Utilizing the 3D modeling technology to design a welding fixture

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Abstract. The article discusses utilizing the 3D modeling technology to design a welding fixture for the mechanical engineering industry. To improve the efficiency of the design process, we used the NX computer-aided design (CAD) system as a design tool. We describe the process of developing 3D models for individual components of a welding fixture with the said system. The possibilities of utilizing the created 3D model to analyze the finished product in kinematics by means of the NX system are considered. An algorithm to compute the parameters of the welding fixture using the finite element analysis (FEA) is described. As evidenced from practice, utilizing the 3D modeling technology allows design engineers to significantly reduce the time spent on a welding fixture design and implementation at a machine-building enterprise.

1. Introduction

The use of accurate welding fixtures allows manufacturers to improve the quality of welds and the installation of welded products, to increase production efficiency and to expand the capabilities of the welding equipment applied in high-tech types of welding, such as robotic and spot welding [1, 2].

The welding fixture that meets up-to-date requirements must be sufficiently strong and rigid and the fastened parts must remain in the required position without deforming during the welding process.

At the production stage, a 3D model provides automated development of equipment and synthesis for numerical control software.

These features can be implemented at the design stage of the welding fixture production due to the use of computer-aided design (CAD) systems [3, 4]. As evidenced from practice, the design process of a future engineering product begins with its conceptual study that is to create a 3D model of the product.

3D-modeling allows building a product part or unit in their final state subject to all design criteria and features in the technical documents [5].

Thus, to manufacture an accurate welding fixture, it is necessary to develop its high-quality 3D model using CAD.

2. Computer-aided design system

To develop a 3D model of a welding fixture, we propose to use the NX CAD system (Siemens PLM Software) [6].

The NX system toolbox offers two options for creating 3D models:

- an option based on operating with basic spatial elements (block, sphere, cylinder, cone, etc.) combined by the operations of Boolean logic into a complex volumetric model;
an option based on a 2D object movement subject to a given law.

Additionally, NX provides a full range of 3D modeling tools that can be used to work out and document different constructive solutions.

The flexible editing capabilities of the 3D geometry proposed by NX synchronous technology tools make it possible to significantly simplify the task of introducing changes to the existing 3D model of a part, which utterly brings it to the physical prototype made of metal.

In other words, ample opportunities for modeling, analysis and visualization in the NX system provide the developer with complete freedom to create a conceptual design of a product [7].

3. 3D modeling of a welding fixture
Let us consider the NX process of creating a 3D model of a device fixating two plates before their welding connection.

When implementing the basing scheme in the fixture, the part is in contact with the installation elements at the support points. The continuous contact of the base surfaces of the part with the installation elements of the fixture is ensured by the application of clamping forces.

As the installation elements, we use a bearing plug with a spherical head that has the following dimensions (mm): Sphere r =D = 20; L = 40; H = 25; d = 12; c = 1.0.

Dimensions of the groove (mm) are: \(d_1 = d - 0.5; \) \(b = 3\).

The bearing plug construction parameters, their dimensions and designations are regulated by Russian state standards [8, 9].

It is possible to build a 3D model of this bearing plug in the NX system using Boolean operations of combining three cylinders and further modifying them.

First, a larger cylinder with a 20 mm diameter and a 25 mm length is built (shown in Figure 1).

![Figure 1. A 3D model of the first cylinder.](image_url)

Next, we build a second cylinder with a 11.5 mm diameter and a 3 mm length. Then, a third cylinder with a 12 mm diameter and height, respectively (shown in Figure 2).
At this stage of construction, each of the three cylinders is represented by an independent set of points.

Since the bearing plug is a monolithic detail, we combine the cylinders into a single structure. To do this, the NX toolkit provides basic Boolean operations - union, difference, intersection.

At the final stage, we construct the chamfer on the third cylinder and build a sphere with a 40 mm diameter; then, after performing a Boolean operation of intersection with the first cylinder, we get the finished bearing plug presented in Figure 3.

The 3D models of the remaining parts of the assembly tool are built based on the described methodology.

At the next stage, the parts of the fixture must be assembled.

To do this, an assembly file is created. We load the assembly components into the working window (the models of previously created parts) and impose them on the coupling components.

Figure 4 illustrates the 3D model of the welding fixture that consists of a base (plate), lever clamps and fixing elements.
One of the important advantages of 3D modeling is the possibility of kinematic analysis of the welding fixture components. Figure 5 shows the operation of the clamp that ensures uninterrupted contact between the base surfaces of the part and the installation elements - bearing plugs. This model allows the user to identify errors made in the design.

In addition to the described features, a 3D model allows calculating the part parameters under load using the finite element analysis (FEA) [10, 11].
The algorithm for calculating the plate parameters in the NX system with FEA consists of the following steps:

- Step 1. Setting material properties of the plate.
- Step 2. Dividing the plate into finite elements.
- Step 3. Simulation of applying the actual load.
- Step 4. Calculating the plate parameters using FEA.

The NX system provides an opportunity for visualizing the calculation results, for instance, to create a chart of the stress distribution in the plate (shown in Figure 6).

![Figure 6. A chart of the stress distribution in the plate.](image)

The obtained chart allows the design engineer to make a conclusion about the presence of problem areas in the investigated product, to perform a design correction of a welding fixture that fulfills the requirements for strength and rigidity.

4. Conclusion
The article presents an example of utilizing the 3D modeling technology to design a welding fixture. As a design tool, we used the NX CAD system.

The created 3D model allows the design engineers to perform automated research of the engineering products under development and to synthesize the technology of its manufacturing.

Due to utilizing the described 3D modeling technology, apart from improving the quality of the welding fixture, it was possible to significantly reduce the time spent on its design and implementation in a machine-building enterprise.

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