the area.

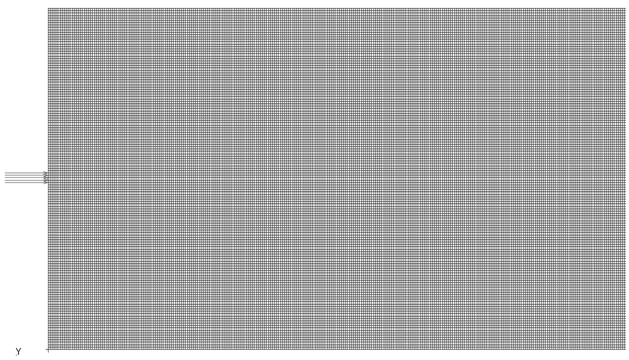

Fig. 1. Model of composite with the imposed boundary conditions under the load

The dynamic load by course and distribution of surface corresponds to the cycle of the diagnostic impulse of the acoustic wave (Fig. 2)

Figures 3 shows horizontal displacement contributions in the direction of length, in the axis of model symmetry, corresponding to chosen moment of the wave propagation process resulting from the division of expected time of passage of the wave front through the analyzed area.

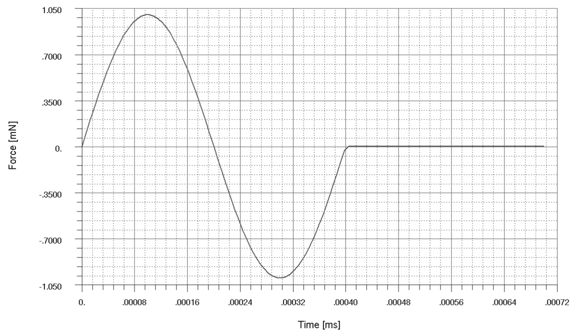

Fig. 2. Course of the exciting force

3. Numerical simulations of fatigue degradation

Structural changes of material caused by fatigue process are mainly micro-discontinuities in the warp as well as on the contact area of warp and strengthening, in the local zones of stress concentration. In the subsequent load cycles these irreversible effects are subjected to accumulation, leading to development of macro-cracks. Assuming, that it is the number of cycles and load amplitude that determine the measure of progress of the degradation process, the rule of cumulative linear damage (number of macro-crack)was accepted, with the speed determined by the Wöller's curve. Its inclination and boundary measures were established experimentally. The assumed rule made the basis of the selection of drivers of numerical random procedure of structural modification of the model, the application of which with reference to initial composite model allowed the generating of its subsequent forms, corresponding to progressing destruction of the material.

The application of the procedure of simulation with reference to propagation of acoustic wave with identical period to models of various degradation level, allowed to seize the impact of structural features of the model on the speed of the wave propagation. Figure 4 shows the received relation between the level of degradation level and the speed of propagation of acoustic wave, which might be the simulation model of diagnostics tool, which ultrasonic research constitutes.

4. Conclusions

The modelled analysis of the results of the process of the acoustic wave propagation with the use of material of thin-walled coating of pipe made of epoxy-glass, confirms the possibility the parameters of physical model of fatigue degradation process to be identified. The basis is formed by the results of the experimental research on the fatigue of the sample pipes within the range of non-destructive and destructive attempts in conditions of changing amplitudes of dynamic load as well as static attempts. This programme of research is currently realized within the frame of the project No: N N502 083138. Its results will allow the precise establishment of parameters of simulation procedures as well as creating the tool of project strength analysis of composite pipe elements.

