DESIGN OF CONSTRUCTION FOR COMPOSITES AND POLYMERS TESTING

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Abstract

The aim of this scientific work is development of construction for measuring equipment ElectroForce BOSE, which should enable dynamical-mechanical testing of composites and polymers specimens by hydraulic electrical actuators. The claim of construction is to enable specimen testing for max. applied force of 10 kN. The construction will serve for specimen testing for aeronautical and automotive industry, The construction claims biaxial material testing, and because of that the claim is also to enable as much as possible reliable simulation of working conditions. Also one of the construction claims was to enable interchange for each of the actuators which could be in operation of work at the same time. It is necessary to give a conceptual solution for construction design, and then model it in NX Siemens software, give all dimensions, choose construction material by applying finite element method, and compose technical documentation.

Keywords: Design of construction; composites and polymer testing; testing via. Actuators; NX Siemens; finite element method

1. Introduction

Turbulent market of today is pressuring companies to respond on customer demands very fast, with right quality and acceptable price. On Institute of Polymer Product Engineering (IPPE JKU Linz) we have to give quick response on companies requirements based on research or testing of some specific part in automotive or aerospace industry. These three factors (Time, quality, and price) are in an interaction and interdependence, so ideal balance between them should be found with the aim to achieve company satisfactory. To make high quality testing results for companies is often hard job, with many risks. One of those risks can be failure appearance during testing process, it is always really important to simulate real conditions in laboratory. This problem can be solved with various designing solutions, analysis, techniques, and methods, and one very famous method is Finite element method wider known as FEM.

In general this paper is focused on solving problem such as specific construction design for material testing. By usage FEM in NX Siemens construction has been tested in extreme conditions. The materials which are exposed to tests are mostly different type of composites and polymers. Taking into the consideration that the work has been done at the Institute of Polymer Product Engineering at University of Linz when we had encountered after the arrival of new testing machine for dynamic mechanical testing. We should designed and adjust the construction that will enable dynamic testing

of composites and polymers in laboratory conditions and multiaxial tensile conditions. The problem was how to come up with the preliminary solution, make construction model in NX Siemens, analyze it by finite element method in NASTRAN, and deliver all necessary technical documentation for its manufacturing.

The finite element method (which is used in this test) obtained its real impetus in the 1960s and 1970s by the developments of J. H. Argyris with co-workers at the University of Stuttgart, R. W. Clough with co-workers at UC Berkeley, O. C. Zienkiewicz with co-workers Ernest Hinton, Bruce Irons and others at the University of Swansea, Philippe G. Ciarlet at the University of Paris and Richard Gallagher with co-workers at Cornell University. Further impetus was provided in these years by available open source finite element software programs. NASA sponsored the original version of NASTRAN, and UC Berkeley made the finite element program SAP IV widely available. [4]

Solution is found in the steel construction which is strong enough to hold out forces over 10 kN. Principle to achieve this is shown in Figure 3. So, in this paper I give design solution for this specific requirements. As result, I offer optimal model which satisfies all requirements to achieve precise test results.

2. Defining the requirements in design, usage of experimental equipment and material selection

The process of progression from the initial specification (definition of the task or problem) to a solution, or complete set of information about each product can be viewed as a series of steps in which the alternate information processing and decision making. Each of the steps may indicate a decision which in any way can change the situation within the set of product information. A set of information about the product consists of all generated drawings, models, analyzes, calculations, technical instructions, notes and accumulated knowledge during the design process. Requirements in the design of construction were specifically define and given in a way:

- Strength of construction must allow performance tests of samples up to a maximum applied force of 10 kN;
- Dimensions of the construction must be compatible with implementation and adaptation of the experimental machine BOSE ElectroForce 3510;
- The design should provide the necessary interchangeability of all actuators that can be found in the construction;
- Design allow height adjustability and flexibility of the side plates;
- Adapt of the construction where actuators reinforce in the uniaxial mode without any complicated procedures, provide a replacement of the same, if necessary, in order to present valid test results.
- Dismantling of the upper plate

A detailed review and analysis of the properties of construction steel I came to the conclusion that the optimal solution of choice of materials for the construction is steel S235JRG2 / 1.0038 / Č0361, because it is very available on the market, affordable prices. [1]

