method is suitable for implementing high-precision non-contact optical measurement systems for determining the surface profile of large objects. High accuracy allows the use of such systems for the analysis of the stress-strain state of objects, as well as the instantaneous three-dimensional model of a large number of objects. At this point, unfortunately, no satisfactory results of our new way of phase shift method, but now implement the software part of the method. In the future we plan to combine the two above-described method of obtaining information about relief to improve the accuracy of scanning up to 10 microns.

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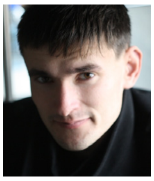

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Major Fields of Scientific Research: Computer vision and image processing

METHODS OF IMAGE RECOGNITION AS A TOOL IN ANALYSIS OF INTERNAL COMPOSITES STRUCTURES

Arkadiusz Rzucidło

Abstract*: The theme of the article is to discuss the suitability of image recognition software to study the structure of composites. These materials are already used for many years as an alternative to many higher-priced used in the aerospace industry and beyond. Research of composite structures are conducted on a regular basis. Application of pattern recognition methods can give a new perspective on analysis and measurements in the features of the composites.*

Keywords*: foam composites, image recognition*

ACM Classification Keywords*: I.3.3 Picture/Image Generation*

Introduction

Composite materials are used in the aviation industry for many years. Due to their properties, their characteristics are desirable in constructions, which through the use of composites are gaining, in many respects. By modifying the properties of materials we usually get increased hardness, stiffness, resistance to wear caused by friction, etc. By using such a solution we can lower the cost of manufacturing of machine parts made of composite material compared to more difficult to process parts from solid material - usually an expensive metal for airborne applications such as aluminum, magnesium, titanium. The participation of composite materials in constructions (specifically aircraft) reduces their weight, very often without losing the strength parameters. Due to such low weight we can gain on decreasing such parameters as: aircraft fuel consumption which is very important in matters such as savings and environmental protection. For example, about 25% by weight of the Airbus A-380 are the composite elements. With the aircraft weight of approx. 240 tons it gives a reduction of about 15 tons of "overweight." As you can see it is quite a significant saving, the more that it translates to the real possibility of taking an additional 150 passengers, or similar load eg. increase the amount of fuel the aircraft in order to obtain greater range. The Airbus A-380 uses a high quality carbon composites especially in: inner wing, pressure chamber, vertical and horizontal stabilizer with the rudder of direction and altitude as well as engine nacelles and other components of wings and body [Netcomposites, 2011].

Although composite materials are undoubtedly the future, also in their case the strength parameter has its limitls. Excellent characteristics of composites lose their strengths at the time of the damage which is the reason for the continuous search for new solutions in this class of materials and methods of their testing. In the case of composite materials very important issue are non-destructive testing methods, which enable us to examine the internal structure of parts or samples. They are particularly useful during the test phase, which allow for a specific product to be used. Implementation of appropriate tests is the more important due to the fact that in the composite aircraft constructions there is much lower range of tolerance for , safety factors [Belzowski, 2005]. Another important group of tests in the research phase are destruction tests, which allow examination of the structure resulting in the production process in terms of both structural correctness - consistent with requirements. Traditional methods of testing in the diagnosis of composites are: X-ray methods and, ultrasound. They allow insight into the structure without destroying the composite. Analysis of data collected during the research takes different forms depending on what form the results of the method offers. One of the characters is a graphic visualization of the test structure, which is subject to further digital analysis. In the following, special attention will be directed to the usefulness of studies using image analysis for diagnosis of composites.

Composites

The Composite is a material that is composed of at least two components (phases), each with different physical-chemical properties and characteristics of such component bear hallmarks of synergy. In other words, the characteristics of the composite are better or at least different to other components used. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites are used because overall properties of the composites are superior to those of the individual components. For example: polymer/ceramic composites have a greater modulus than the polymer component, but aren't as brittle as ceramics. In the general division of materials, composites can be divided into: laminates, sandwich structures with cellular filler (honeycomb structure), or hybrid structures [Mackiewicz 2005].

The basic structure can be presented as matrix system and placed in it second component with much better mechanical properties (Figure 1).

