Using 3D Texture for Analysing Fibre Reinforced Plastic

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ABSTRACT

Fibre reinforced plastic is because of its stability and lightweight one of the main leading materials for the future. Because of its inner structure, 3D texture analysis is one appropriated analysis tool. The adaption of a 2D texture analysis algorithm to a 3D version has shown promising results by evaluating computer tomography data of fibre reinforced plastic. First tests have proved that the algorithm is able to detect errors and fibre orientation.

1. INTRODUCTION

1.1. Fibre reinforced plastic

Fibre reinforced plastic is plastic in which fibres are inserted to give it more stability. As material for the fibres carbon or glass are mostly used, but sometimes also aramid.

So fibre reinforced plastic is at the same time lightweight and stable. This makes it very interesting for automotive and aircraft industry, where this material is already used for small series (Lässig et al. 2012). The stability is very important for the safety and the lightweight is important for the energy efficiency. Real usable electric vehicles will not be possible without using lightweight stable material.

But also in other industries like wind energy or sport materials, fibre reinforced plastic is used (Lässig et al. 2012). All in all fibre reinforced plastic is one of the main leading materials for the industrial future.

In order to spread and increase the use of this material, it is absolutely necessary to achieve mass production. By developing adequate production methods for this purpose one important point is quality control. The most detailed information about the quality of fibre reinforced plastic is achieved with computer tomography (CT). With CT one gets especially information about the inner structure and inner defects. To analyse this amount of information 3D texture analysis is an appropriate tool.

1.2. 3D texture analysis

One common definition says: “An image texture is described by the number and types of its primitives and the spatial organization or layout of its primitives” (Haralick 1979). In 2D image processing the primitives are pixels and the types are their gray values or colours. The spatial organization refers to the term structure. Structures and patterns are the way the human eye recognises texture. Defects can be seen as variety of the basic structure. This property of texture is already used in 2D image processing for automatic defect detection (Pannekamp 2005), as you see in the pictures below (Figure 1 and Figure 2).

The basic structure of fibre reinforced plastics is defined through the fibres and their spatial organisation. Defects are varieties of this basic structure. This makes texture analyse a very useful tool for checking the quality of a fibre reinforced plastic product.

For analysing the whole product and not only the surface, a 3D image (voxel volume) is created by a computed tomography scan. In this case the primitives are now voxels, and no longer pixels, and the spatial orientation is extended to three dimensions.

The aim is to extend existing 2D algorithms to 3D data evaluation and develop new 3D algorithms, which enable automatic analysis of a part by its 3D texture. The adapted 2D algorithm was developed by Chen and Pavlidis (Chen 1979). Its basic idea is to split the 2D image first into small parts. Then the texture of each small part is compared to the texture of the small parts in its neighbourhood. If they have the same texture the parts are merged to a new segment. By continuing this process one receives at the end a texture segmented image. This algorithm has been adapted by using small volume parts instead of 2D image parts. The texture information stored for each segments, can be used for defect and fibre orientation detection. First test results show the general feasibility of this procedure.

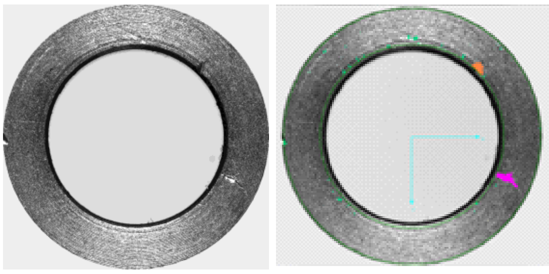

Figure 1: *Image of industrial part (left), detected impact damages (right)*

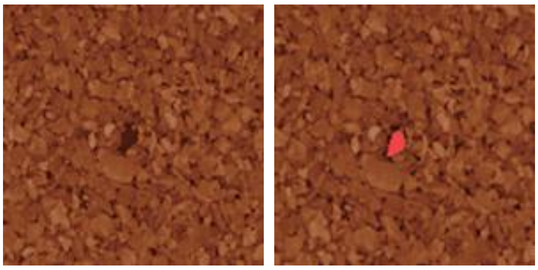

Figure 2: *Image of cork tile (left), detected defect (right)*

2. RESULTS AND DISCUSSION

The implementation of a new 3D texture analysis algorithm shows promising results for automatic defect detection and analyses of fibre orientation. All 3D volumes shown in this section have been provided by RayScan Technologies GmbH.

