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CAVE 3D PROJECTION SYSTEM IN THE PROCESS OF PRODUCT DESIGNING

Abstract. The article presents changes taking place over the years in the organization of the preparation of technical and construction documentation. A modern CAVE 3D projection system, implemented at OBRUM for supporting design processes, is discussed. The principle of system operation, its characteristic features and limitations are described. The summary emphasizes the advantages of the system that enable elimination of errors and direct contact with the customer at the stage of creating a conceptual design of a device or of product design to be submitted for approval.

Keywords: design, engineering, virtual prototyping, 3D design, CAVE 3D projection system, technical documentation, design documentation.

1. INTRODUCTION

The task that OBRUM has always been assigned with was to conduct comprehensive scientific, research and development work aimed at preparing and launching manufacture on an industrial scale of new or improved products. This task remains valid and OBRUM actively participates in the process of technical modernization of the Polish Armed Forces.

The changes that OBRUM has undergone over the years: of the form and ownership structure (from an experimental manufacturing plant to a commercial company that now is part of the Polish Armaments Group (PGZ)) required the management to make organizational and technical decisions aimed at attaining the best possible results. There were expectations that modern structures with features competitive on the Polish and foreign markets would be created under optimized conditions of funding research and development. The process was formally explicated in a document issued by the Ministry of National Defence: Decision No. 72/MON [1].

In the processes of creating a product in a full cycle of implementation, starting from the concept through scientific analysis, design work, research and development and engineering, up to the implementation of the results of work in the form of batch production, among the most important elements of work are the processes of developing and verifying the technical documentation of the product. All requirements and procedures of drawing up documentation at particular stages of creating a new or improved product are described in Decision No. 349/MON [2].

In its organization chart, OBRUM had always included a unit responsible for this scope of activities. Its structure and its name also changed with time. Some of the designations given to that unit included: Department of Studies, Engineering Department, Design Department, and now Design Office [3], [4].

In the course of over 50 years of OBRUM's research and development activities, the design methods and available tools evolved. A major breakthrough, in both qualitative and quantitative terms, in the work of the designer/engineer at OBRUM was the emergence of computer techniques that supported the design process. Computer techniques were gradually implemented at OBRUM since the beginning of the 1990s. Changes [5] that have occurred over the years in design techniques, from working on the drawing board (using the drawing toolbox and drawing with ink on tracing paper), to the modern execution of device design, were tremendous.

Throughout the years of the functioning of the unit responsible for the design and construction processes, there were also deep organizational changes resulting indirectly from existing tools, including available software, computer programs enabling virtual prototyping in 3D space [6], [7].

2. IT SUPPORT FOR DESIGN WORK

In the design process, one of the key elements of the cycle is the development of a conceptual design or preliminary design, often in many variants of the solution that allows technical analysis in accordance with the formulated requirements or the Technical and Tactical Objectives. At this stage the design verification is very important, which is aimed primarily at detecting and minimizing possible errors. An important element of this work is also the communication with the client/contracting entity that allows verification of requirements and expectations and making arrangements at the initial design stage.

The availability of modern IT tools at OBRUM enables virtual prototyping, computer modelling of parts and units in a 3D space. This provides the possibility to verify the mutual functional interrelations and the initial elimination of possible errors already at this early stage. Checking and verifying the documentation drawn up is a multi-stage process which ends at the stage of preparing the target "flat" documentation in 2D.

At OBRUM, SolidWorks 3D software is primarily used to develop and produce design documentation. This tool [6] allows for advanced parts creation by combining solid and surface modelling in one environment. Various operations available in the system are used to create parts:

- base extrude;
- base rotate;
- extrude multiple;
- cut in solid by extruding;
- rounding the edges of solids;
- chamfer;
- adding thickness to surface.

2.1. Verification of design documentation

During the fabrication of a model of a part, a list of operations carried out in the fabrication is automatically created. In each of these operations changes can be made by editing the contour from which the part was created, and changes can also be made in the operation itself by altering its parameters. Each part is automatically assigned a weight and material properties, and that part can be used in various assemblies being designed. Assemblies formed from the parts created have their weights and moments of inertia automatically adjusted.

