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New concepts for quality assurance of lightweight material

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1. Introduction

Fiber-reinforced plastics are a high-performance material, which is used especially in automotive and aerospace industries [1]. For the planned reduction of fleet consumption to 95 g CO2/km, the automobile industry is forced to act [2]. Fiber-reinforced plastics, therefore, present a great potential for the weight reduction and fuel saving. However, the mechanical properties of glass fiber-reinforced plastics compared to metals are very low so that fiber-reinforced plastics can only be used to a limited extent for structural components. For structural components carbon fiber-reinforced plastic is used but the price of this material is high.

In order to compensate for this drawback, discontinuous fiber-reinforced plastics can be combined with continuously reinforced plastics, which are reinforced in the direction of flow of the force and thus improve the mechanical properties. Sheet Molding Compound (SMC) provides a good basis for this. SMC belongs to the group of glass fiber reinforced duromers and is applied to many components on the automobile, such as spoilers or underlays [3]. The material is available as a pre-impregnated semi-finished product and, therefore, has advantages in terms of cycle time and productivity.

The reinforcement takes place with continuous carbon fiber-reinforced plastics (CFRP). These have high costs with respect to the raw material. For this reason, it is necessary to ensure the quality of the semi-finished products and, thus, of the final component at an early stage of the process chain. The challenge is that the final part is not composed of a homogeneous material but of a large number of components such as the matrix system or the reinforcing fiber [1].

In the combined process chain, a large number of errors can occur. This includes defects which are located on the surface of the components, such as shape and contour deflections, as well as internal defects such as delamination or air inclusions. In order to be able to examine the semi-finished product, it is necessary to use non-contact measurement technology. The various defects cannot be detected by a single sensor system. The laser stripe sensors method is suitable for the investigation of the outer shape deviations of the part [4]. Non-destructive testing (NDT), such as active thermography, have been shown to be promising for internal defects [5-6]. Moreover, ultrasonic-testing with air coupling can be a possible method [7], but it has been shown to be unsuitable for this application [8].

Thus, in order to be able to carry out a holistic quality assurance, it is necessary to combine several methods.
Different measuring systems are discussed and evaluated in the following for their application with regard to the material combination and the fusion of different measuring systems.

2. State of the Art

2.1. Laser stripe sensors system

A laser stripe sensor system is an optoelectronic distance measuring instrument based on geometric relations from camera to laser and to the detected objects (triangulation principle). Therefore, a laser-generator irradiates the object and a camera detects the reflected laser beams. Being aware of geometric system configuration, the distance, particularly the surface distance elongation can be calculated. With a single laser stripe, a high-elongation of one surface stripe can be detected – which means detecting a single relief stripe [4]. To get a three-dimensional relief of the whole component surface, the system has to move along the surface. After scanning, the single stripes can be stringed together and represent the 3D image of the object’s surface [9]. The combined picture of a calibrated system is called ‘Cloud of points’ (COP). This COP can also be converted to a 2.5-dimensional picture (the high-information is represented by the pixel’s colours), so-called ZMap.

Depending on the geometry of the detected object (and its surface) there are some possibilities for a poor quality of COP: On the one hand, the camera’s field depth is restricted, which means, that there is a small optimal distance range between the object’s surface and the camera. For this reason, the system has to move over the relief in exact the same distance while scanning the surface. Another reason for a poor quality could be a shadow-effect of a single laser stripe sensor system: This problem could be solved by using two systems, which is shown in figure 1. For a shadow-effect parallel to the scanning direction, the systems could be twisted crosswise to the scanning direction [4]. Utilizing (detecting) highly reflecting materials or unfavourable geometries (e.g. special types of corners or edges) could result in useless reflection and so in a poor quality of COP. This effect is highly influenced by the laser-intensity and the system’s triangulation-angle [11].

![Fig 1. Laser stripe sensors and shadowing effects](image)

Previous experiments have shown that the most influencing parameters for scanning CFRP-components are: The laser-intensity, the integration time (camera), the threshold (lower intensity-minimum, which is needed to set a pixel as detected), the triangulation angle and the arrangement of a camera to laser [10]. The laser-intensity is determined by the voltage of the laser power supply. The camera’s integration time is the time range, how long a pixel is influenced by the rays for one picture.

2.2. Thermography

Numerous studies have already shown that thermography is a NDT method which can be used to detect impact damage or fiber breakage well [11-13].

Thermography can be divided into active and passive thermography. In passive thermography, temperature differences caused by upstream processes are visualized [14]. In this way, for example, the temperature of the surface of components can be monitored. In the case of active thermography, the object is stimulated to electromagnetic radiation by thermal energy. In this way defects due to inhomogeneous temperature distributions can be determined [15].

The excitation can take place in different ways. Pulsed-phase thermography is available for a fast analysis which, compared to other methods, has increased sensitivity to errors [16]. This requires a flash lamp, as well as a thermal imaging camera. Using the Fast Fourier Transformation further evaluations can be carried out and thus more information can be obtained in comparison to the pure temperature curve.

2.3. Multi-sensor measuring machine

No non-destructive method is currently able to check a component holistically for all possible defects and faults. Each individual method has its own focus in order to check certain features and also has different resolution [16].

Through the use of different sources of information, it is possible to generate new knowledge, which has a higher degree of detailing and is often made available in a shorter time and at a lower cost [17].

In order to check components of discontinuous and continuous fiber-reinforced plastics for internal defects and geometrical deviations, it is advantageous to use several sensor systems and to fuse the results of the individual measurements.

3. Material

For the conduction of test measurements different sample geometries are used. For the thermography experiments, flat specimen with a thickness of up to 4.7 mm and a maximum size of 400 x 250 mm² are used. In experiments with the laser stripe sensors system, a hat profile is examined. Both sample geometries are shown in figure 2. All samples consist of the same material. The discontinuous glass fiber SMC consists of a vinyl ester resin (DSM) with 23 vol.% glass fiber content. A fiber volume of up to 50% is achieved for the continuous fiber material, which is a hybrid resin (DSM). The Continuous and discontinuous material is bonded to each other.
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