Steel Structure Inspection Using a Laser Scanner Device with Finite Element Method

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Abstract The following research covers optimal solutions for design of connection joints in metal structures based on digital modeling and 3d scanning devices. The paper discusses the properties of metal as a building material, welds and bolted joints, where to use the FEM finite element method in practical application, as well as the stages of CAD computer modeling. Computer aided design covers the development of geometric shapes in a digital format. The structural model is designed using a portable laser scanning device. One of the joints is selected and a unit of force as a load is applied. The finite element method is the most common tool for solving engineering problems. Problems may concern structural loads, temperature transfer, fluid flow or electromagnetic potential. To solve given issues, finite element analysis involves transforming a large complex system into smaller elements. While it is easier to solve a small element using given variables, it can be solved for a large system.

Key words: CAD, 3D, SCANNER, MESH, CNC, CAM, FEM.

Introduction

Generally, steel structures in construction projects have advantages mostly for its physical and mechanical properties and therefore the ability to solve specific tasks. Steel structures are mostly required for their specific characteristics as a building material over the reinforced concrete. Steel structures and steel as a material could be considered in construction projects because of its weight, rigidity - to maintain strength both in compression and in tension, mobility - to move as a component. Therefore, steel structures in the construction projects were used to reduce the time required to complete the process. Timelines in the construction process, large scale projects, high quality and reliability, budget, aesthetics, these are the reasons to create or select new technologies for manufacturing structural components, ensure transportation of products, and a high level of process organization and automation. In the design of steel structures, it is important to choose proper connection nodes, calculate loads, manufacturing technologies and the use of different configurations. In general, for any form of design it is crucial to define elements and their mutual fastening connections. In reality, a clear boundary between a separate element and separately formed connections is often erased, since functionally they are combined with each other. The process of shaping a structure begins with the selection of elements and connections. The form of a structure is a specific set of many different elements, in a connection with each other, that constitute a certain system. The search for and study of new forms of construction design, today involves a wide range of researchers and specialists. It should be noted that it is the main challenge of the art and science of design. The challenge of designers is to determine not only the optimal form of the structure, but also the best and most acceptable ways of its implementation, of achieving its own form. It is this aspect, the identification of actually possible and accessible ways of shape, that largely serves as the main characters for assessing the quality of the technical solution and the solution of the problem of designing a structure. CAD technologies plays a leading role in construction practice, which facilitates the processes of implementing large-scale projects and additionally creates new opportunities. On the other hand, in modern engineering and technology, it is widespread to use three-dimensional scanning equipment in practice, which allows the conversion of complex and intricate geometric shapes into

digital vector format. The solution of the construction of buildings is a complex process, especially with the adaptation to digital manufacturing technologies, computer modeling and computing systems. Obtaining a geometric form through digital devices and computer modeling reduces the amount of time spent on project implementation. It also facilitates the manufacture of accurate prototypes and makes it possible to achieve different, difficult-to-obtain geometric forms. The capabilities of the hardware devices are always limited, requiring specific knowledge and qualifications depending on application and purpose. Given factors must be taken into account at each stage of project implementation and design.

Main Part

Digital manufacturing is versatile and is commonly used to complete engineering tasks, as well as in medical, biological, chemical and other technical or natural science directions. In construction practice, the use of given method requires certain limitations and restrictions, which can be classified in the following sequence during the design process: 1. Determination and analysis of the capabilities of the material used in the construction process; 2. Determination of the potential of digital production equipment, preparation, modification, equipment, according to the selected material and work specifications; 3. Design of a computer model based on the capabilities of the equipment; 4. Design of a computational structural model, setting specific functional and architectural requirements, checking reliability; 5. Use of a computer aided model CAD for programming digital equipment, writing a path and code for CNC device and digital manufacturing process CAM. Therefore, digital production is preceded by the generation of a computer model. This stage can be completed using various computer programs, directly drawing the geometry of the model in vector format. It is worth noting the existence of digital archives of drawn models and stores where ready-made forms are located. In addition, for our research, we will be able to obtain a model by measuring a physically existing object with a three-dimensional scanning device, during which the