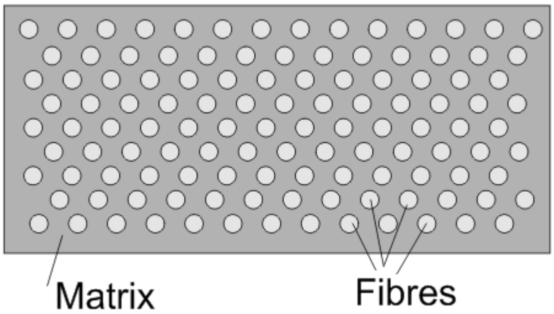

Fig .1. Example of composite structure

Matrix holds together the reinforcement, provides sufficient compressive strength, moves of external stresses to the reinforcement, stops growth of cracks and gives the products the desired shape. Wrap is usually a polymer, metal, alloy or ceramics.

Reinforcement's task is strengthening the material and improve its mechanical properties. Its arrangement (design) may take various forms, from structural (fixed direction of reinforcement) to completely random (eg. molecular), which is shaped by processes occurring during the formation of the composite.

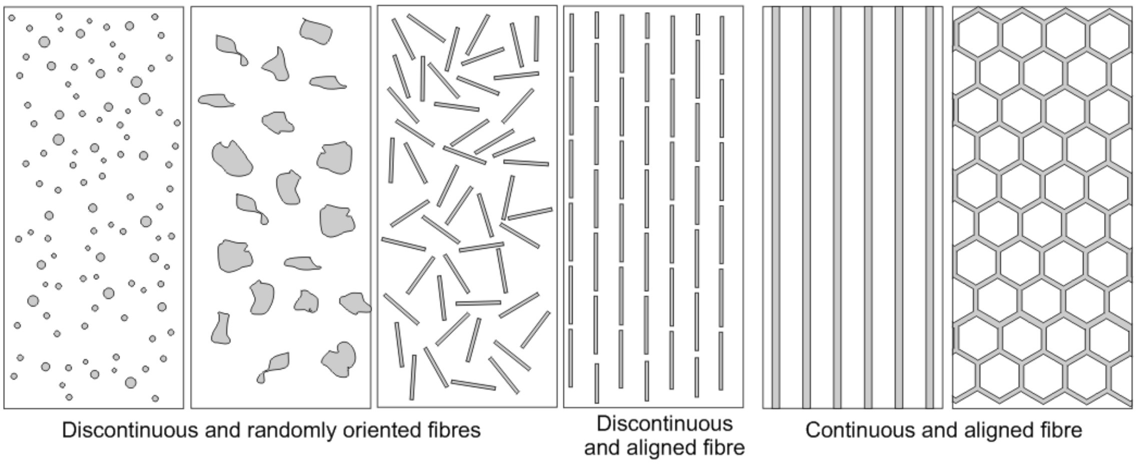

Fig.2. Fiebre orientation

Analysis of composites of regular structure, where shape and arrangement of reinforcement and the wrap is easy to predict seems to be relatively simple. Selection of the spatial parameters of sample, which will be a representative miniature of the material should not be difficult and usually depends on the size of materials (and their location) used in composite. The issue of size is usually associated with shape and volume of the reinforcement , while location (arrangement) is characterized by parameters such as resolution, accumulation, or orientation (Figure 3).

Slice (sample) of material for analysis must contain specific ingredients in quantities that are "stored" in its construction. Selection of sample size of composites with irregular structure needs different approach. Examples of such materials are, powder or foam composites. Their construction is random, despite the possibility of influencing the shape and size of the matrix or reinforcement. Selection of sample size to study the structure properties in this case is more difficult. Distribution of powder or foam is random, hence the "cutted" section of structure may contain too much of one phase in relation to total volume of material. Looking at volume, the whole product can be constructed correctly, but localized and selected sample can be built incorrectly.

