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COMPUTER-AIDED DESIGN OF INDUSTRIAL INSTALLATIONS

PROJEKTOWANIE INSTALACJI PRZEMYSŁOWYCH Z WYKORZYSTANIEM PROGRAMÓW KOMPUTEROWYCH

Abstract

The paper concerns the design of industrial installations using computer programs. It also contains a description of problems that must be solved by a constructor who designs industrial installations, their components and characteristics at different stages of industrial design.

Keywords: Computer-aided design, industrial installations

Streszczenie

Artykuł dotyczy projektowania instalacji przemysłowych z wykorzystaniem programów komputerowych i zawiera opis problemów jakie musi rozwiązać konstruktor projektujący instalacje przemysłowe i ich elementy oraz charakterystykę poszczególnych etapów projektowania instalacji przemysłowych.

Słowa kluczowe: komputerowe wspomaganie projektowania, instalacje przemysłowe

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1. Introduction

Industrial installation design is a complex process and requires a solution of many problems, mainly mechanical ones but also electrical and those connected with the assembly, construction, control and measurement. Calculating individual components, the industrial designer needs to know not only the rules of construction, but also many regulations and standards that allow to carry out the correct calculations. The complete engineering design of an industrial installation contains the descriptive and executive documentation that includes many areas, so avoiding mistakes is very difficult. Therefore, different kinds of CAD computer software are helpful for the design and strength calculations.

2. Design stages

2.1. Design data

The basic source of data in order to begin the design work is a technical project, including the process design. The process design involves the detailed data describing the technology of manufacturing or processing products. The final product may be a finished product or a product intended for further processing. The whole process is presented in the form of diagrams, for example the so-called P & ID diagram as well as the descriptive part. From the designer's point of view, the process design includes basic information enabling to start the design work for the respective areas, such as machine, apparatus and device specifications, guidelines for selection of materials for components, data for the design of piping, fittings, guidelines for electrical, control and measurement projects. In addition, the process project includes the design data sheets necessary for the design of new devices as well as the layout drawing. On the basis of the process project, the data and the detailed design of industry installation for different areas can be carried out [1, 2].

2.2. Mechanical aspects of industrial installation design

When a technologist chooses equipment to carry out the process, he usually chooses standard solutions available on the market. However, it is not always possible to find the optimal size and efficiency of the available device. Therefore, some of the devices should be designed and manufactured in accordance with the data contained in the data sheet. It consists of a descriptive part that includes the process data and work parameters of a device as well as the data for the technical execution of the project, such as calculation parameters, size and markings of nozzles, the sketch with the overall dimensions and the location of each nozzle, the material data, anti-corrosion protection guidelines or guidelines for the foundation of the device and thermal insulation. The main parameters taken into account by the manufacturer are pressure and temperature of the manufacturing process. On the basis of these parameters, the constructor's task is to design a device and create the technical documentation. The new device should meet the technological specifications, endurance and safety, so the construction of a new apparatus or device requires knowledge not only of the typical design solutions and methods of strength calculations but also regulations and standards [3].

After having been designed and made, the installations must undergo inspection, that will guarantee safe operation. It particularly relates to devices with high pressure and temperature or when corrosive or explosive chemicals are processed. The design and implementation of such devices is supervised by such departments as the Office of Technical Inspection (UDT). Procedures and requirements which the designer should follow while preparing the documentation are contained in the regulations and specifications of UDT [4] and in Directive 97/23/EC concerning pressure equipment [5]. Common standards for the installation design have not been established yet, so, for example, in Sweden, the United States, Britain and Germany there are different standards, requirements and design guidelines.

2.3. Aspects of assembly of industrial installation design

The project of the assembly includes the detailed guidelines for installation of devices, appliances, fittings and other components included in the industrial installation. The proper assembly ensures the proper operation of the installation. The individual components of it are mounted on steel structures or foundations and are connected by pipelines. Pipelines ensure a product flow between the individual devices according to the technological process. The pipeline documentation is an important part of the assembly area as pipelines are exposed to high pressure, temperature and toxicity of the product flowing therein. The technical documentation and strength calculations of pipelines are subjected to the requirements of standards and regulations. The technical project of a pipeline contains the descriptive section with guidelines for implementing, installation, testing, and isometric drawing showing the route of the pipeline as well as the detailed specification of materials, a list of the components of the pipeline, a guideline for anti-corrosion protection and other requirements.

2.4. Construction aspects of industrial installation design

The technical project of the installation includes projects of foundations, buildings (e.g. warehouses, social rooms), supporting steel structures, platforms for equipment maintenance, motorways, access roads, etc. The constructor's task is to place individual system components in accordance with the guidelines. He should also take into account where to situate equipment of control cabinet and the foundation of pipelines. The building technology project includes the guidelines for the execution and acceptance of individual work, strength calculations and specifications of various elements of a building or steel structure, guidelines for anti-corrosion protection of steel and concrete elements

2.5. Electrical aspects of industrial installation design

The project scope includes the diagrams of electrical installations that provide power to individual devices and lighting diagrams of essential elements of installations, buildings and access roads.