Fig. 1: Taking measurements for construction on BOSE ElectroForce 3510 machine[1]

Test equipment ElectroForce® test instrument from BOSE offers outstanding precision and versatility for different types of testing samples. ElectroForce 3510 is designed for dynamic force up to 10 kN and it has a large range of frequency bands. Dynamics test of sample depends on the very characteristics of the sample, the method of fixing the machine, and the configuration of the sample. It's most commonly used for testing samples from the aerospace, and automotive industries, as well as for testing of composite and polymeric materials, and a variety of sporting goods and electronics. There are opportunities for testing the dynamic fatigue of material, work on testing fatigue is practically possible nonstop because the machine has a well-developed cooling system, and a lot of those. ElectroForce for linear actuator uses direct electromagnetic force, and quality design allows greater acceleration, more frequencies and high speed. [1,2]

3. Selection of computing tool - Siemens PLM NX

The system is Siemens PLM NX selected due to its comprehensive and possibility to upgrade modules for specific areas of design. This chapter presents modules Siemens PLM NX programs that allow companies efficient and effective innovation, and a control of whole range of services that are related to the individual phases of the product life cycle. The selection of this program is contributed due to the positive experiences of successful companies that use Siemens PLM NX, and numerous awards. NX (created by merging Unigraphics and I-DEAS program) is a complex CAD / CAM / CAE system that covers a large range of jobs in the construction and manufacturing systems: from the creation of the first preliminary proposal, simulation and analysis, modeling of individual components and assemblies, creating 2D documentation, programming CNC machines up to do quality control. NX is a system that allows data management and connection with a variety of information systems in the enterprise, such as Teamcenter system. NX is a fully associative with each other modules that unite the working environment and unique graphical objectively oriented database. Database that enables parallel operation of a engineer (Eng. Collaborative Engineering). In practice, this means that at some point develop a model can simultaneously perform the simulation of manufacturing parts on CNC machine, creating 2D documentation or analysis of the strength of the model. NX program consists of several modules:

- Modules Design (CAD)
- Modules for designing various kinds of tools
- Modules for the simulation of production on CNC machines (CAM)
- Modules for special areas of mechanical engineering
- Modules for the simulation of the finite element method (FEM, CAE)

Siemens vision of CAE simulations is to deliver engineering solutions that will decide on the management performance of the product throughout the production cycle. Siemens has improved and formed their products: Nastran, SDRC and I-DEAS NX™ CAE program. Effective use of simulation can help project managers reduce many costs and risks. CAE simulation enables engineers to understand, predict and digital improve of the products performance. Like that concept of design can be more researched which in turn reduces direct costs associated with expensive real prototyping and enables more educated decisions. The key is to increase the value of simulation features in common use as early as possible, if possible, and further development of the process. CAE solutions: NX Scenario - for quick assessment of strength, currents, thermal status and trends; NX Master FEM - (formerly known as I-DEAS Master FEM); NX Nastran FEA [7,8]

4. Solution and construction goal

The problem was how to design a construction that will enable the dynamic-mechanical testing of composite and polymer samples by means of hydraulic and electrical actuators attached to the frame structure, while she herself was attached on ElektroForce instrument. The application of structure was to enable testing of the samples to the maximum applied force of 10 kN. Since such structure is not in everyday use for school performance tests specimens, but is used to test samples in everyday use that are in extreme conditions, such as parts for aircraft and automotive industry, and for an authentic simulation of real conditions, performance tests required a multi-axis voltage state, which this construction provided. Also one of the conditions was to provide structure for interchangeability of the three actuators, which can be found in operation at the same time. After preliminary design followed the modeling software in Siemens NX, material selection and application of the finite element method to the construction, and the construction has satisfied all the conditions for the implementation of the envisaged tests.