2.1. Defect Detection

In Figure 3 (on the left side) a slice through a 3D volume data set of a fibre reinforced plastic part with some cracks is shown. These cracks are defects which affect the stability and usability of this part. The texture of the whole volume (not only one slice) has been analysed. The result is also shown in Figure 3 (on the right side). It shows an obvious correlation between texture difference and the cracks in the part. So it is possible to detect the position and size of cracks by 3D texture analysis.

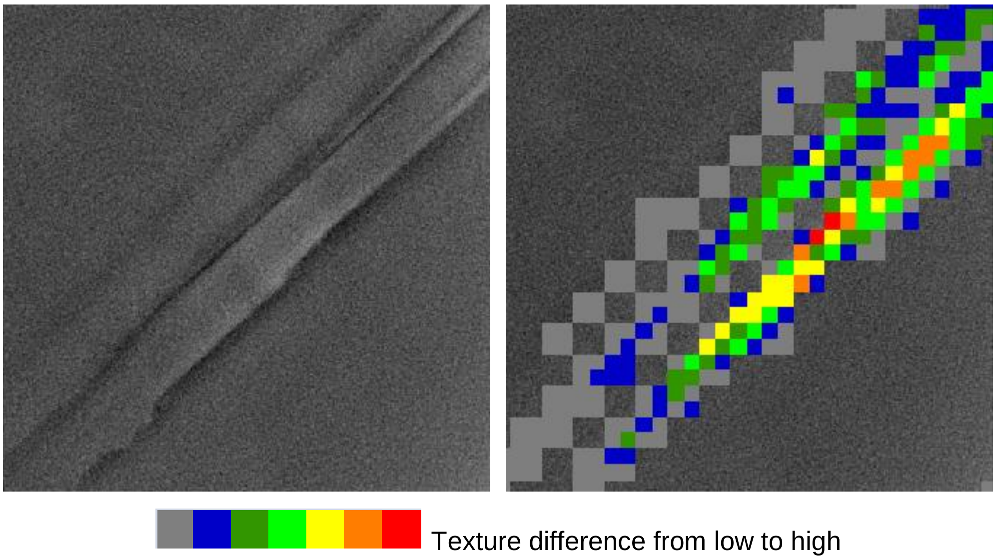

Figure 3: *Slice through volume data of fibre reinforced plastic part (left), marked texture difference (right)*

2.2. Fibre Orientation

Not only defects like cracks can affect the properties of fibre reinforced plastic. Fibre orientation is one of the most important product information. The right or wrong orientation has strong positive or negative effects on the stability of the part.

It turned out that from the 3D texture analysis the fibre orientation can be extracted. In Figure 4 (on the left side) a fibre reinforced plastic cube is shown. The extracted orientation is also shown in Figure 4 (on the right side). Explanation of the used colours is described in Table 1. The correlation between the extracted information and the real orientation can be seen even more clear if a slice through the cube (Figure 5) is inspected.