2.6. Control and measurement aspects of industrial installations

Control and measurement equipment is used in every industrial installation in order to ensure control of the technological process. The control and measurement project includes

measurement, control and regulation diagrams, lists of equipment, control and measurement cabinet foundations including material specifications and descriptions of the construction, operation and measurement devices. The parameters that are supposed to be controlled, include, among others: pressure, temperature, flow, and level of refrigerant in the tank.

3. Computer-aided design programs

Visual Vessel Design program, developed by the Norwegian company Ohm Tech A/S [6, 7] is used for design and calculation of industrial installation elements. The assistant and aid function as well as the included manual help and facilitate the design. This program allows to use several design standards, such as European (EN 13445) and American (ASME VIII Division 1), UK (PD550), Swedish (TKN), and Norwegian (TBK2). It includes computational models that allow for the structure of typical industrial elements: heat exchangers, columns, tanks, etc. The constructor can use such materials and standard parts as bolts, flanges, gaskets, pipes, forgings, plates, foundation bolts, according to various European and international standards. The designer can generate a design documentation in the form of assembly drawings of a device and engineering drawings of its individual elements. Drawings can be exported to other CAD systems by means of files: .dxf and .dwg. Progress visualization of the project enables successive element joining and checking their position and dimensions in the modules: 2D and 3D. The program validates the data entered by the designer considering the limits resulting from construction and geometric solutions as well as regulations and standards. In addition, Visual Vessel Design program generates the general report, which lists the performed calculations, record of changes, calculation parameters, warnings, and information about errors that occur in the project, nozzle specification, a list of the components and materials that have been used, as well as the percentage level of the material usage (in the form of a graph). This information facilitates the analysis of existing stresses and allow for the optimal design of the device. AutoCAD P & ID software constitutes a part of a software suite for designing industrial installations by Autodesk. This program allows to create, modify, and manage piping diagrams and measuring equipment. The program includes a library of industry-standard symbols (PIP, ISA, JIS and ISO/DIN). A scanning tool enables the detection of errors connected with the position of elements relative to each other. The software allows to create reports and descriptions. The data can be exported to tables in drawings and to other programs, such as Microsoft Excel [8, 9].

AutoCAD Plant 3D is an application destined for industrial installation design. In this program, there is a direct exchange of basic data between the 3D model, piping diagrams and control and measuring equipment, as well as isometric and orthogonal drawings. This guarantees the control of data entry news and design changes. The program enables the design based on standard parts catalogs, such as: ANSI, ASME (B16) and DIN/ISO. It is also possible to use the extensive database of catalogs and the additional equipment library. This information is helpful for the design of pipelines and supporting constructions. Functions of AutoCAD Plant 3D application enables to lay out pipelines routes, the edition of the pipe line and its components and determine the method of joint. Isometric, orthogonal drawings can be easily generated from the 3D model [8, 9].

Autodesk Revit Structure application is used for the industrial design. This program, designed for 3D modelling enables cooperation with AutoCAD Plant 3D program. It is equipped with special tools necessary to design, analyze, and document the design, which significantly improves the coordination of projects from several fields and cooperation among designers. It also has options how to minimize designer's errors. AutoCAD Structural Detailing is an application in which the way of part construction and efficient creation of drawings is considered [8, 9].

AutoCAD and Autodesk Inventor are programs for the overall design and preparation of technical documentation. With broad capabilities, they are quite commonly used by designers. Additionally, Autodesk Inventor enables 3D modelling of plant equipment. Thanks to special features, the import of three-dimensional models from Autodesk Inventor to AutoCAD PLANT 3D program and combining them with piping models is possible [8, 9].

Autodesk Navisworks software enables a complex assessment of the installation validity check. It is possible to simulate movement within the model approximation, maximizing, shifting, rotation, etc., using advanced navigation tools. Through these capabilities, you can avoid potential problems before the installation construction. The software can detect errors of the installation component position and easily correct them [8, 9].

4. Examples of computer-aided industrial installation element design

4.1. Heat exchangers

Heat exchangers are important parts of industrial installations. There are several types and varieties of heat exchangers [10–12]. In the standard BN-68-2250-01 [13] heat exchangers are divided into: shell and tube shell-and-tube, and plate heat exchangers. Each of these heat

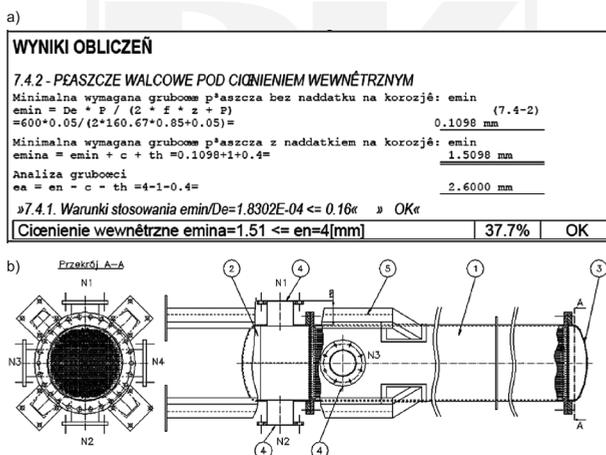


Fig. 1. Shell-and-tube heat exchanger: a – fragment of calculations, b – design solution: 1 – shell, 2 – upper head, 3 – lower head, 4 – nozzles, 5 – legs