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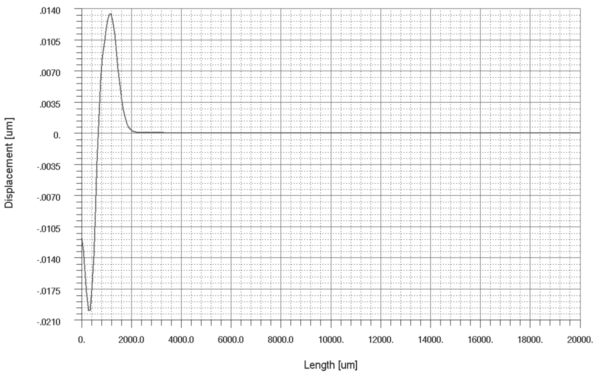
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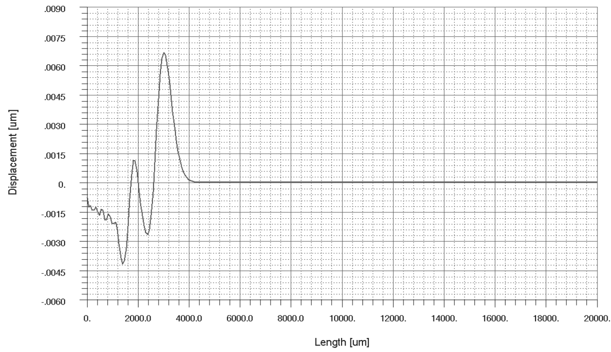
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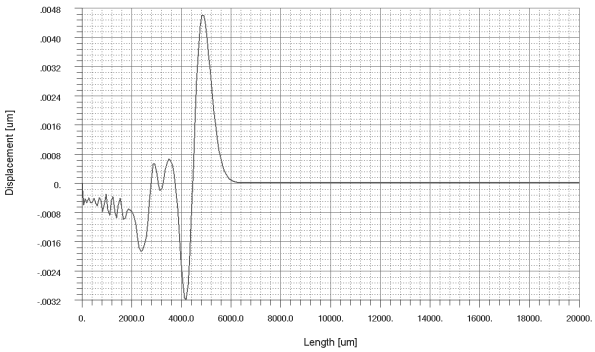
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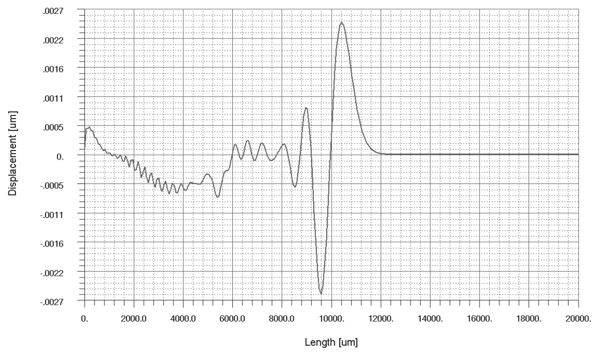
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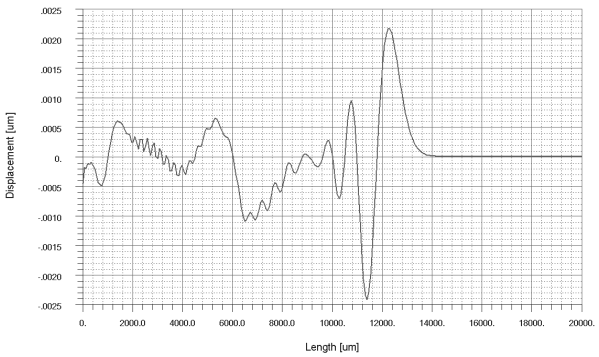
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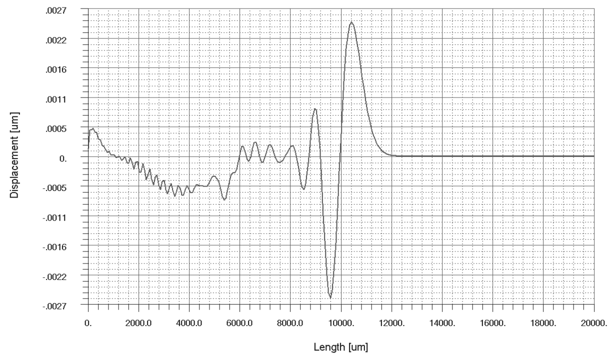
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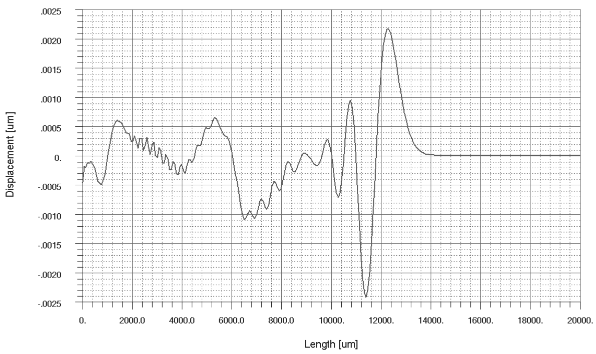
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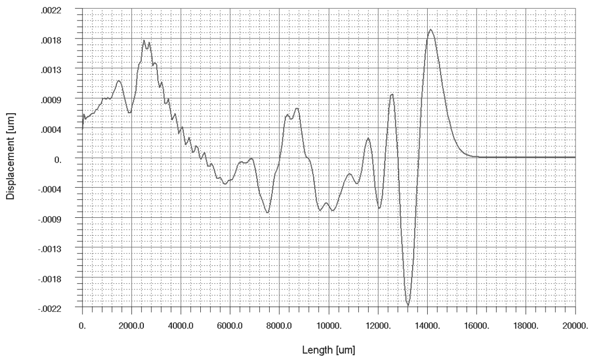
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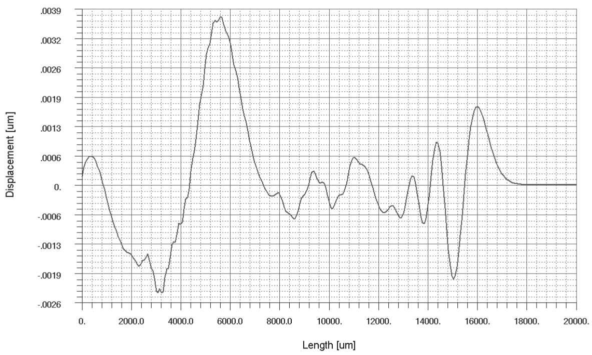

