HEAVY MACHINERY - HM 2011, 85-90
ISBN 978-86-82631-58-3
Paper accepted: 30.05.2011

Basic principles of artificial intelligence in modeling assembly operations in CAM

Marina Pljakić[1,*] - Aranđel Babić[1]
[1] University of Kragujevac, Faculty of Mechanical Engineering Kraljevo

Abstract: *Virtual product design represents a technological key for reduction of costs arising from the errors generated in the processes of engineering design during product life cycle. It is important to establish a connection between CAD design of products and complex limitations of assembly operations in CAM so that the design process is provided with the conditions for development and modification in a virtual environment before the beginning of production. The advantage of this linking in design processes is in overcoming creation of expensive physical production systems so that all variant research could be carried out on a virtual model. This integration can be seen on the example of tank waggons***.** *Artificial intelligence is designed to collect, represent, organize, and use computer knowledge, and in the possession of properties, has a significant effect in establishing intelligent production.*

This paper is realized as part of exam on Ph.D. studies: Integrated design of prefabricated structures and processes, Faculty of Mechanical Engineering in Kraljevo.

Keywords: CAD, CAM, assembly, artificial intelligence.

1. INTRODUCTION

Assembly processes during the product life cycle represent a considerably higher level than composing parts into a whole, be it design of products or design of manufacturing technology at the component level. It is a milestone in the technological cycle, the point at which the product begins its lifetime and for the first time has the possibility of functioning. Hence, the most visible aspect of the product quality is reflected in the designed assembly process.

Traditionally, Design for Assembly DFA is based on studying Design for Disassembly DFDA, most frequently on the assumption that “if a part can be disassembled, it can also be assembled and vice versa”. In a real environment, this can be quite different from the inverse process of joining. It is known that the number of feasible assembly structures for a given product increases exponentially in accordance with the number of components. The analysis of conceptual solutions provides a conclusion that a designed optimum process of disassembly does not have to represent the best conceptual solution for assembly. Design for Assembly is an engineering process which integrates a large number of DFX approaches within simultaneous design of products and processes.

The complexity of assembly processes and technological processes for manufacturing components for the designed product has a huge influence on costs, profit and possibility of recycling. The engineering model of product integrates a large number of DFX approaches, where only after a detailed consideration can it be estimated and adjusted before it is launched into production (the milestone in product development). According to some authors, product design makes 6% of the costs intended for product development, where more than 70% of production costs refer to the phases of conceptual design. It means that good preliminary design decisions can be made only after detailed analyses of the complexity of production and product life cycle. *[1]*.

*Corr. Author's Address: Faculty of Mechanical Engineering Kraljevo, Dositejeva 19, Kraljevo, Serbia, pljakic.m@mfkv.kg.ac.rs

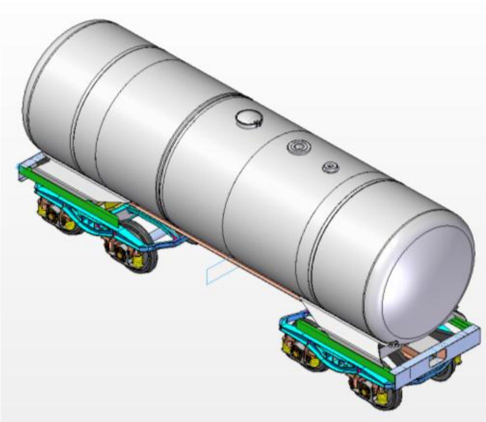

Fig. 1. *A model of a tank wagon*

2. ARTIFICIAL INTELLIGENCE AND DESIGN FOR ASSEMBLY

In addition to a half-century of intensive development, artificial intelligence is still the area that is difficult to define. One can say that it is part of computer science that deals with systems that connect the features normally associated with intelligence in human behavior. Intelligent human behavior including perception, reasoning, problem solving, understanding language, learning, communication and action in complex systems. Artificial Intelligence deals with intelligent behavior of artificial systems, with its main goal the simulation of human behavior on a computer, where the knowledge and use of the key features.