Movement analyses can be performed and loads on individual components can be determined already at the stage of sketches (preliminary design). Fig. 1 shows a functional model of a complex device (a truck-mounted bridge, represented in the form of a sketch), for which analysis was carried out of its movement during its deployment. The individual elements in the form of a sketch were assigned approximate weights and, where possible, moments of inertia. During the analysis, the forces acting in the cylinders and the pressure on the ground of the first wheel of the truck and of the support were calculated. This allowed to determine whether the whole set will not lose its stability during its deployment. The forces created are presented graphically in Fig. 2.

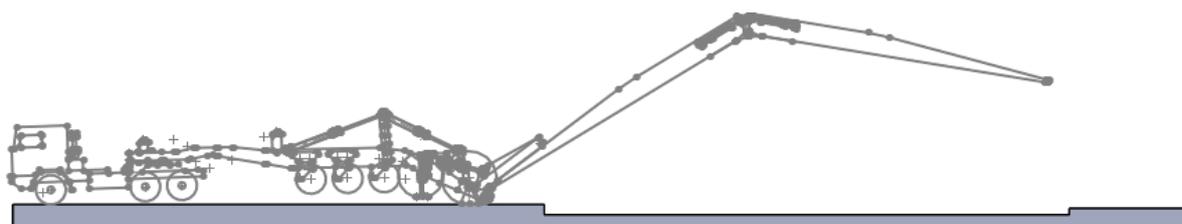


Fig. 1. Bridge deployment

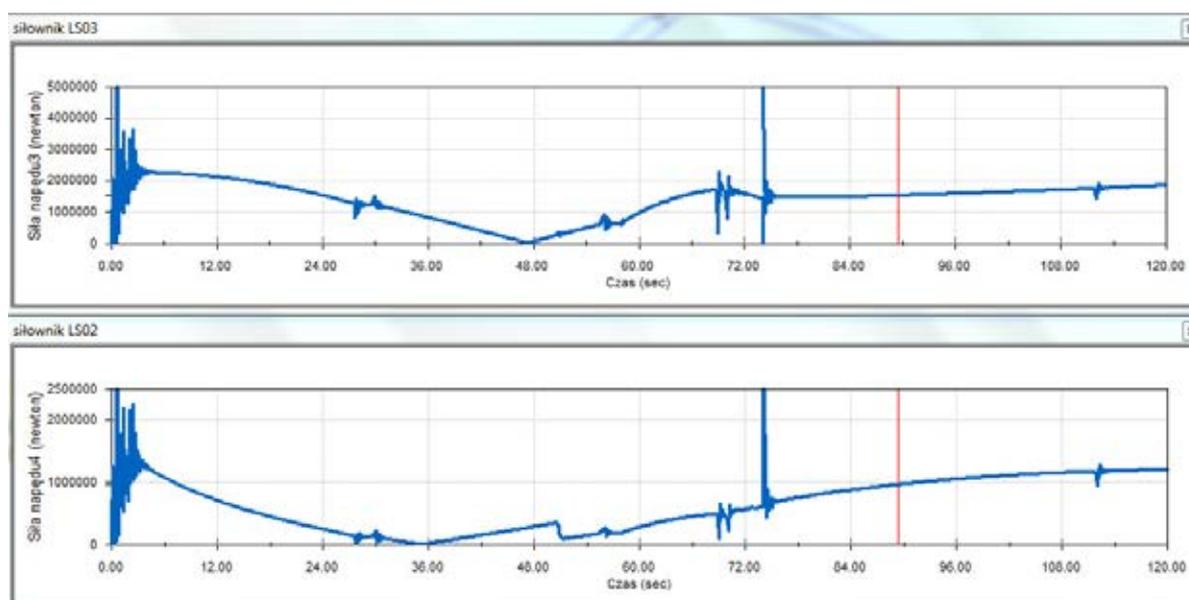


Fig. 2. Examples of graphs plotted during analyses

After developing all the elements of the device in the form of 3D models, a complete analysis of the movements of the device can be performed, using the information about the weights of the assemblies and their moments of inertia. During such complete analysis, collisions occurring between the various moving assemblies can be detected. This way potential errors (collisions) can be eliminated at the stage of designing.

