Scientific highlights

In the scientific aspects of the project, it has been planned to cover multidisciplinary aspects of composite modelling with application to civil, mechanical and aircraft engineering. The aim of the project is to develop new areas of competence at Lublin University of Technology comprising:

1. multi-scale modelling and experimental verification of anisotropic behaviour of composite materials under combination of dynamic loading, environmental and temperature effects. The modelling includes calculation of local stress concentration in the material and defect nucleation, also defect growth. Modelling of the material at the nano- and micro- scale level and taking into account dynamic and thermal loading as well as the influence of technological and environmental effects play a very important role in applications of modern composite materials.

2. implementation of the results of the composite modelling to macro scale dynamical structures with taking into account the newest results of non-linear mechanics, vibrations, chaos and control techniques

Multi-disciplinary approach - by combination of those two topics - gives the possibility of wider insight into modern materials - from their properties till application in the engineering structures.

Ad.1.

The internal structure of modern composites made of different phases is very complex. The major current problem for theoretical analysis of composites requires linking together nano-, micro-, meso- and macro-scales in order to get good description of the composite behaviour. Variety of the composite types subjected to different loadings requires application of various approaches to composite modelling. In the reporting period the following tasks were undertaken:

a) Further investigation of polymer matrix composites: estimation by SEM an initial material structure on the new polymer composite samples delivered by Polish Aviation Works Świdnik (industrial partner of the project). The effect of the high temperature on the behaviour of composites was investigated. Tests for cyclic loading were done- using the testing machine MTS equipped in temperature chamber in order to estimate damage tensor components. The on-line monitoring of the specimens displacement were done with the ARAMIS system, bought within the project. The fatigue tests with polymer matrix composites were also performed for different temperature levels

b) Further investigation of: cement matrix composites (concrete) comprising testing of the concrete behaviour under cyclic loading for cylindric specimes. The phenomenological model including the degradation process was proposed

c). Description of damage process in Functionally Graded Materials (FGM) was proposed. The created FEA model allows for modelling of the layered composite structure behaviour under mechanical or thermal loading including thermal shock. Edge crack propagation process in FGM was experimentally investigated and analytically described

d). Testing of cracks propagation process in ceramic matrix composites was initiated. In particular, alumina matrix composite with different content of zirconia was investigated in order to estimate the fracture toughness and elastic constants. The specimens were subjected to static and impact loading in order to assess the influence of the loading rate effect

e) Creation of the numerical micromechanical approach for modelling of plywood. The internal structure of the venir was modelled by the representative volume cell by truss structure. Several damage scalar parameters were intorduced to define the complex damage state

f) Testing of crack propagation in two phase ceramic matrix composites by three point bending tests including static and low velocity impact loading

g) Additional equipment purchased in the reporting period: compression platens and general-purpose bend fixtures (together with servo-hydraulic testing machine) enable:
- testing of macroscopic internal damage for (composite) cylindrical specimens
- estimation of cracks propagation by 3-point bending and 4-point bending tests

h) During the reporting period LUT staff involved in the project developed the new testing method, enabling tracement of damage evolution in different composites. During unloading process all composites behave mainly elastically, what makes possibility to estimate variation of their elastic properties

i) Concerning theoretical modelling of the composites, the further skills in application of ABAQUS code were achieved. Particularly in the field of modelling of thermal shock problems in layered ceramic matrix materials. Cracks propagation and delamination was also investigated

Ad.2.

The experimental testing of the mechanical system with a pendulum have been continued. The active magnetorheological damper (MR) introduced into the system allowed for control of chaotic motions. The stability of the system has been checked analytically and verified experimentally. Transformation from regular to chaotic oscillation have been found theoretically and confirmed by experiment. It has been shown that, in the narrow parameters range, there is a region of a stable oscillation of the pendulum around the upper position.

Research on composite beam and plate structures have been continued. The control technique, by using SMA and PZT actuators, has been implemented to cantilever beams subjected to horizontal or vertical kinematic excitations. Mathematical models of the geometrically nonlinear beams have been used to study different control techniques of the system response.

The dynamics of heavy cables with sag has been developed. The 4D model of the cable, received after Galerkin's reduction, has been investigated by analytical and numerical method. On the basis of former results of RU dynamics group, the model with parametric and external excitations has been solved by Multiple Scale method. Moreover, numerical model has also been prepared in the Dynamics package.

The nonlinear modes theory has been extended for nonlinear systems having parametric and self-excitations. The problem is represented by nonautonomous ordinary differential equations. The Nonlinear Normal Modes have been established around the resonance regions. A special formulation for NNM as a function of vibration amplitude has been proposed.

Dynamics and optimisation of the composite plates with taking into account axial load has been investigated by numerical and mathematical models. Critical loads for various fibre orientation and composite parameters have been analysed. To get maximal plate strength and minimising its minimal weight parameters like fibre angles and layer thickness have been optimised.

Research in the field of machining of composites has been continued on milling process. Experimental signals from milling process of composite material has been received in LUT Laboratory. To define a new quality factors of the cutting process, the method of recurrence plots to numerically and experimentally obtained signals, has been proposed. A new approach to modelling of milling composite materials has been elaborated.

LUT researchers involved in the project had several meetings with staff from helicopter factories: PZL Swidnik SA and WSK "PZL Rzeszów" SA. Practical application of results obtained in the ToK – concerning active elements - in helicopters was discussed.

Applications of the active elements in composite structures is a continuously developed topic. It has been decided that SMA actuators will be tested in GU by Prof. Cartmell group. Various types of PZT actuators have been tested in the mechanical Engineering (LUT) laboratories together with Electrical Engineering Department (LUT). Numerical FE Abaqus models of the embedded PZT element inside the composite have been extended. Behaviour of the active structure has also been tested experimentally. Vibrations suppression by activation of PZT elements bounded to a beam has been observed by application a special dedicated controller.