Research activities in the world is focusing on different aspects of design and planning for assembly process. Various approaches have been undertaken to develop specific aspects of the design and planning process, including product and process design methodologies, CAD and manufacturing (CAD/CAM), design for manufacture and assembly (DFMA), a detailed analysis of production and assembly operations, an automated sequence planning, layout and equipment selection, computer simulation of the assembly process, integrated systems and intelligent assembly and disassembly of the system.

Due to the complexity of assembly and product design, there is an increasing need to integrate artificial intelligence (AI) such as knowledge-based expert systems, and neural network, for maximum benefits and for expediting advanced design processes.

Introducing artificial intelligence to DFAD and implementing it effectively can yield several advantages. First, increase the design quality. Designers may need less training and expertise for utilizing CAD tools. Designers can obtain on-line advice on how to improve their work. Better quality designs with fewer errors can be expected. Secondly, artificial intelligence can reduce the cycle time of the design procedure. Besides saving the time of training, it can also save time for designers to obtain specific knowledge and problem solutions, thus, the overall design time is reduced, resulting in reduced cost. These advantages are important for wider application of DFAD practices in industry.

There are several ways to introduce artificial intelligence into DFAD, which are summarized as follows:

• *Rule-based knowledge (expert) systems* are programmed in LISP, PROLOG or expert system shells, and have been applied in industry (O'Grady and Oh, 1991)).

• *KBS for interface with assembly CAD*. Design for Assembly Consultation (DACON) was developed by Swift (1987) and provides a CAD interface for drawing assembly components after they are designed with expert analysis; Hernani and Scarr (1987) developed an expert system interfaced with CAD to recommend assembly design rules.

• *KBS for interface with facility design*. Facility Design Expert System (FADES) (Fisher and Nof, 1987) provides economic analysis and selection of assembly technology.

• *KBS for assembly and manufacturing design*. or Assisted Design for Assembly and Manufacture (ADAM) (Sackett and Holbrook, 1988)), generates advice on reducing the number of components, rationalizing the assembly and insertion guidelines. Chen and Pao (1993) combine neural network and rule-based systems for the design and planning of mechanical assemblies.

• *Constraint net knowledge systems*. In this approach, design knowledge is represented not as a collection of rules, but as a collection of interconnected assembly constraint objects. An efficient search can be performed over these networks to evaluate the propagation of design changes (Oh et al., 1995)). *[2][3][4][5]*.

3. ASSEMBLY OPERATIONS

Complex assembly operations considerably increase the costs of production of complex products. Also, the products whose dismantling requires complex operations increase the maintenance and recycling costs. Costs for assemblying and disassemblying significantly influence the costs in product lifetime, which requires the application of design solutions that provide efficient assemblying.

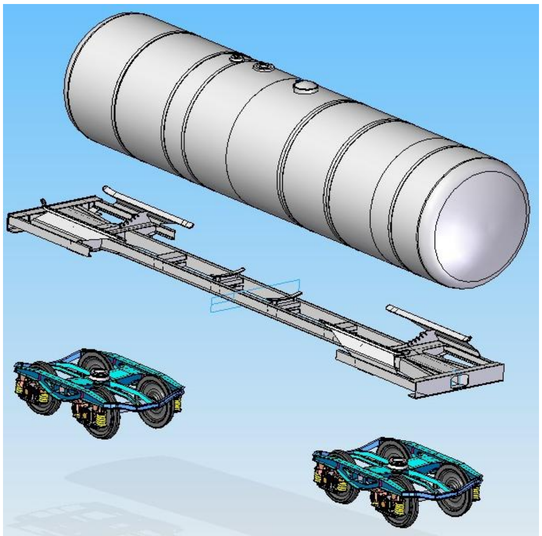

Fig. 2. *The main elements of the assembly of a tank waggon*

The complexity of assemblying can be defined as the complexity of restriction of mutual motion of the parts which are assembled. In order to prevent problematic assembly operations in the CAM environment, it is necessary to foresee the complexity of mutual assemblying of components during product design in the CAD environment by applying virtual tools for assemblying. The virtual system which connects design solutions from the CAD environment with the complexity of assembly operations in the CAM environment virtually evaluates and validates the design of product and assembly structure. The modelling and assembly technology can be used for manufacturing a tank waggon, whose main elements are the underframe, the bogie and the tank *[1]*.