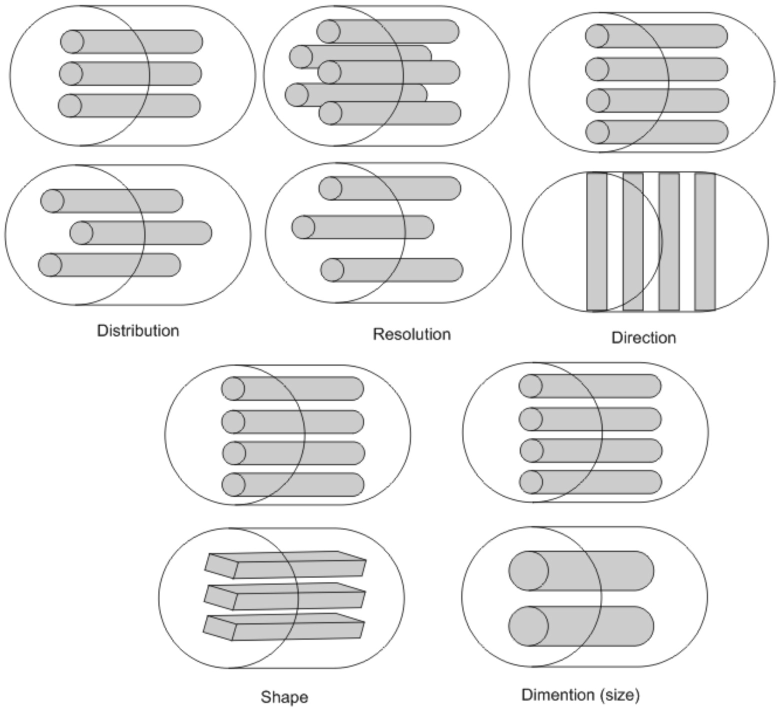

Fig.3. Fibre parameters

Too small sample with large concentration of excess phase will definitely affect the measurement of tested parameters badly and distorts the results (fig. 4a). At the same time oversized sample may not cover important details. Due to that fact size of characteristic elements in the composite will be insufficient to make the test. The measurement will be inaccurate.

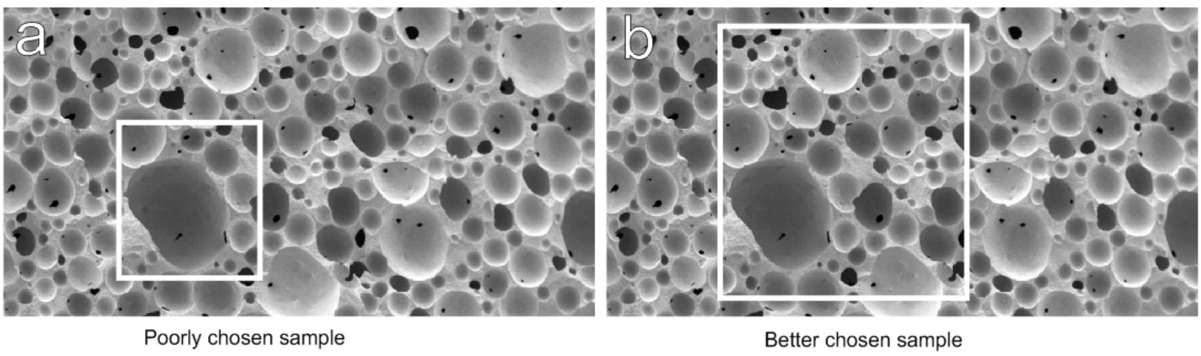

Fig. 4. Determination of sample filed [Potoczek, 2010].

The structures of materials such as foam based composites are materials with random structure. In the literature they are classified as C4-type structure (called co-continous ceramic composite) [Potoczek 2010]. They are usually two phase polymer-metal form. Polymer foam produced by foaming the polymer, infiltrates itself with metal to form three-dimensional composite. Structure of such material depends on the instantaneous system of air bubbles, which modify the gelling element, thus creating space to fill with metal. Technology is developing very fast and now there are known techniques that allow to control with some probability, both qualitative and quantitative arrangement of foam in composed material. It is possible to control size of the bubbles, their number and most importantly the space, which is very important in infiltration process. It is represented by "windows" between the bubbles that are in contact with each other. Infiltration parameter control allows to quantify the composite-metal structure. It prevents the formation of closed vesicles. Such closed vesicles are the weakest point for whole designed element by lowering its mechanical properties. Control of created composite is therefore absolutely necessary. It is also recommended to run test with non-destructing method. Good results can be achieved with tomography samples test. It allows for precise digital projection of the tested structure. Such model is subject of visual inspection, verification and measurements control. In this matter, method with good results is image recognition technique.

