APARATURA
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New construction of cooling unit dedicated to use in aerospace parts production

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ABSTRACT:

Continuous development in aerospace industry puts increasingly higher challenges for manufacturers of aerospace parts. The production process of aerospace parts must meet strict requirements. One of them is inspection of part's dimensions at the various stages of its production. It is important to proceed with the measurements when the part reaches desired temperature (usually 20°C). Temperature of the parts after machining process may be raised to approx. 60°C, hence they need to be cooled down. Cooling requires especially long time in case of large volume parts, which leads to prolongation of their delivery time. The research and development work in this field is therefore focused mainly on developing new solutions which may accelerate the cooling process. The present study describes the influence of temperature of workpiece on the result of dimensions measurement and a new design of refrigerator developed and patented by WALDREX Sp. z o.o. Refrigerator is equipped with an insulated container with cooling coil. The container is fixed in a stainless-steel frame. Provided solution enables fast and cost-effective cooling and keeping workpieces at a given temperature.

Nowe rozwiązanie konstrukcji jednostki chłodzącej do zastosowania w produkcji części lotniczych

Słowa kluczowe: lotnictwo, obróbka skrawaniem, chłodzenie

STRESZCZENIE:

Rozwój lotnictwa stawia coraz większe wyzwania dla producentów części lotniczych. Wytwarzanie tych części jest związane z koniecznością spełnienia rygorystycznych wymagań przez zakłady produkcyjne. Jednym z nich jest prowadzenie kontroli wymiarów detalu w poszczególnych etapach jego produkcji. Istotne w tym przypadku jest wykonywanie pomiarów w ustalonej temperaturze (zwykle 20°C). Elementy wytwarzane w procesach obróbki skrawaniem po jej wykonaniu mogą mieć temperaturę podwyższoną do ok. 60°C. Chłodzenie elementów o dużej objętości jest długotrwałe i zwiększa czas ich produkcji. Stąd prowadzone są prace badawczo-rozwojowe mające na celu opracowanie nowych rozwiązań przyspieszających chłodzenie detali. W pracy analizowano wpływ wartości temperatury detalu na wyniki pomiarów oraz przedstawiono nowe rozwiązanie konstrukcji chłodziarki opracowane i opatentowane w ramach prac prowadzonych przez przedsiębiorstwo WALDREX Sp. z o.o. Konstrukcja jest wyposażona w izolowany pojemnik osadzony w ramie ze stali odpornej na korozję, w którym znajduje się wężownica oraz ciecz chłodząca, co umożliwia szybkie i ekonomiczne chłodzenie detali i utrzymywanie ich w określonej temperaturze.

1. INTRODUCTION

The development of civil aviation leads to constant increase in number of Polish and global air transport passengers. Between the years of 1993 and 2010 there was an eight-fold increase in the number of passengers serviced by Polish airport. Over next six years number of passengers doubled and reached almost 30.5 million creating the necessity for increasing number of airplanes in domestic airlines. At the same time, the development of military aviation and air transport increased the demand for modern aircraft and helicopters [1, 2].

Aircraft manufacturers commission production of many parts to subcontractors. These companies usually perform only a few treatment operations on the specific workpiece. The subcontractors are mostly small and medium-sized enterprises, specialized in a few technologically advanced treatment processes of aerospace parts. Aerospace parts are manufactured in complex and multistage processes. This concerns particularly parts of turbine engines working in extremely difficult conditions including high temperature, oxidising gases environment and severe mechanical stresses. Turbine engine components are manufactured in processes such as: precision casting involving directional solidification, machining, heat treatment, welding, surface treatment – particularly carburizing and deposition of thermal barrier coatings [3-10]. Most of the components are processed by means of machining (grinding, turning, milling) with use of highly advanced 5 and 6-axes CNC machine tools.

Production of aerospace parts is associated with many strict requirements. They are determined by standards drawn up by organisations of the representatives of the largest aerospace companies based on their many years of experience. The requirements relate mainly to the dimensions of the part, condition of the surface after treatment, mechanical properties, quality of the materials used, ambient conditions. Among others the most important is ambient temperature and humidity in the facility [11-15].

