# *CHARACTERIZATION OF DEFECTS IN POLYMER COMPOSITES USED IN MEDICAL DEVICES BY MEANS OF X-RAY MICROTOMOGRAPHY*

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**Summary:** This paper presents a study on micro-structural characterization of carbon fibre-reinforced plastics used in medical devices. The focus of the investigation is on determination of void content in the materials, since voids act as defects and will affect the service life of the composites/devices. The results show that x-ray microtomography is an accurate and powerful technique to identify defects in composites, and it is of great value in quality control.

## 1. INTRODUCTION

In recent years the demand for medical devices that can improve the quality of life has grown rapidly. The reasons for the rapid growth are aging societies, improved patient awareness, and general complexity and tempo of modern life. Most of the medical devices have to be light, strong, damage resistant, easily customizable and adjustable, which puts high demands on the materials. Carbon fibre-reinforced plastics (CFRPs), which often are used in high performance applications (e.g. automotive, aerospace), have also gained popularity for use in medical devices such as orthoses, wheel chairs, etc (see Fig. 1a). However, to obtain damage resistant and durable products it is important to maintain low amount of defects in the material. A common type of defect in CFRP, which can have a very detrimental effect, is voids. High void contents may affect the static and fatigue strength, as well as cause a greater sensitivity to environmental conditions (e.g. moisture uptake). Especially the interlaminar shear strength [1-2], compressive [3] and bending [4] strength of composites are severely degraded by voids.

Currently the most common procedure for micro-structural characterization of composites is to perform optical microscopy on polished cross-sections of specimens. The methodology has certain advantages, such as robustness and simplicity, but has also many limitations: time consuming process to analyse data; specimen preparation is a very tedious and operator dependent process; the method is destructive. The aim of the current paper is to use x-ray microtomography (XMT) [5] for characterization of the micro-structures of CFRPs used in medical devices. The focus is on determination of void content in the materials. A number of different medical devices were tested and depending on the types of constituents and composite lay-ups the parameters for XMT-scanning had to be adjusted. 3D quantitative data analysis of XMT-scans is presented and compared with results from analysis of 2D images. The advantages of the XMT-method to characterize micro-structure of composites in terms of accuracy and application of the results (e.g. quality control, modelling of composite properties) are discussed.

## 2. EXPERIMENTAL METHOD

The XMT-studies were carried out using a Zeiss Xradia 510 Versa, at Luleå University of Technology. In total 7 medical devices were studied, 6 of them made of CFRP and one from glass fibre-reinforced plastics. No special specimen preparation was done in terms of cutting and/or polishing. The pieces for scanning were simply cut out from the medical devices by the use of an ordinary band saw. Depending on the shape of the particular medical device the specimen size for scanning was up to 80 mm in length and 20-40 mm in width (see Fig. 1b). The

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thickness of the specimens varied between 3-6 mm depending on the composition of material/device. The typical tube voltage and output effect for the XMT-scanning was 60 kV and 5 W, respectively, and the exposure time varied from 6 to 20 seconds, depending on sample. The typical field-of-view was approximately 12 x 12 mm, see Fig.1b, and the spatial resolution approximately 12 μm.

## 3. RESULTS

Although the main materials in the studied devices were carbon fibres/polymer (except one device), some other materials were also present, e.g. glass fibres used as stiches and insert layers as well as rubber-like skins with fillers. Due to such different micro-structure and composition, scanning parameters and scanning times had to be adjusted for each of the material. The resulting images were of high contrast (see Fig. 1b) and details of micro-structure (e.g. voids, fibre bundles) are well visible. The contrast between fibre and matrix (polymer) is not as high for carbon fibres as for glass fibres, but it is still possible to distinguish different constituents. High contrast between voids and other materials made it fairly easy to evaluate the void content in the materials. Some of the medical devices were of high quality (void content < 0.3%) while others showed void contents as high as 5%. Results obtained from analysis of 2D slices and 3D scans are in good agreement. However, processing of individual 2D slices is much more time consuming and possibly also more operator dependent.

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(a) (b)

**Figure 1:** (a) Examples of various medical devices made out of carbon fibre-reinforced plastics. (b) The specimen in the holder (on the left; red square indicates field of view 12 mm x 12 mm) with examples of frame from XMT scan (upper right) and image used in 2D analysis of porosity (bottom right).