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Effect of the aging process at a temperature of 300 degrees Celsius of Ti6Al4V alloy on mechanical strength under static loading conditions

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Abstract. Conventional construction of components is slowly being replaced by rapid prototyping and the use of DMLS technology. The development of DMLS requires conducting experimental studies that build a knowledge base that allows for the averaging of mechanical properties. verification of how the initiation of the crack occurs in the material and how the energy is propagated in the samples that were made by a conventional method compared to the samples, where the method of sintering titanium layers will be used. The literature analysis showed no research results relating to the impact of values of strength parameters on the structure of materials produced by the DMLS method. Titanium samples made with the additive method and the conventional titanium grade 5 Ti6Al4V titanium method, which is used, among others, in medicine, were used for the tests. The article presents the influence of material structure on mechanical properties (Re, Rm, A, Z). The presented research is preliminary research defining the properties of the material, which are gaining more and more application by using the DMLS method in the construction of machines and in medicine.

1 Introduction

Increasing techniques play an increasingly important role in the industry and everyday life branches. They have found wide application in the automotive, aerospace, chemical, heating and food industries. The wide range of applications of titanium alloys is associated with their good mechanical and physical properties. The Ti6Al4V alloy, also known as Ti64, is an $\alpha + \beta$ titanium alloy characterized by low density, high specific strength, good creep resistance and good anti-corrosive properties in many environments. Considered the most popular titanium alloy, Ti6Al4V occupies almost half of the market share of titanium products currently used in the world. Despite high demand, the production of Ti6Al4V products is always difficult due to poor thermal conductivity, propensity to strengthen distortion and active chemical reactivity to oxygen. The conventional production of Ti6Al4V products is

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based on forging, casting and rolling of batch materials, followed by subsequent machining to final shapes and dimensions. These traditional production processes always lead to a large amount of material waste, high production costs and a long implementation time. In such circumstances additive production (incremental) allowed for the creation of advanced production technologies for the direct production of structures of virtually any shape. adding material in a layer-by-layer manner [1]. In the article [2], the authors applied different heat treatments, referring to the microstructure and mechanical properties, were examined by X-ray diffraction, scanning electron microscopy. The material analyzed showed that the Ti6Al4V gradient breakdown mechanism changes from brittle failure to malleable after heat treatment at 800 ° C for 120 minutes and furnace cooling. These results suggest that the structure and specific heat treatment can improve the stability and predictability of the Ti6Al4 porosity, and thus facilitate the behavior of the material during loading. The authors of the article [3] present the material produced by the additive method and subjected to heat treatment at 850 ° C for 4 hours. The use of the heat treatment process resulted in increased strength. Ti6Al4V titanium alloy can be used in various industries, in the article [4] selective sintering of titanium was used in a dental application. Mechanical tests showed that the compressive stiffness of the samples was within the range of spongy bone tissue. The article [5] presents the issues of fatigue life calculation under operating conditions. The result of the work is a comparison of fatigue life for the load spectra determined by the accepted methods of cycle counting and for accepted models of two-parameter fatigue characteristics. The article [6] presents research on how material can behave during static and cyclic loads, which are obtained on the basis of random load spectra. Comparing traditional production methods, the biggest advantage of the additive method is the ability to freely produce a complex part directly from the material, without the use of traditional production methods, in particular forging, casting or machining [7]. Incremental methods are a viable technique because they are characterized by a low amount of waste. Unused powders used as a sintering material can be recycled making the whole process more cost-effective.

The primary goal of the preliminary tests is to show the change in aging behavior of the Ti-6Al-4V material at a temperature of 300^{0}C compared to a material that has not been heat treated. In addition, basic microscopic photographs were taken to analyze the fracture surfaces of the samples tested.

2 Material and Methods

The tests were carried out on a two-phase (α + β) titanium alloy, whose chemical composition is shown in Table 1. The main alloying elements of this alloy are aluminum, which stabilizes the α phase and vanadium stabilizing the β phase. Ti-6Al-4V alloy was chosen because of the wide range of applications in many industries.

Table 1. Chemical composition of titanium grade 5

Al	V	C	Fe	O_2	N_2	H_2	Ti
6,4	4,1	0,1	0,16	0,18	0,01	0,003	reszta

The samples for the preliminary tests were made using the additive method on a 3D EOS m100 printer. The laser created from fiber material has a power of 200 W, thanks to which the machine's work is stable and the element produced is of high and durable quality. The sample geometry is shown in Figure 1.

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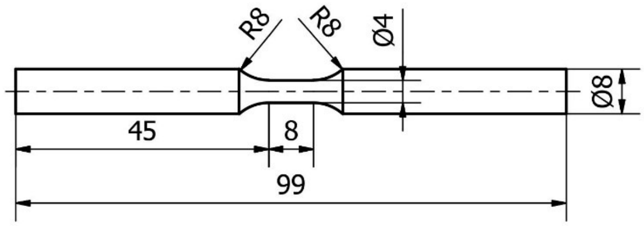

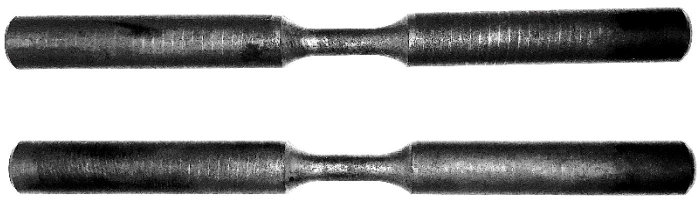

Fig. 1. Drawing of the geometry of the sample with a photograph of the samples used for the tests

A total of 6 samples were used for the study, divided into two groups. Table 2 presents the division of 3 samples and has been heat treated at 300 ° C immediately after printing for 24 hours in the argon shield. Another 3 samples were not subjected to any thermal rotation.