The correct ambient conditions are necessary to keep the workpieces temperature in a strictly controlled range between subsequent machining operations. This is problematic particularly in summer, as the air temperature becomes high, causing heating of the production facility building. High temperature prevailing the building has a negative influence on quality of produced parts. Air conditioning manufacturing allows maintaining the correct ambient temperature and the temperature of workpieces. Air conditioning also contributes to the correct operation of the machine to prevent heating electronic components to a high temperature. Installation of air conditioning in industrial halls requires large investments, causing significant increase in the production costs. Research and development work conducted by the companies are aimed at lowering the cost of production of aerospace components. Newly developed solutions also concern the cooling of machined parts. Accelerated cooling speeds up the quality control and decreases interval between subsequent stages of the treatment [6, 12-15].

The subject of the invention presented in this work is refrigerator dedicated for cooling workpieces after machining. Refrigerator ensures easy storage of workpieces and keeping them at given temperature independently of ambient conditions.

2. DESCRIPTION OF NEWLY DEVELOPED REFRIGERATOR

Refrigerators are commonly used in food and beverage industry to store food at low temperature. Construction of a refrigerator consists of several components such as compressor, evaporator unit, condenser, expansion valve, heat exchanger and thermostat. Cooling process is possible due to flow of cooling liquid (coolant) in a closed circuit. The compression of gaseous coolant causes its temperature to rise. At the next stage coolant releases its heat in the condensation process. The flow of liquid coolant through the expansion valve to the evaporator decreases its pressure and allows it to evaporate. This process is endothermic. Subsequently gaseous coolant returns to the compressor to begin next cycle.

Refrigerator developed by WALDREX Sp. z o.o. is equipped with cooling aggregate with circulation pump, cooling chamber and insulated housing. Diagram of the refrigerator is shown in Figure 1. The frame of the refrigerator is composed of welded rectangular hollow stainless steel sections – 1 with two shelves – 8 and 9. The frame is mounted in the insulated housing – 2 [16].