Rys. 1. Wymiennik ciepła płaszczowo-rurowy: a – fragment obliczeń, b – rozwiązanie konstrukcyjne: 1 – płaszcz, 2 – głowica przednia, 3 – głowica tylna, 4 – króćce, 5 – nogi

exchangers can have a different structure. The most common ones are shell-and-tube heat exchangers. An example of heat exchanger shell calculations made on the basis of Visual Vessel Design program has been shown in Figure 1a whereas in Figure 1b there is the design solution, prepared in accordance with AutoCAD program [14, 15].

In accordance with the standards specified by TEMA [16] the shell-and-tube heat exchanger can be divided into three main components: the shell jacket and the heads: front head and rear head. Each of these elements can have an individual design solution according to the needs.

4.2. Tanks

Tanks constitute a different group of industrial installation components. In general, they are divided into horizontal and vertical tanks. A typical design of the tank, made by means of using AutoCAD, is shown in Figure 2.

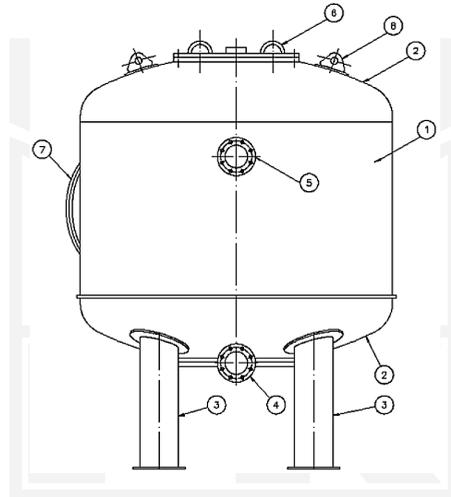


Fig. 2. Tank construction: 1 – shell, 2 – elliptical bottom, 3 – legs, 4, 5 – nozzles, 6, 7 – manhole, 8 – lifting lugs

Rys. 2. Konstrukcja zbiornika: 1 – płaszcz, 2 – dno wyoblone, 3 – nogi, 4, 5 – króćce, 6, 7 – właz, 8 – uchwyty

The tank consists of a shell 1, made of a tube or sheet of plate. Shell elliptical bottoms 2 are welded to the shell 1, closing the tank space. Additional elements welded to the upper and lower shell cover are legs 3 and lifting lugs 8. Besides technological nozzles 4 and 5, the tanks should have manholes 6, 7 that enable the internal audit, cleaning, tests and tank repair [14, 15].

4.3. Pipelines

Besides heat exchangers and tanks, towers, separators, pumps etc. are basic components of industrial installations [1–3]. All these components are connected to each other, according

to the diagram, by means of pipelines. The basic elements pipelines are made of are: pipes, flanges, reducing pipes, tees tee-connections, etc.

Figure 3 shows a fragment of the 3D pipeline technical documentation made by means of the Inventor program.

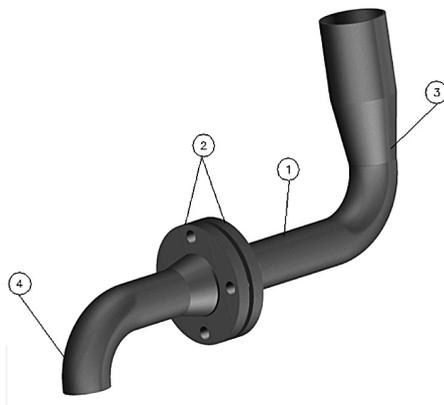


Fig. 3. Pipeline design: 1 – pipe, 2 – flanges, 3 – reducing pipe, 4 – elbow

Rys. 3. Konstrukcja rurociągu: 1 – rura, 2 – kołnierze, 3 – zwężka, 4 – kolano

Fittings that satisfy technological and safety functions are mounted in both the components and pipelines. The fittings include: valves (isolation, throttle, safety), bolts and measurement and control equipment. There are mechanical and thermal loads in the fittings and thus it must be selected according to its guidelines included in designed standards in order to ensure not only the implementation of tasks resulting from the ongoing process, but also for safety [14, 15].

5. Conclusions

Designing industrial installations is a great challenge for designers. Variety of issues arising in many areas require a lot of designer's experience and the proper coordination of a project preparation. The use of CAD software for design significantly improves the quality of projects and accelerates the time of their execution. A designer can use the library of ready-made elements, and add new ones if needed. Making changes in the design and review of documentation is done in an easy way. It is possible to check systematically if there are no errors in the project, which reduces the costs of modification during the construction. An important advantage of the CAD software is the ability to present a 3D installation model system, particularly during the evaluation of the project installation correctness.

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