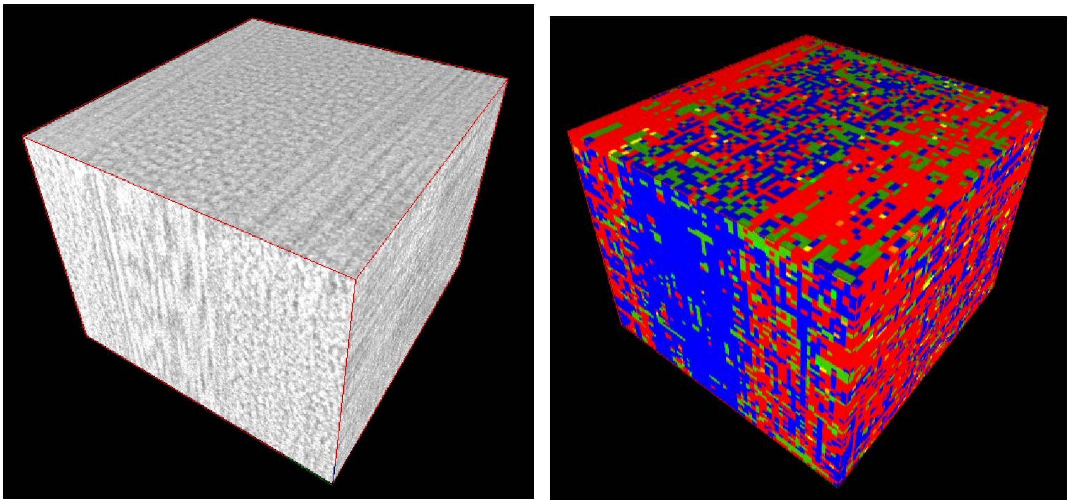

Figure 4: *3D View on fibre reinforced plastic cube (left), marked orientation (right)*

Table 1: *Colours describing fibre orientation*

	Orientation in direction of…
	...x-axis
	...y-axis
	…z-axis
	...(1,0,1) or (1,0,-1)
	...(0,1,1) or (0,1,-1)
	...(1,1,0) or (1,-1,0)
	...(1,1,1), (-1,1,1), (1,1,-1) or (-1,1,-1)

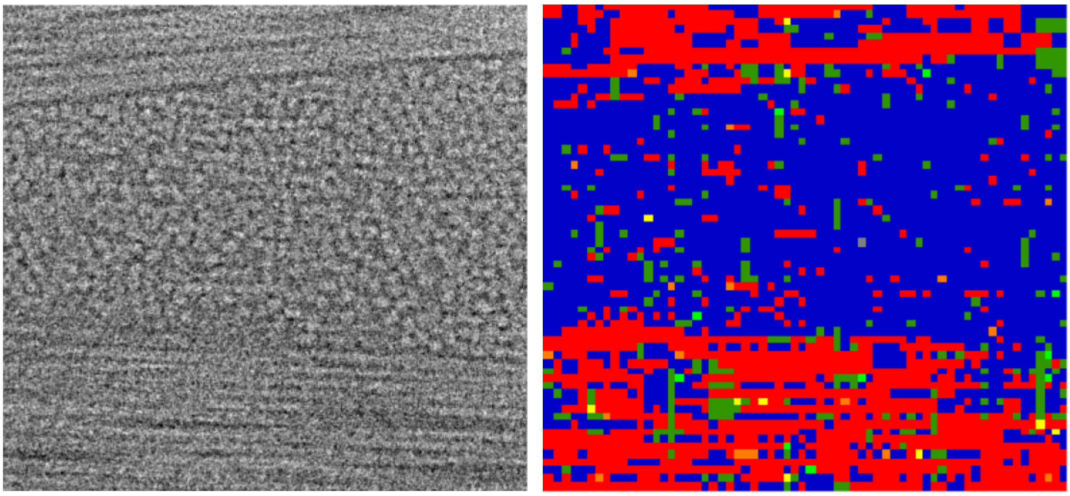

Figure 5: *Slice through cube (left) and orientation (right)*

3. CONCLUSIONS

Even if some defects are visible without using analysis tools, it is absolute necessary for automatic defect detection and analysis of fibre reinforced plastic to develop adequate analysis tools. Such analysis tools can offer not only qualitative information, but also quantitative information, like size of a defect or orientation of fibres in degrees.

The developed 3D texture analysis tool is one step in the right direction. The advancement of this tool and the development of other automatic tools will be an important contribution to bring fibre reinforced plastic in large-scale production.

4. ACKNOWLEDGEMENTS

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