FATIGUE OF SELECTED GRP COMPOSITE COMPONENTS AND JOINTS WITH DAMAGE EVALUATION

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Summary. The paper summarise the most important results of selected experimental programmes on static and fatigue strength of heavy loaded components and joints made of GRP composites, having been recently performed in fatigue laboratory of the SVÚM a.s. research and testing institute. Components like GRP trailer leaf springs, springs for railway freight vehicles are addressed, along with heavy loaded joints like stud connections in rotor blade roots at different loading and environmental conditions.

1 INTRODUCTION

Glass fibre reinforced plastics (GRP) have been used as a structural material already for more than fifty years. In the beginning of their applications, very little was known about fatigue and damage mechanisms of GRP materials. It was hoped that fatigue resistance would be at least as good as those of metals. The propagation of microcracks in the matrix was expected to stop at the fibres. Since then composite materials have successfully been applied in many other areas of engineering and industry, not only in gliders and aircrafts, where they allowed tremendous improvements in structures. On the other hand, penetration of GRP to other industries than aircrafts or wind turbines has been pursued quite slowly, rather due to conservatism of many designers, who have not been familiar with numerous characteristic differences in comparison with steels, than due to unsuitable properties of the materials themselves.

One of the most important differences between GRP and metals is fatigue damage process. In metals, fatigue loading usually results in forming areas of repeated plastic deformation, usually very local – formation of persistent slip bands. Initiation of small fatigue microcracks is the next stage, followed by formation of main crack growing more or less rapidly to final failure. In case of high cycle fatigue, the damage is always very localised and no changes of global component properties can be usually observed, just sudden final break. On the contrary, fatigue damage process in GRP materials is mostly continual and global in the volume. Resin cracking followed by gradual damage of interfaces between fibres and resin is
a continuous process being developed during the whole fatigue life and resulting in three
typical fatigue damage phases: (i) initial stiffness drop-off, (ii) more or less long phase of
linear changes and (ii) rapid stiffness reduction before final failure.

In some cases, particularly when microstructure imperfections in the material occur, the
three phases can be depressed and the component breaks suddenly like a metal one. Such
issues are discussed in the paper using selected examples of fatigue tests of heavy loaded GRP
components and glued joints. An attention is addressed to different laboratory methods of
damage accumulation monitoring and their comparison.

2 EXPERIMENTS AND RESULTS

Four experimental programmes were performed, namely (i) static pull-out and fatigue tests
of full-scale experimental model test pieces of joints between studs and GRP of a wind
turbine rotor blade, (ii) full-scale static and fatigue tests of studs glued into a wood epoxy
wind turbine rotor blade root (Fig.1), at room temperature and – 40 °C, (iii) fatigue tests of
GRP trailer leaf springs and (iv) fatigue tests of railway freight vehicle leaf springs.

It was confirmed during the different kind of tests that fatigue damage accumulation can be
well monitored particularly when there are no defects or imperfections in the material. Then
the damage curve usually had the typical three-stages sigmoidal shape. In case of fatigue tests
of stud joints, where damage was located into the bonded area inside the specimen,
temperature changes were considerably more sensitive than displacement (Fig.2). Sudden
break was mostly characteristic for defect material with insufficient wet out or with different
bubbles and voids. After a more detailed analysis of fatigue tests, some further links like
connections between total fatigue life and initial stiffness or initial temperature increase
gradient were indicated.

![Fig.1: Full scale rotor blade root with studs during preparation of fatigue test](image1)

![Fig.2: Displacement changes and temperature increase during fatigue tests of studs](image2)