3.1 Structural connections at the component level

In the design of assembly processes, a much better effect of assembly rationalization is accomplished by simultaneous analysis of the product structure and the analysis of connections at the component level. It is very important to design components in such a way that their problems in assembly could be solved at the same time. It means that the application of assembly criteria results, from the aspect of defined shapes, in well designed parts. The solution of the appropriate assembly process depends on the correct description of these characteristics of the part. From the aspect of assembly, the shape and assembly surfaces have a big influence.

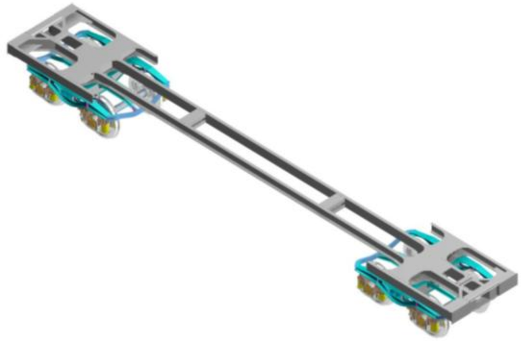

Fig. 3. *The assembly of the underframe and the bogie*

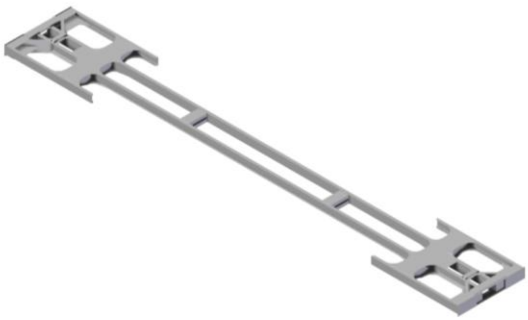

Fig. 4. A model of the underframe

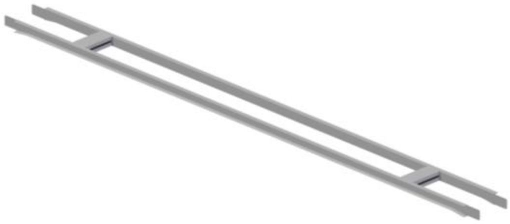

Fig. 5. *The central/medium girder*

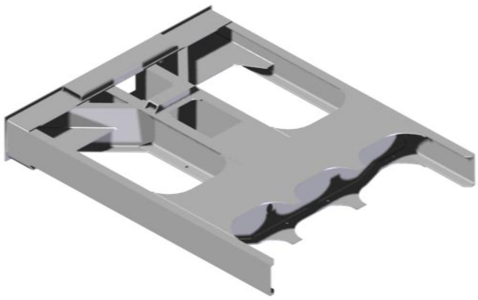

Fig. 6. *A model of subassembly of the cross bearer, headstock and sidemembers*

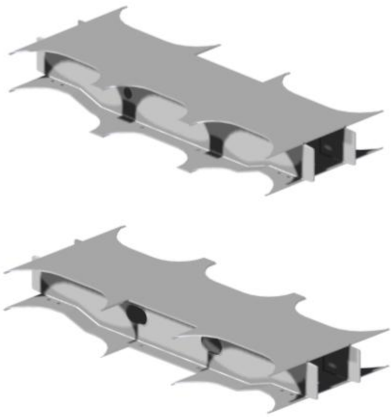

Fig. 7. *A model of the cross bearer*

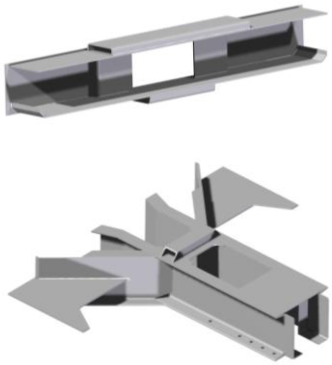

Fig. 8. *A model of the headstock with the beam*

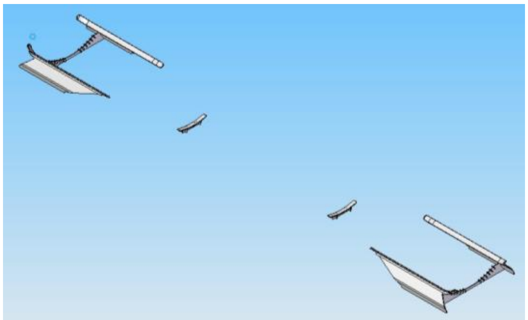

Fig. 9. Connecting elements between the tank and the underframe of a tank waggon

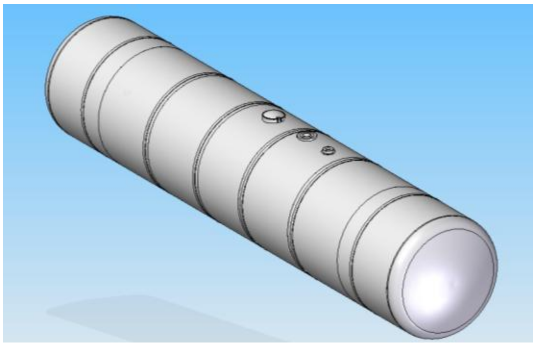

Fig. 10. *A model of the tank*

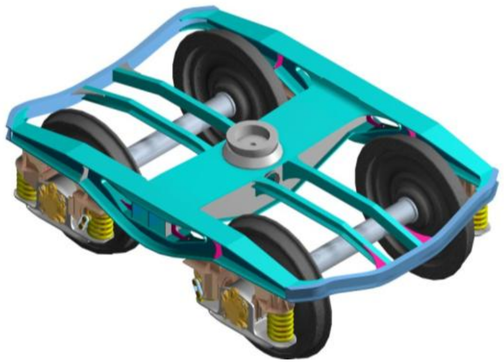

Fig. 11. *A model of the bogie*

4. A SYSTEM FOR CODING ASSEMBLY STRUCTURES

Most assembly operations can be divided into several elementary operations of joining parts which cover fitting a part into another one. Each part has a primitive vector (F) which shows the orientation of the part and the vector of the main axis which shows the part symmetry. A basic system for coding assembly structures was developed by studying geometrical similarities between different pairs of parts. The code actually contains the information equivalent to CAM operations.

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4.1. The generator of sequence of assembly operations