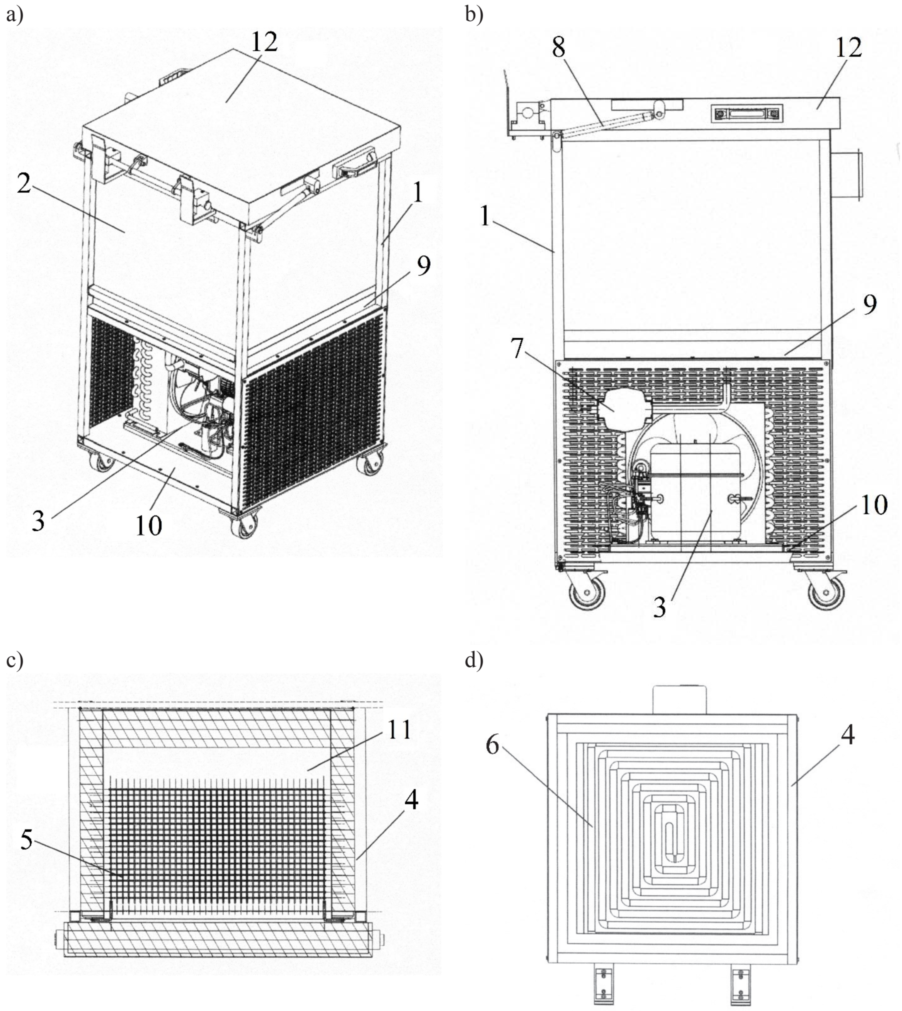

Figure 1 Diagrams of developed refrigerator unit and its key features: 1 – stainless steel frame, 2 – insulation, 3 – condenser unit, 4 – container, 5 – stainless steel mesh basket, 6 – evaporator unit, 7 – circulation pump, 8 – cover release, 9 and 10 – shelves, 11 – cooling chamber, 12 – top cover

The stainless steel container – 4 with cooling chamber – 11 is placed on the top shelf. Inside the container there is a welded stainless steel wire mesh basket – 5 and cooling liquid – water. The basket is equipped with handles to ensure easy and safe removal of the workpieces immersed in water. The pipe coil evaporator – 6, is situated between the container and mesh basket. The evaporator is a part of cooling unit additionally consisting of condenser – 3, circulation pump – 7 connected with the container. The components of the condenser unit are installed on the top shelf of the refrigerator frame. The cooling unit is equipped with: a compressor, a fan, a condenser, pressure switches, a sight glass, a fluid distributor and the valves system. Temperature is adjusted by external electronic controller.

3. THE EFFECT OF TEMPERATURE ON MEASURED DIMENSIONS OF THE WORKPIECE

The control of workpiece dimensions plays a significant role in the production of aerospace parts. Physical and geometrical dimensions are performed using CMM measuring machines usually with an accuracy of 0.001 mm, tolerances are often below 0.1 mm. The thermal expansion phenomena causes either expansion or contraction of the workpiece due to temperature alterations, which has a significant influence on the result of measurements. Therefore criteria describing ambient conditions inside the quality control facilities are strictly defined. The temperature of workpieces is elevated after the machining processes and often reaches 40÷60°C. Cooling of large volume parts down to 20°C may take several dozen hours, it corresponds particularly to parts manufactured of materials with high values of linear coefficient of thermal expansion such as aluminium alloys. Thus acceleration of this process is a critical issue in reduction of components delivery time and costs.

In present work the effect of stainless steel component's (Fig. 2) temperature on measured value of characteristic dimensions subjected to a quality control check. The measurements were performed using CMM measuring machine – Oberon 3D Aberlink Zenith 3 with workspace dimensions of 1000 × 2000 × 800 mm. The device enables performing measurements with accuracy of TP20 2.7 + 0.4 L/100 µm, TP200 2.6 + 0.4 L/100 µm i SP25M 2.4 + 0.4 L/100 µm, according to EN-ISO 10360-2 standard, respecting the temperature gradients as follows: 1°C/h, 2°C/24h i 1°C/m [14, 15]. Tolerance range for component's dimensions was set in range of ±5 µm. The component had a temperature of: -15, 20, 40 and 60°C.

The measurements results (Fig. 3) indicate a severe impact of component's temperature in analysed range on the values of dimensions. Only in the case of measurements at 20°C all of the analysed measuring distance met accepted tolerances. Both increase in temperature up to 60°C and decrease to -15°C caused alteration of values of measured dimensions. As a result, most of them did not fall within the tolerance.