ctual forms are automatically converted into vector format. After computer modeling, it is possible to use it not only for the purpose of digital production, but also for the calculation of the structure, by converting it into a digital structural model. The practice of computer calculation of a structural model dates back to the 1960s. Computer modeling, on the basis of which the above-mentioned process and digital production are carried out, has been widely established in engineering since the second half of the 1980s. Scanning devices are based on two methods of obtaining data: 1. Laser Based – which involves sending a set of rays from the device's sensor in the direction of the object and determining the coordinates of the segments that make up the surface on the x, y, z axes through the feedback of the rays from the object; 2. Photogrammetric – this method involves perceiving the contours of the object's surface from different viewing angles using a photoactive sensor and a lens with the help of the focus effect; 3. Combined – when, in addition to determining the geometric shapes of the surface, determining the texture and colors of the surface is also actual. Data can be obtained in different sizes, which refers to the resolution of scanning geometric shapes. Objects scanned with high resolution often complicate software processing processes, so it is common to divide the object into sections and perform work in parts, depending on the capabilities of the computer. The study uses the Sense 3D scanner (Figure 1), which is based on the photogrammetric method of data acquisition.

Fig. 1. Sense 3D Scanner

The object choosed for scanning and research is a steel joint connection with traverses (Figure 2).

Fig. 2. Object for 3D Scanning

To create a high-precision model, it is recommended to scan the object several times, and then integrate each of them into the appropriate computer program (Figure 3). A shape decoding algorithm can be used in the integration process. The aforementioned algorithm decodes such primary figures as an ideal surface cone, cylinder, cube, etc. The system consisting of combinations of the aforementioned figures can be compared with the actual scanned model, which allows us to determine deviations from ideal shapes.
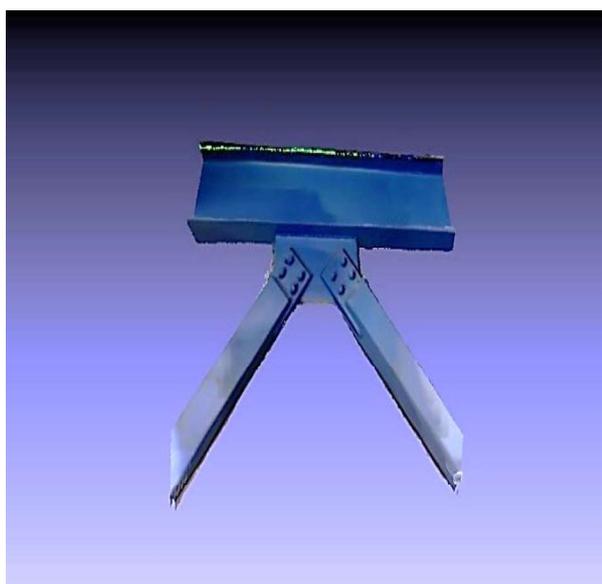

Fig. 3. Scanned Object

To build a digital computational model, used the computer aided software - Solidworks, where it is possible to both model and assign appropriate physical and mechanical characteristics to the components of the model. First, the model is built using an actual data from obtained by 3D Scanner device (Figure 4).

Fig. 4. Computer Aided Model

It is important to assign physical and mechanical characteristics directly to the scanned object (Figure 5). For this process, it is necessary to a complete and high-resolution object by scanning, which is achieved by capable computer equipment and a powerful scanning device.

Property	Value	Units
Elastic Modulus	2039420	kgf/cm^2
Poisson's Ratio	0.29	N/A
Shear Modulus	815768	kgf/cm^2
Mass Density	0.00787	kg/cm^3
Tensile Strength	3314.0575	kgf/cm^2
Compressive Strength		kgf/cm^2
Yield Strength	1835.478	kgf/cm^2
Thermal Expansion Coefficient	1.22e-05	/°C
Thermal Conductivity	0.124044	cal/(cm·sec·°C)
Specific Heat	107.075	cal/(kg·°C)
Material Damping Ratio		N/A

Fig. 5. Phisical and Mechanical Properties of Material

After creating geometric shapes, they are transformed into a digital structural model,

each of whose constituent segments is a finite element. The larger the amount for this element (Figure 5), the more difficult the calculation process becomes for a software.