The solution was to design main part of the construction as on figure 3 which consists two plates, top and bottom, and four supporting pillars. Additional components of constructions are two side horizontal plate on which are mounted hydraulic or electric actuators, one auxiliary detachable vertical plate with the same purpose as the previous two, but this, if necessary, can be dismantled in the event that we do not need multi-axis testing, but only one axis, its stabilization allow two identical carriers. [1]

Fig. 2: Construction for composites and polymers testing [1]

5. Results of stress analysis by FEM

Analysis by finite element method was performed in the software NX Nastran, and the conditions under which analysis is performed are set in the way it is conducted under extreme conditions when the construction is weakest and that is when the side panels are on half of the construction height, or when they are at maximum distance from the console attachment, also analysis is carried out under conditions where the load (force) is the highest possible which can occur as a result of the test material, and it is 10 kN. Testing has been done in conditions set in the way that the ends of the pillars of the structure designed as a console, and a force that occurs as result of electric or hydraulic actuators that is acting in the horizontal direction in the middle of the construction at a height of 10 cm above the side panel, which corresponds to a distance shaft of electric actuators with side plates when they are mounted on the same. These conditions correspond to the real, but also to extreme conditions in which the construction can be found in exploitation. It is important to say that the structure is very rarely found in extreme conditions, but due to security measures, the analysis is carried out in a manner such that these are normal conditions. The aim of the construction is to be openable and detachable for easier assembly and disassembly, to withstand these conditions and that on it as such could perform a variety of tests. Strength is the ability of opposition appears undue damage that may arise due to the load. This load, because of stresses and strains that produce, causing two main types of illicit damage: fracture (or the occurrence of cracks, leading to breakage) and plastic deformation. Of course, the limit stresses are relevant characteristics of strength of materials. This means that they should be selected according to the one (characteristic) values of strength, which can not be achieved. If the stress time-varying (dynamic), the relevant characteristics of strength will be the dynamic strength (the fatigue limit). In the event of prolonged static load, especially at elevated temperatures, the relevant characteristics of strength will limit creep or long-term static strength, and so on. It is clear that the values of the boundary stresses are different for different types of load (tensile, compression, bending, shear, torsion). The ratio of the relevant characteristics of strength and work stress which shows how many times the relevant characteristics of the strength is greater than the operating stress σ is called a degree of safety. [5]

The degree of safety v must be greater than or at least equal, very carefully and very responsibly chosen values so the required degree of safety v needed. [6]

After this expression strength is controlled at the relevant place of the component and therefore it is a condition of strength. In doing so, the required level of security is determined on the basis of experience and knowledge, and limits to him by

estimating the extent of damage which could arise from unauthorized impairment (ceiling), and the least possible expenditure of materials, that is the price of the product (the lower limit).

The ratio of strength and degree of safety v needed is the limit that the drive stress σ must never cross, and is called allowable stress.

After calculating the level of security of the structure which is 8.57, I carefully selected the required degree certainty which is 3, the inclusion in the above formula have been given to maximum stress σ construction during the test is 42 N/mm², and it is not greater than the allowable stress σ which is 120 N/mm². So we came to the conclusion that the design meets the requirements of strength: $\sigma \leq \sigma_{\text{allowable}}$, 42 N / mm² $\leq$ 120 N / mm².

Comparing to other test results of similar construction this construction is strong and enough to hang out all possible loads in extreme conditions and give preciscous results. [3]

Fig. 3: Results of stress analysis by FEM [1]

6. Conclusion

In this paper, problem was to design and manufacture construction which enable composites and polymer testing in uniaxial and multiaxial conditions with max. applied force over 10 kN. This work gives solution by usage of principles of methodical design and development construction for testing composite and polymers materials in uniaxial and multiaxial stress conditions at the BOSE ElectroForce 3510. The procedure for making digital documentation for the construction and testing of composites and polymer materials in uniaxial and multiaxial stress is shown in the system Siemens PLM NX. In the practical part of the work is description of detail process of making a 3D model construction and its simulation by finite element method in NX Nastran, as well as the creation of technical drawings. Through the examples it's described development of construction and there are shown basic functions and features that are used in software Siemens PLM NX. It's very important that this work is based on new research. The results are showing that maximum stress σ in construction during the test is 42 N/mm², and it is not greater than the allowable stress σ which is 120 N/mm². So we came to the conclusion that the design meets the requirements of strength: $\sigma \leq \sigma_{\text{allowable}}$, 42 N / mm² $\leq$ 120 N / mm². Based on global growing production and manufacturing in future there will always be need for new researches and testing to implement our ideas in the real world and to protect ourselves.

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