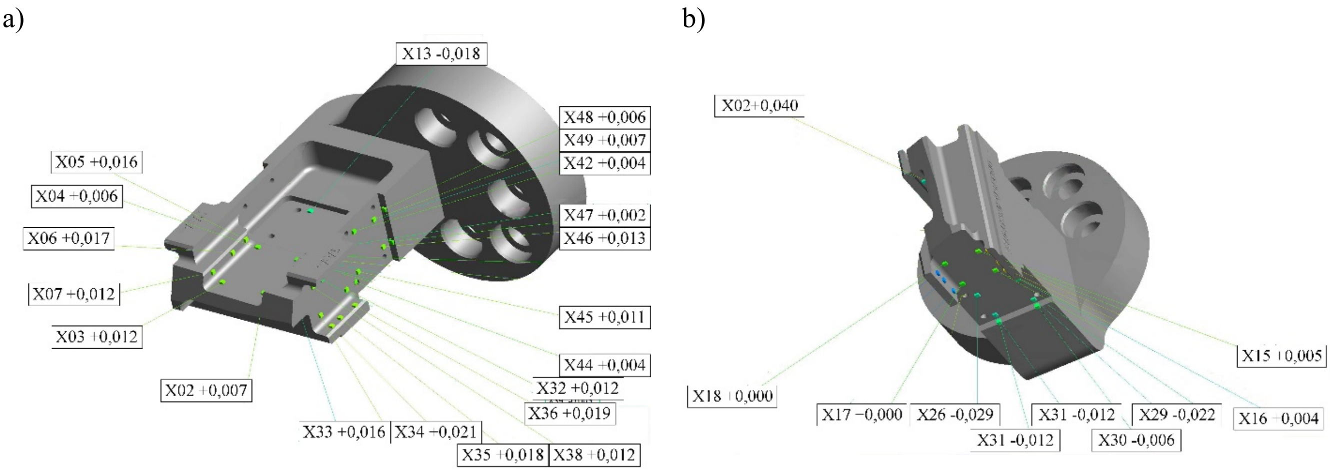

Figure 2 A view of measured component and deviations of dimensions measured in the experiment