A servo hydraulic testing machine INSTRON 8501 max was used for preliminary static tensile testing. static force 120 kN, max. dynamic force of 100 kN, displacement of the piston ± 50 mm. The machine makes it possible to carry out tests of materials and structural elements under monotonic and cyclic loads and work under the control of proprietary computer software created by UTP in Bydgoszcz. The software allows, among others for the cooperation of a testing machine with a laser mesh interferometer.

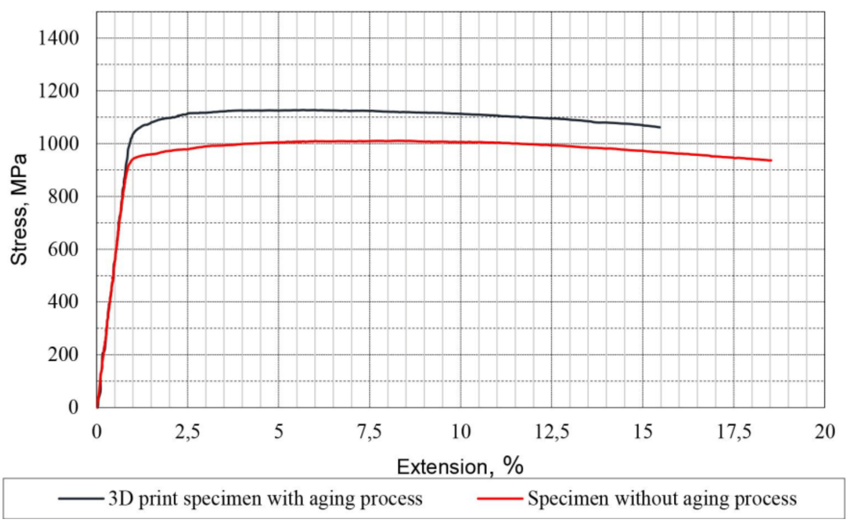

Fig. 2. The graph shown results of static tensile test

To analyse the breakthroughs, the Delta Optical Discovery 40 microscope was used along with the DLT-Cam PRO 8MP camera. Figure 3 shows the photo of the fracture of the printed sample using the Ti6Al4V titanium powder sintered 3D method.

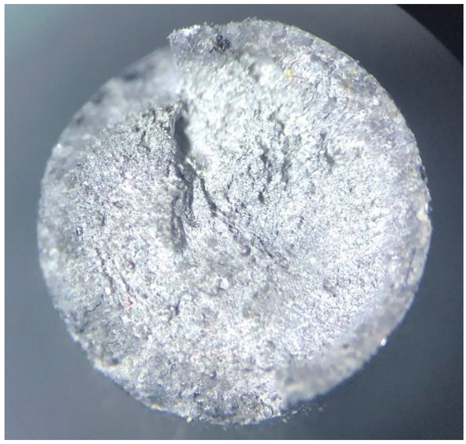

Fig. 3. Photo of the cross-section of the sample after static tensile test

The microstructure can be related to the phases and grain structures present in the alloy. The microstructure directly regulates the material properties of the end products, but also depends on the processes used, e.g. heat treatment. Incremental processes, in particular based on lasers, introduce a very large amount of induced residual stresses due to large temperature gradients.

The final residual stresses increase as the number of layers increases [8], and the peak value always occurs on or near the free surface of the final deposited layer. The residual stress profile consists of a large amount of tensile stress in the upper area of the printed part, which is compared to the yield point of the part. Together with the addition of new layers, previously constructed layers and their stresses are transformed into compressive stresses caused by the subsequent thermal cycle.

3 Conclusion

In this article, a strength test was carried out for the material aged at 300 ° C for 24 hours in relation to the same material without the heat treatment process. The presented test results show that the material made with the additive method of titanium powder sintered after heat treatment shows a higher strength in relation to the material without treatment.

This phenomenon may be due to the fact that during the preparation of sintering titanium powder in the material, micropores are formed. By subjecting the material to an additional heat treatment consisting in the process of aging the material at a suitable temperature, the material grains are systematised and oxygen is precipitated, which significantly improves the strength of the tested alloy. The analysis of the literature review showed a great interest in last year's strength and material tests for grade 5 titanium alloy. This is due to the incoming new incremental technology used in the aerospace and dental industries.

This method allows to obtain non-standard geometries and in the medical industry to personalize implants and implants for the anatomical construction of each patient.

Further work on the strength of the titanium alloy produced with the additive method must be carried out, and the research presented in this article is only the beginning of a broad material, intrinsic and durability analysis that will be made for the Ti6Al4V alloy made in the DMLS method.

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