Special Aspects of Quality Assurance in the Design, Manufacture, Testing of Aerospace Engineering Products

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Abstract

A quality assurance model is proposed for the design, manufacture, testing of aerospace products based on robust design approaches and the widespread use of additive technologies. Examples of developing proposals and optimizing the design of aerospace engineering products based on the presented are given. Tests of optimized prototypes of products made by selective laser sintering show positive results.

Keywords: quality, quality assurance, design, robust design, FMEA, QFD, engineering, additive manufacturing, model

1. Introduction

Aerospace engineering companies use quality management approaches based on quality management standards (ISO 9001, AS / EN 9100) and proven engineering methods for quality management, such as APQP advanced product planning process, SPC statistical process control, measurement system analysis MSA, QFD quality function deployment, analysis of the types, causes and consequences of potential FMEA nonconformities. The application of these methods, along with robust approaches to design, three-dimensional design systems and engineering analysis (for example, ANSI), makes it possible not only to produce products that meet the requirements, but also significantly reduce costs at the development and design stages [1, 2].

At the same time, the potential of traditional Russian approaches and technologies for the design and manufacture of aerospace engineering products has been almost exhausted. In recent years, the introduction of additive production of aerospace technology has accelerated, especially thanks to advances in the production of metal powders for 3D printing [3]. Additive technologies present unique opportunities for the design and manufacture of promising aerospace technology products. Such well-known manufacturing companies as Boeing, Airbus, SpaceX, Blue Origin, Rocket Lab and others, every year in the designs of their products increase the number of parts made using 3D printing [3–5].

2. Examples of the implementation of modern approaches to quality assurance in the aerospace industry

Integration into a single system of robust approaches, engineering methods, software systems for three-dimensional design and finite element analysis, 3D printing makes it possible to create and produce promising products of a completely new concept.
2.1 Designing special technological equipment for implementing tests simulating the effects of aerodynamic loads of the assembly and protective unit of the scientific and energy module

In [6], a detailed description is given of the application of the QFD and FMEA methods in the design of a special technological tooling by a Russian aerospace industry company to implement tests simulating the effects of aerodynamic loads of an assembly-protective unit of a scientific and energy module. Using the QFD method [1, 2], the characteristics that most determine the quality of the tooling were revealed. As a result of QFD of the first level, the most important design characteristics of special technological equipment have been identified that have the greatest impact on the strength and rigidity of the structure, as well as the fulfillment of other technical requirements: tool material, thickness of ribs and sheathing sheets. During the following QFD levels, the most important design characteristics and production process parameters were identified. To ensure the quality of the design, an additional QFD analysis was carried out, which examined the parameters that ensure the quality of the design of technological equipment, as a result of which the key parameters of the design process of special technological equipment were identified: the need for calculations in the ANSYS system, the use of 3D-model geometry in the tasks of technological preparation of production.

An FMEA analysis [1] was carried out for the design of special technological equipment, as a result of which actions to prevent and reduce risks were identified. Potential design inconsistencies “Necessary structural strength”, “Material stiffness and the design of elastic pressure bags distort pressure” and others, which can lead not only to incorrect test results, but to damage to the tooling, are examined.

Taking into account the requirements laid down in the terms of reference for the design of special technological equipment for testing, and the results of the analysis by QFD and FMEA methods, technological equipment was designed. The calculations for the strength and rigidity of the tooling structure were made in the ANSYS finite element analysis software system. The estimated safety factor is not lower than required, therefore, the design meets the specified reliability requirements in real operating conditions.

2.2. Improving the performance characteristics of light and ultra-light launch vehicles (LV) with the introduction of modern approaches to quality assurance and additive technologies

Nowadays Russian Federation works at improving tactical and technical characteristics of light and ultra-light launch vehicles (LV) with the introduction of modern approaches to ensuring quality and additive technologies. The work is aimed at increasing the competitiveness of launch vehicles in the launch services market. The development of LVs of the light class and ultralight class is due to the currently observed tendency to increase the need to launch small spacecraft.