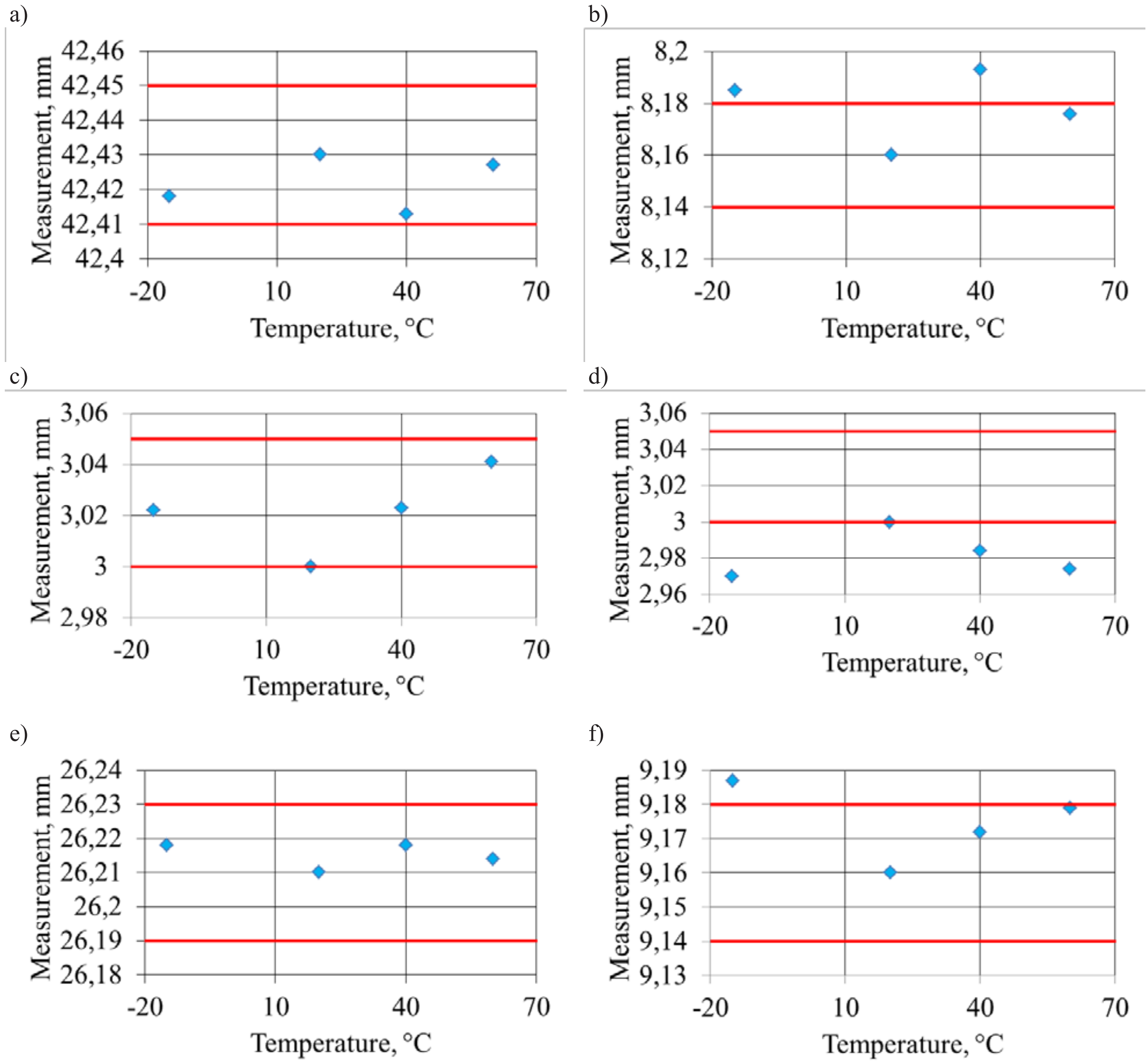

Figure 3 Measured dimensions of the component as a function of temperature: a) 42.4 mm between two circles, b) 8.2 mm between a straight and a circle, c, d) 3 mm between two planes, e) 26.2 mm between a circle and a plane, f) 9.2 mm between a straight and a circle

4. SUMMARY AND CONCLUSIONS

Development in aerospace industry raises increasingly higher challenges for companies engaged in production of aircraft components. Constantly growing demand for aerospace parts creates a need for implementation of new solutions to decrease the delivery time of the components. Strict requirements dictated by aerospace standards make the quality control a significant part of production process. Particularly the machined parts need to meet rigid dimensions tolerances. The components subjected to machining processes (e.g. milling, turning, grinding) may have their temperature elevated up to 60°C. The tolerances are usually ±0.1 mm or less and are specified at 20°C. Therefore the quality control measurements are carried out usually at 20°C. According to the performed analysis, variation of the component's temperature between -15 and 60°C has a critical impact on the result of the measurement. Controlled dimensions match the tolerance when measured at 20°C. Most of the measured dimensions did not meet the requirements after either decreasing the temperature of the component to -15°C or increasing it to 60°C.

Cooling down large volume workpieces, from 60°C to 20°C may take up to several dozens hours, which leads to prolongation of their production time. The new refrigerator developed and patented by WALDREX Sp. z o.o. enables a considerable reduction of the cooling time. The new refrigerator allows easy storage of workpieces between succeeding processing operations and quality control tests, which is especially relevant in the summer when ambient conditions inside the production facility become extreme (e.g. high temperature and humidity). The solution implemented in newly developed refrigerator involves the cooling medium – water, poured into an insulated container. Temperature is controlled by heat transfer between the water and the coolant flowing through the cooling coil placed inside the container. The mesh basket with handles ensures easy and safe removal of the workpieces from the cooling container. Presented device provides an economical solution for cooling components subjected to measurements control between subsequent machining processes or other treatment.

5. ACKNOWLEDGEMENTS

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