For testing foam composites choosing the right size of test sample is one of the most important parameters affecting further results of image recondition analysis. Analyzed foam have different sizes of air bubbles, therefore area for testing should contain structure of a similar sized air bubbles, both the largest possible acceptable size and also the smallest structure of similar size. Both in first and the second case, sample sizes may differ from each other and will be subject to the findings. There is also different case of foam composites where structure is irregular and sizes of air bubbles is heterogeneous. In this case, analysis of a sample size will be the most important. Another important parameter is the method of recording digital image data acquired for research, which will determine accuracy of details of projected sample. The goal of the research is to determine the best and acceptable parameter of image resolution and the number of bits that describe various points of the image.

Image recognition software in study the structure of foam composites

The image recognition techniques can be divided into three stages: image acquisition, its pre-processing or in other words filtration and the analysis of optimized digital data. The first two stages are independent of issues in which they need to be applied. They cover all activities well-known and developed in the form of filters or macrocommands for graphic programs of image processing or classification. In this matter, actions on the examined issues will be limited to trials of composition of appropriate techniques to obtain the image with specified object of study. The key goal of the research will be defining methodology of image recondition through selection of techniques contained in the programs for images analyze or developing a new method that is appropriate in the research topic.

In addition to determining mentioned parameters of the sample, not directly related to the same method of analysis it will be important to establish parameters for initial preparation of data processing of acquired images. Such processing is aimed at the best possible preparation and separation of phases of the composite for testing. Limiting of the spread of proposed values for each settings will allow for accurate identification and proper selection of filter and further exact analysis of the sample.

Foam composites usually consist of two phases one of which is gelatinized non-metallic part and a second metal infiltrated into the foam. Due to such an arrangement, initial processing of samples for image analysis will consist mainly of binarization, which will determine the contrast range of both materials in the composite. The main issue will be setting proper, characteristic limit which will give the most effective image for the analysis of digital data.

Data prepared for analysis must be processed with a use of suitable software base. Current programs for analyze are very powerful. The scope of their applicability makes this kind of software very popular and commonly used for digital data laboratory testing. Therefore quite large group of useful applications can be found on the market.

After comparison of popular graphics software for digital data analyze there are two positions worth to be mentioned which seem to be proper for analysis of the structure of foam composites. They are: Aphelion Amerinex Applied Imaging Inc.. [MediaCyb, 2011], and Image Pro Plus by Media Cybernetics, Inc. [Amerinex, 2011].

Suggestions of using these programs are not random. These are applications that are doing well both in two-dimensional images environment as well as can ease research in three-dimensional environments. Such flexibility is desirable due to the subject of research, and plans that involve measurements of three-dimensional spaces. Both programs have similar functionality, that was checked for several samples. They contain similar tools needed in images preparation and tools for measurement and analysis of data obtained during testing. Also automatic statistics tools are very useful due to possibility of a quick way to give the analytical results. These tools have the additional advantage which is the graphical interface for visualizing data in both digital and graphical character. The programs also have ability to create macrocommands that can accelerate the entire research process.

