End-to-end engineering technologies as resource-saving technologies

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Abstract. The article discusses approaches and methods to engineering design in light of INDUSTRY 4.0 technology. Versions of serial and parallel design are described. An analysis of end-to-end design in accordance with INDUSTRY 4.0 technologies is presented, the advantages of this approach to creating complex mechanical engineering facilities are shown. These examples show a reduction in resources and time to develop new design objects. So the use of Wave technology in design allows you to reduce the cost of engineering personnel by 66%, increase iterative procedures while reducing the time of design procedures, reduce the number of elements of the system, without reducing its reliability.

1 Introduction

INDUSTRY 4.0 technologies penetrate all spheres of human activity. These sets of technologies are aimed at improving technological processes and facilitating human labor. However, it should be understood that INDUSTRY 4.0 technology is only a tool in the hands of a person, especially this is relevant in the construction process. Whatever complex technologies are in human service, the process of development new products is a creative process that is impossible without a competent engineer. The engineer must have the skills to work with the relevant software products. The more complex the final product, the more complex the analysis and synthesis tools are used in the construction process. The construction procedure applies to all areas of human activity. The construction procedure applies both to mechanical engineering facilities, as well as to building facilities, enterprises as a whole, software products, etc. Let's look at the construction procedure at the machine-building complex.

2 Methods and Materials

The process of construction a complex machine is an iterative procedure (Fig.1) with six clearly defined stages [1]:
1. Identification of product requirements;
2. Problem definition;
3. Synthesis of design solutions;

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4. Analysis and optimization;
5. Evaluation of construction results;
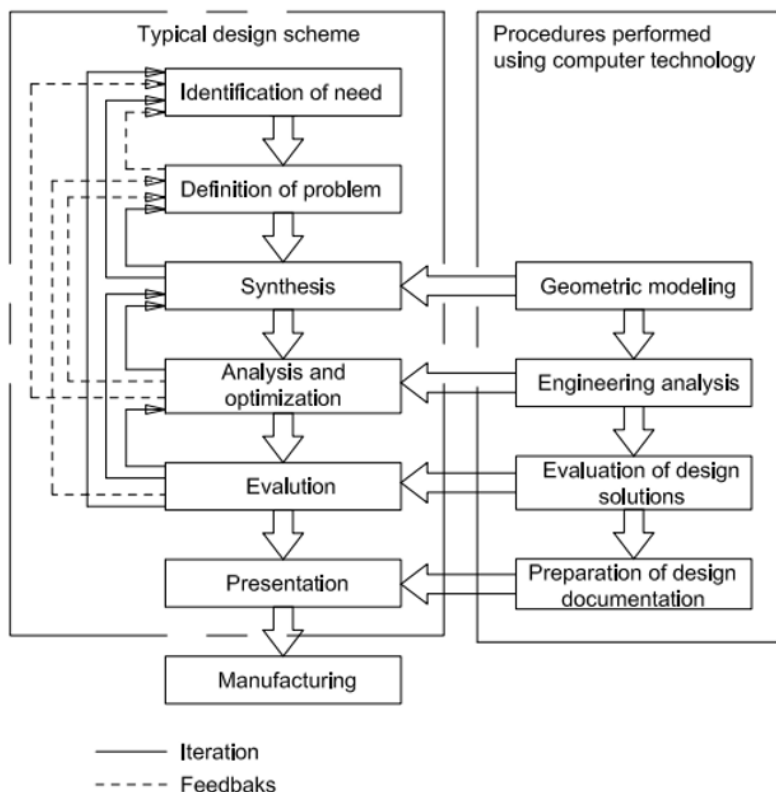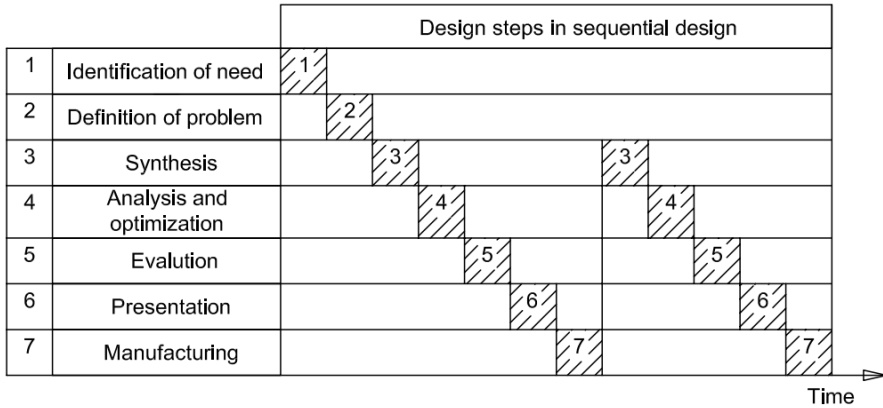6. Presentation of results.