Fig. 3. The diagram of propagation of displacement wave in the direction of the model length in time from $1.0 \cdot 10^{-3}$ (a) to $4.5 \cdot 10^{-3}$ ms (i)

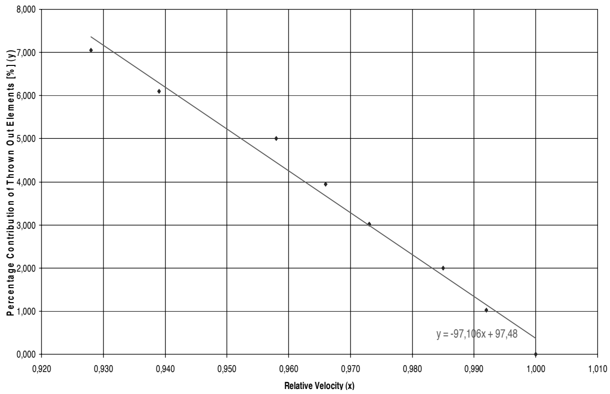

Fig. 4. Simulated relation between the degradation level and the speed of the wave

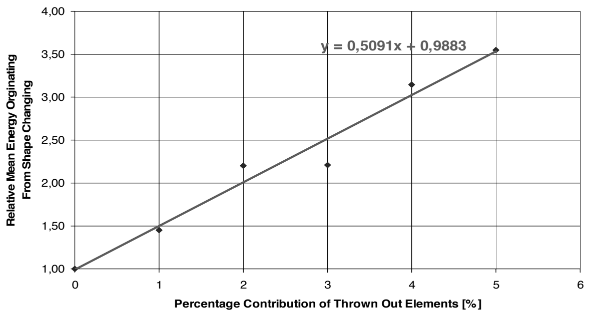

Fig. 5. Relative shift of the average shear energy in the function of the level of material degradation

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