Fig. 6. Body Mesh Prepared for FEA

The geometric shape model is converted into a mesh. Generating the mesh allows for FEA calculations. Each component of the mesh represents a finite element. Finite elements are connected to each other according to physical and mechanical properties of material. Determining physical and mechanical characteristics is necessary to obtain stress-strain values in structural elements (Figure 7), and its connections (Figure 8).
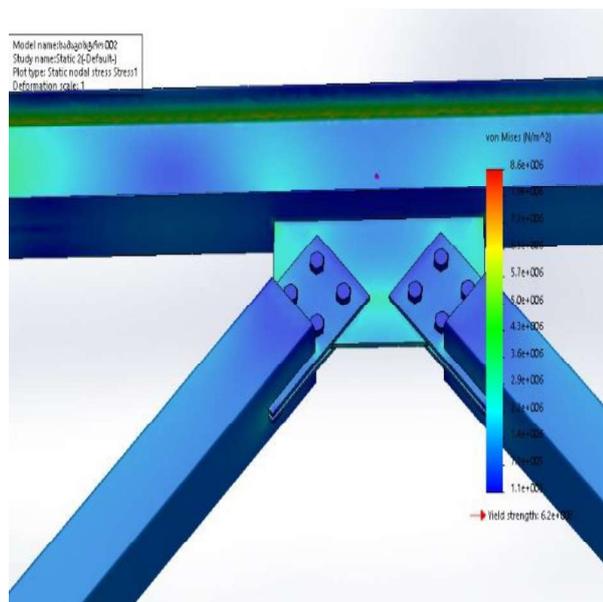

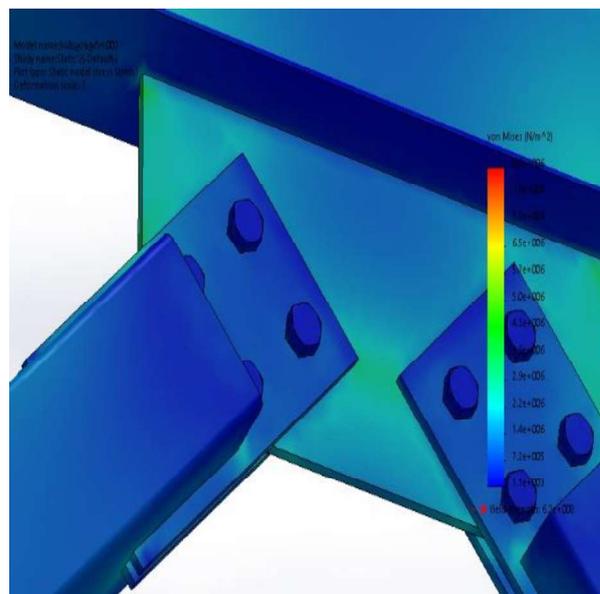Fig. 7. Stress Distribution with CAD Model

Fig. 8. Bolt Connections

Based on CAD modeling, in addition to defining stress and strain, FEA gives the ability to determine the actual displacement (Figure 9).
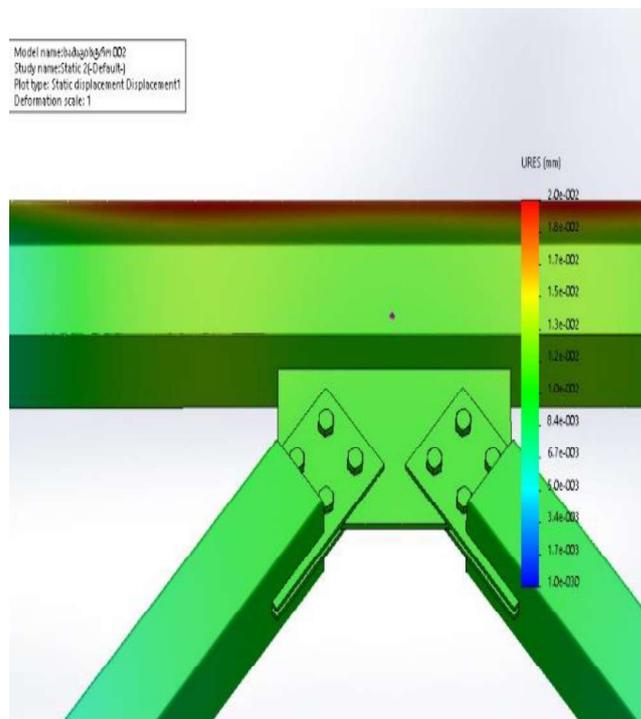

Fig. 9. Actual Displacement

Conclusions

The given method makes it possible to improve the structural model and connection

nodes, in particular, to cut out sections where the stress is insignificant and to reduce the weight of the frame. In the case of solving problems using this method, the created digital models can be used at the level of computer aided manufacturing CAM, which significantly simplifies and speeds up construction processes. Involving digital manufacturing technologies into construction processes significantly reduces not only time spent on completing the tusk but also significantly lowers the costs and expenses on building materials.

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