The techniques for the study of images of foamed composites

The basic test for foamed composites are quantitative tests. In case of two-dimensional samples contained in the classical images, process of research is identification of phases in the sample and counting percentage share in flat image of the sample. Tests can be performed only on the previously prepared (cut) cross-sections of the sample, which are photographed using scanning electron microscopy (SEM images) (fig. 5)

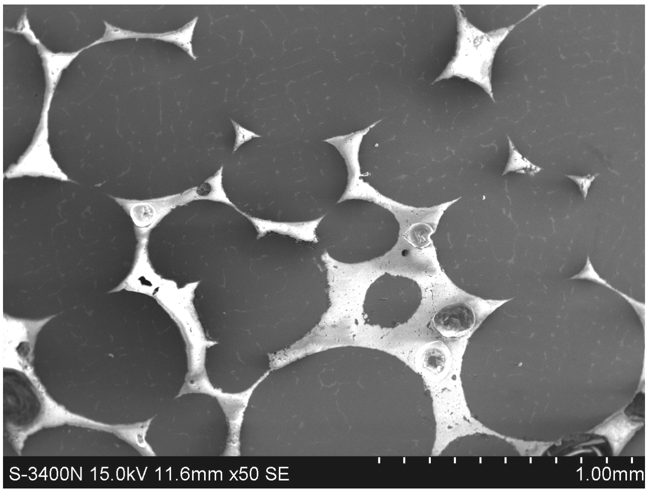

Fig 5. SEM image of Polished section of AlCu5/Al2O3 composite obtained by pressure infiltration [Potoczek 2010]

Testing of two-dimensional samples can be extended by identification of an area which has not been infiltrated with metal. Closed Al foam cells create a notch, which badly affects the strength of the composite. It is therefore undesirable phase.

Studies on 2D images are also measurements of infiltration surface. This is the area of windows caused by contact of air bubbles in the foam. This is a very important parameter for this type of composites. However, this measurement made on two-dimensional images is not accurate and is rather an intermediate data to determine distribution of the windows in the whole sample. This way of determination of the surface infiltration will require analyzing large numbers of images.

In addition to tests run on classical two dimensional images, it is planned to make a much more sophisticated analysis. This will be the study of spatial structures. Using classic images, one can identify what you see in the picture of the sample and not in the whole sample as a three-dimensional object (fig. 6). By analyzing a block a lot more can be said about the composite structure and parameters of interest such as infiltration areas or undesirable closed spaces with bubbles of foam. With such an analysis chemical components forming such a matrix can be precisely selected. It also allows for better choice of parameters of filling the foam with metallic phase.

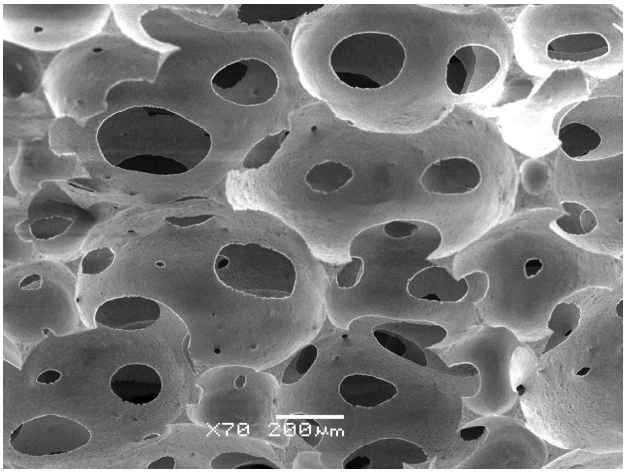

Fig. 6. SEM image of porous ceramics obtained by the gelcasting of foams method [Potoczek 2010].

Both presented here image analysis software allow to create three-dimensional structures of obtained two-dimensional images. In case of this issue the levels that make up the 3D image will be created based on materials obtained from computer tomography of tested samples technique.

The design of foam samples reminds densely packed spheres, which overlap each other in places forming infiltration surface (Fig. 6). By combining successive cross-sections and creating the a three-dimensional image, one can make visual inspection and measurements of samples in any plane.

Both studies of two and three dimensional images allow to characterize technology of manufacturing and testing of foam composites in a slightly different approach as it was before.

Conclusion

Conducted research in the field of image recognition software, and methods contained in them confirms the possibility of analysis and measurements of interesting parameters of foam composites samples. Initial benchmarks have shown that both of these programs are good tools for analyze of phenomenon of composite infiltration and characteristic features of the foam. A choice of software is not determined by its functionality becouse in this respect because both programs are equivalent. Decisive factor will be the criterion of cost, which indicates so far for choosing the Aphelion software.

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