Fig. 1. Construction diagram (taking into account typical Shigley construction diagram) taking into account the application of computer technologies
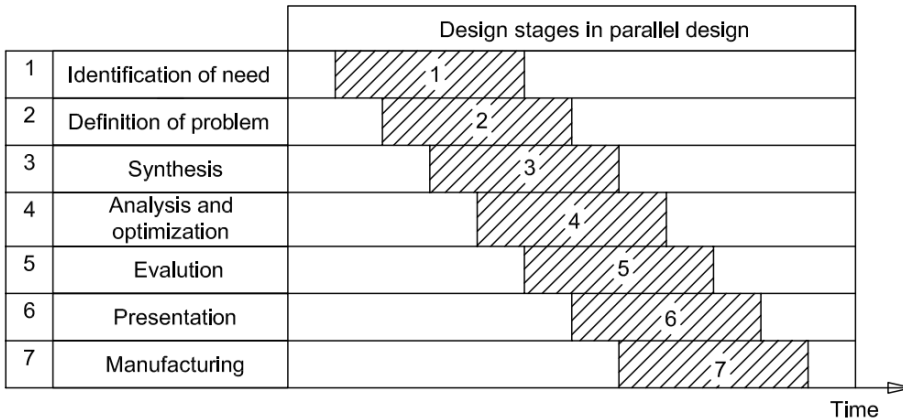
At the first two stages, the product requirement is identified, an accurate description of the problem encountered in the absence of a specific object (terms of reference for creating a fundamentally new object) or a description of the requirements for making adjustments to an existing object is created.

The stages of analysis and synthesis are often iterative procedures, closely interconnected. These steps are repeated until an optimal, conceptual description of the design object is obtained, taking into account design constraints. During the synthesis and analysis phase are performed geometric modeling (CAD) [2] and engineering analysis. Engineering analysis uses mathematical modeling. The mathematical models are analytical or algorithmic (simulation models). For example, for the development of analytical models are used software products such as: MATLAB, SimInTech [3]. These models are based on numerical methods [4]. Algorithmic or simulation models are CAE modules. These modules perform calculations based on the CAD model of the construction of the designed object. Engineering analysis of design in CAE modules is most often performed by finite element (FEA) method [5]. This method has proven itself well and gives reliable results.

At the stage of evaluation of project results, most often, they resort to the production of prototypes. Manufactured machines are tested in a natural environment. For example, agricultural machines operate in fields during the agricultural season and perform the types

of work for which they are designed. In case the production of the prototype is difficult (for example, it involves a large financial cost or the impossibility of conducting a full-scale test), a layout is made on a scale and tested in laboratory conditions close to full-scale. At this stage, can be identified problems in the design or its operation. After testing, if necessary, adjustments shall be made to the design documentation based on the test data.

At the stage of presenting the results, a package of documents is prepared for launch into the series of the designed machine.

a. Sequential Conctruction

b. Parallel Construction

Fig. 2. Sequence of project stages

Execution of all design stages is possible sequentially (Fig.2 a) or in parallel (Fig.2 b) [6, 7]. The fundamental difference between these approaches is the sequence in which each step is performed. In sequential construction, each phase begins only at the end of the previous phase. It will be appreciated that in this case the design process may be delayed in time. Also, in the event of a delay at some stage, they can lead to a breakdown in the design timeline. In the case of parallel construction, the engineering specification is issued to all process participants at the same time. This approach allows you to reduce the time of design procedures. It is on parallel construction that the end-to-end design method is based.