Competitors of this project to one degree or another are the projects of light and ultra-light carriers of the USA, China, Japan (Firefly Space Systems, Rocket Lab, etc.). The reduction in the mass and dimensions of the spacecraft and the spacecraft is a focused technical policy aimed at lowering the cost and increasing the availability of space services for the mass consumer. Accordingly, additive technologies are already used in a number of projects [5].

The analysis was carried out using the QFD quality function deployment method at the stage of developing technical proposals. At this stage, all the technical characteristics (mass, geometric, energy, etc.) of the future rocket are described. As a result of QFD, the most important implementation methods were identified for improving the tactical and technical characteristics of the launch vehicle, which have the greatest impact on the reliability and cost of putting the payload into orbit, as well as other requirements: reducing the launch vehicle mass by optimizing the design and choosing the launch vehicle manufacturing technology.

Decrease in the mass of the launch vehicle due to structural optimization and the choice of manufacturing technology for the launch vehicle require topological optimization of the design using such engineering analysis systems as ANSYS Topology Optimization, Siemens Solid Edge, Function Driven Generative Designer, and the use of advanced technologies for the manufacture of parts and assemblies, such as 3D printing.

Further, to assess risks and select areas for improvement, an FMEA analysis was carried out for the construction of a light class LV. Based on the results of the FMEA, proposals were developed to reduce risks, including: topological optimization of the design of highly loaded parts and assemblies, 3D printing of parts and assemblies obtained as a result of topological optimization, field testing (static, dynamic, thermal vacuum) of parts and assemblies manufactured on 3D printer before entering them into the design of the LV.

New features of three-dimensional design systems, topological design optimization and the use of additive technologies make it possible to obtain ultralight parts and assemblies (weight reduction in some cases reaches 55%), not inferior in strength to parts and assemblies that are currently in operation as part of the LV design. In addition, topological optimization and additive technologies can reduce the number of parts in the assembly units of the product design, the time and cost of technological preparation of production.

Before the introduction of additive technologies in the production of aerospace engineering, topological optimization, 3D printing and full-scale testing of prototypes...
(static, dynamic, thermal vacuum) are carried out. Next, the technological process of 3D printing is developed for each group of similar parts and assemblies taking into account control and destabilizing factors, followed by the development of technological instructions and an organization standard.

At the stage of introducing additive technologies into the production of aerospace equipment, the “Fork” part was used as a prototype. Optimization was performed (in the ANSYS system) and the part was manufactured by selective laser sintering. The material of the grown part is 316L steel (chromium-nickel steel). In fig. Figure 3 shows the initial geometry of the “Fork” part and a variant of optimized geometry. The weight reduction of the optimized part was 40%.

![Figure 1. The geometry of the “Fork” part: (a) source; (b) optimized.](image1)

![Figure 2. “Fork” part on the substrate of the 3D printer.](image2)

![Figure 3. “Fork” part Tensile Test Results.](image3)

![Figure 4. Bracket for installing sensitive elements.](image4)

3. The modern model of quality assurance in the design, manufacture and testing of aerospace engineering

The modern model of quality assurance in the design, manufacture and testing of aerospace engineering products includes the use of quality assurance methods, software systems for design and optimization, and the use of additive technologies (Figure 5).

The presented model is based on a new approach to the design and manufacture of products — bionic design. Figure 4 shows a bracket for installing sensitive elements of the spacecraft for remote sensing of the Earth.

Bionic design is the design and subsequent manufacture of products with an extremely complex design geometry, similar to the structure found in living nature.

![Figure 5. Bracket for installing sensitive elements.](image5)
modern QFD and FMEA quality assurance methods and additive production approaches.

Figure 5. The modern model of quality assurance in the design, manufacture and testing of aerospace engineering.

4. Conclusions and discussion

The aerospace industry is a promising industry worldwide. Aerospace technology manufacturers apply modern approaches to ensuring quality throughout the entire product life cycle. The key areas of implementation and development of the presented model of quality assurance in the design and manufacture of aerospace technology are robust approaches and parametric identification of the product model [1, 2, 7, 8]. The main direction of further use of the expected results is the testing of the proposed model for the development of new products of aerospace technology.

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