Individual parts can be transferred from the assembly or device motion simulation process to the SolidWorks Simulation software and strength analysis of these parts can be carried out. This procedure ensures correct operation of the assemblies during the operation of the device. A tool that supports the computation processes and utilizes the finite elements method (FEM) is a module included in the PREMIUM software package [6].

Fig. 3 presents the results of the FEM calculation of the frame of bridge-laying vehicle shown above (Fig. 1).

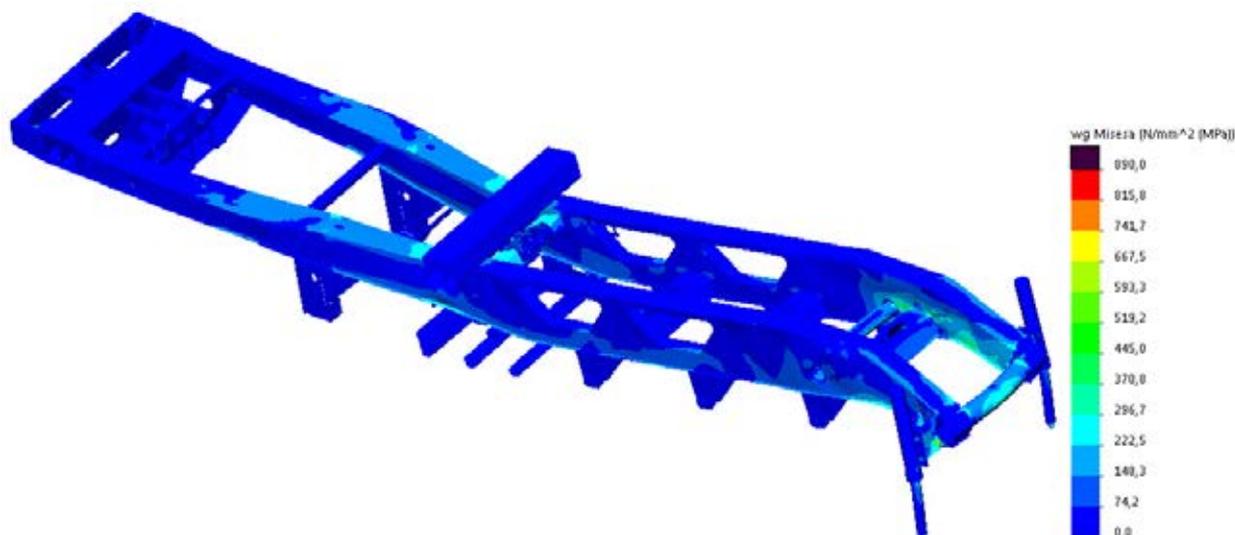


Fig. 3. Distribution of reduced tensions in the vehicle frame according to Huber-Mises hypothesis

After completing the design model, 2D documentation of all parts and assemblies is generated. When such documentation is generated, all drawings have the same dimensioning style, line thickness, and cross-section and view markings depending on the settings of the 2D documentation templates. Lists of materials are automatically created, specifying the numbers and amounts of the material needed to manufacture individual parts.

The developed design documentation is then verified in virtual space. With the correct standard component databases, comprehensive verification of assemblies and parts is possible. Thanks to this, there follows another stage of verification that minimizes designer/engineer errors. This stage of work has a major impact on the cost of eliminating errors during the fabrication of the product from metal.

In the further development phase, after fabricating the product from metal, the product(s) is/are subjected to bench and factory testing. The final act of verifying the developed product are qualifying tests, carried out under the supervision of representatives of an appointed state commission. The results (remarks, conclusions, recommendations) of all tests are reflected in the necessary verification of the created design documentation after each stage of the research.

The described methodology of verification of design documentation applied in OBRUM's current activities may be considered a "classic" procedure.

3. CAVE 3D PROJECTION SYSTEM

Rapid development of computer science and image projection devices (projectors, 3D projectors, monitors, projection screens) over the last decade yielded the appearance on the market of a large number of innovative devices and systems for image projection, either on the plane or in 3D space.