End-to-end design (Fig.3) is based on parallel construction. End-to-end design offers a number of advantages:

1. shortening the duration of project procedures;
2. possibility of simultaneous work on the project of a number of specialists;
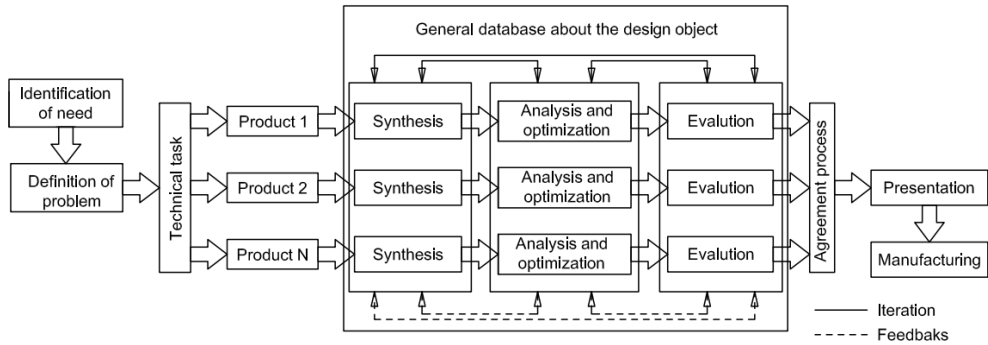3. possibility of avoiding production of a prototype [8].

Fig. 3. Stages for end-to-end design

The shortening of the design time clearly demonstrates Fig.3. The terms of reference for the development of units or individual machines, which will later become parts of one machine, go simultaneously to each division. The work is carried out in parallel, while the general information related to the final product is in the common database. Information is exchanged between all involved units.

A number of software products provide the possibility of simultaneous work of specialists. And it doesn't matter the presence of these specialists in one place. Work may be remote. For example, currently the software product NX Siemens implements WAVE technology [12]. This technology allows the simultaneous work of the designer, designer and technologist on the same object, allows you to reflect all changes in the design when they are made to it. WAVE technology was implemented in the NX Unigraphics program, later NX Siemens. This technology allows you to create a Link model with a link to the parent model. Link is a kind of shell and changes to this model require a change to the parent model. This approach allows technologists to develop technological tooling for the manufacture of a part, the designer to work with the appearance of the entire product, to engage in ergonomics, but you cannot worry that changes will be made to the parent part.

3 Results and discussion

Thanks to the development of construction and engineering analysis technologies, it is possible to avoid the production of prototypes [8, 9]. Modern software products make it possible to evaluate a number of design features, the expediency of using a particular material in machine elements, operability and many other design parameters without conducting full-scale experiments. Among such products are NX CAE [10] and ANSYS [11]. Engineering analysis is based on the finite element method (FEA). These products are presented on the market of the Russian Federation. According to the American Association of Automotive Engineers, by avoiding field tests, it is possible to reduce the duration of the project from 4 years to 18 months. [14].

Also, as an example of resource-saving technologies, we can consider the experience of Bye Aerospace developing an electric fully composite aircraft eFlyer 2. Thanks to the use of eFlyer 2 software products, it was possible to reduce the team of engineers from 50-60

people to 20, as well as by avoiding field tests by an order of magnitude reduce the time for the project [8].

Undoubtedly, such technologies can be called not only modern, but also resource saving technologies.

4 Conclusion

The development of modern construction technologies allows you to carry out the design process from the terms of reference to launch into the series with minimal time. INDUSTRY 4.0 technologies allow you to implement the most complex projects in a short time. In the hands of experienced and thought-provoking engineers, modern CAD is turning into a powerful tool.

The timely introduction of INDUSTRY 4.0 technology at the enterprises of the country will allow to master the production of high-tech products. The backlog in engineering now can lead to catastrophic consequences in a couple of years.

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