The scope of uses of the modern systems is very broad: from commercial applications (e.g. visualization of products with the presentation of their functions, home theatre organization) to military applications (complex simulators for training aircraft and vehicle crews and for conducting exercises of soldiers and uniformed services in virtual reality). Among the most interesting solutions which utilize multi-channel 3D projection are CAVE 3D systems [8], [9], [10], [11].

3.1. Operating principle

CAVE (Cave Automatic Virtual Environment) is a multi-dimensional system of stereoscopic display of high resolution images, equipped with a control device for navigation in 3D space and an integrated system for tracking motion and user gestures [11]. Example images displayed in the "cave" are shown in Fig. 1.

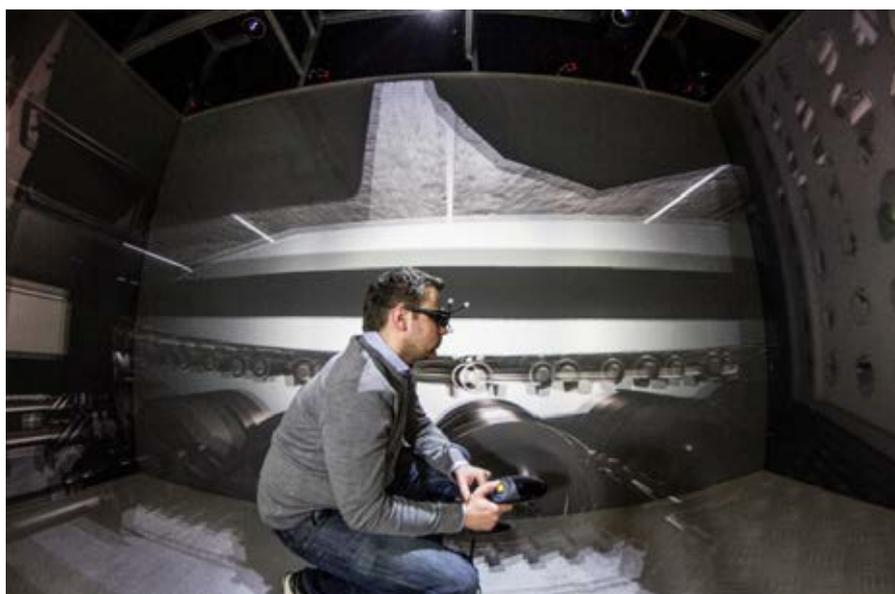


Fig. 4. Image displayed in CAVE 3D (photo by OBRUM)

A typical CAVE system is a rectangular cuboid whose edge length usually ranges from 2.5 to 5 metres. In addition to ready-made solutions available on the market [10], it is possible to design and build a system with dimensions adapted to the available space and user's needs. The projection system consists of four perpendicularly arranged projection screens (three walls and a floor), but there are also more sophisticated configurations with five or six surfaces, enabling the user to be completely immersed in virtual space. Special sensors placed on all real objects inside the cave and the use of an advanced motion tracking system (a system element is shown in Fig. 5) enable interaction of the system with the virtual world. The user, through the movements of his/her body, has the ability to manually navigate the image and elements placed in the scene, and the system automatically adjusts the user's position in the virtual environment,

changing the point of view and perspective, which further strengthens the feeling of immersion in the virtual space [11].



Fig. 5. Headset with passive markers (photo by OBRUM)

Numerous advantages, the most important being: stereoscopic spatial 360° image, wide viewing angle, 3D projection in real scale, surround sound, advanced motion tracking system with intuitive control and a specialized control device make CAVE 3D a modern visualization tool.

3.2. Scope of application

CAVE systems are more and more widely used and are utilized in various fields, among them:

- science and education;
- military and other uniformed services;
- entertainment;
- industrial engineering;
- culture and arts.

3.3. Use of the system in the designing process

The CAVE 3D projection system can be used as a modern, innovative tool for the presentation of conceptual designs, preliminary designs, analyzes (allowing for a thorough overview of the setup and layout topology and ergonomics of equipment in the product) and for testing all functionalities in a newly designed product. However, this requires developing and implementing a new methodology of integrated product design with a visualization system (CAVE 3D).

OBRUM has acquired and implemented the CAVE 3D system with the objective to use it in complex design work. OBRUM has successfully completed the first projects in this area. Practical applications in OBRUM projects included:

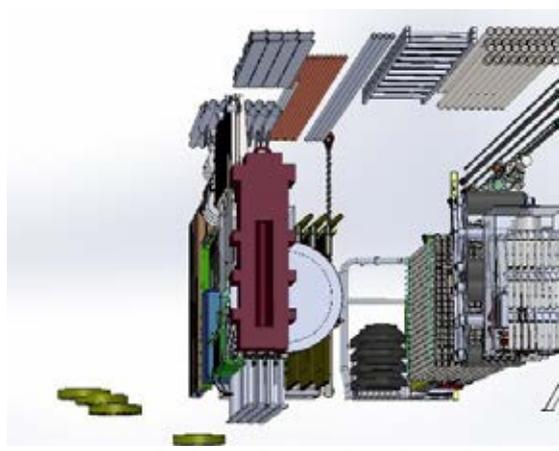
- virtual prototype of the PL-01 Concept tank (Fig. 6);



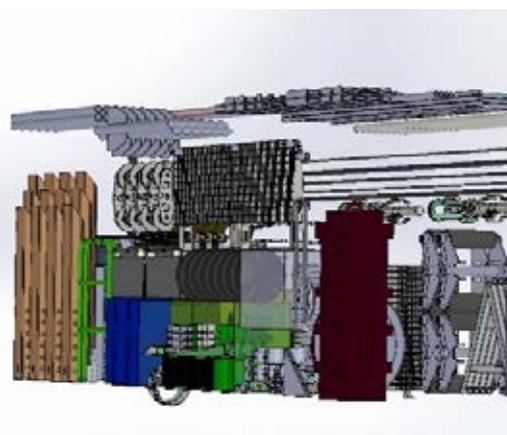
Fig. 6. Virtual prototype of the PL-01 Concept tank

The CAVE 3D immersive projection system has already been successfully used at OBRUM to build a virtual prototype of the concept vehicle PL-01 Concept, verify its ergonomics and develop its weapon configurators and basic mechanical systems [8].

- container for logistic equipment of the MS-40 bridge (Figs. 7, 8).



a - 3D design of container interior



b - 3D design of container interior

Fig. 7. Interior of the MS-40 bridge container

The arrangement of the equipment inside the container was designed with the help of virtual 3D prototyping (Fig. 7).

During the logistic designing of the container constituting the set of the MS-40 truck-mounted bridge, the CAVE 3D projection system was used to present the arrangement and layout of the transported parts (Fig. 8). The proposed solution was discussed with the customer: a representative of the Armament Inspectorate of the Ministry of Defence.



Fig. 8. Interior of the container – CAVE 3D visualization

4. SUMMARY

To solve complex and intricate constructional issues, the design team mainly uses 3D spatial models created with computer aided support. Usually, they do not see the whole device and all its functional features. By applying design integrated with a CAVE-type real-time visualisation system, the design engineer and the client can enter the visualisation system and find themselves virtually inside the computer model of the product under design [8].

The possibility of presenting different variants of the solution being developed makes it much easier to verify the conceptual or initial design for compliance with the requirements (design guidelines, Preliminary Tactical and Technical Specifications, etc.). It also allows to work out a common ground of communication with the client/contracting entity. The client can see in virtual space, in a 3D CAVE, what the designed product will look like, the arrangement and layout of equipment, operational interrelations of selected components, etc. It is possible to observe the changes made on an ongoing basis (this requires verified or modified design documentation). The multi-channel 3D (CAVE) projection system provides a particularly useful mode of communication, especially when contacts and visits of foreign clients are limited and when approval of the solution concept or presentation of the verified technical documentation is required.

Presentation of the product or of its components in the CAVE 3D system requires having complete and current CAD models integrated with the visualization system. Presentation (e.g. to the client) of subsequent current design versions (embodiments) requires design work to be carried out in advance by modelling, virtual 3D prototyping. However, it must be borne in mind that such work requires time and brings additional costs.

Our innovative multi-channel projection system has created new competencies for OBRUM, which adds to the competitiveness of the company both on the domestic market and on foreign markets.

The experience gained can be used to create further, mechatronic large-size products for military and civilian purposes.

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