In order to determine the sequence of assembly operations, it is necessary first to recognize all pairs of parts that can be mutually assembled. The geometrical information provided through STEP can give information on maximum and minimum limits of each part in all three directions. A simple algorithm is used for examining whether there is a mutual intersection of these limits of parts, i.e. the possibility of their joining. Examination of each part results in a list of all parts with which it is intersected and with which it can be joined. Modelling of tank wagons at the level of assembly structure is very important because kinematic requirements are fulfilled by definition of assembly relations. Solid Edge possesses a module for modelling products at the assembly level, the so-called *assembly* module. The assembly structure is established on the basis of assembly relations defined, in this software package, through fitting of surfaces, alignment of elements, parallelism, perpendicularity, etc.

5. ASSEMBLY PROCESSES

5.1 Assembly at the local and global levels

It covers all assembly steps and actions, including descriptions of the part surfaces that are called joining surfaces. Also, it covers all motions and paths that are included in any part of the assembly process. At the global level, the design of assembly structure of tank waggons was performed by using the “Bottom-up“ approach, where the components were joined for the purpose of obtaining an assembly structure as the highest level of hierarchical structure. The parts were joined through joining primitives, by establishing corresponding relations among the surfaces.

Tank waggons represent products with a complex assembly structure, where certain components are manufactured by a lot of small and medium enterprises using the principle of distributed production. Definition of manufacturers/suppliers of certain assembly components by the principle of distributed production requires analysis and coding of complex structures of products for the purpose of generation, and then adding of components to the assembly structure. The wish is to form, on the basis of general assembly principles, a system for coding the sequence of CAM operations in assembly structures, which should be the basis for introduction of distributed production of tank waggons.

6. CONCLUSION

The development of complex products such as tank waggons is based Computer Aided Design (CAD), then the sequence of assembly operations in CAM for the purpose of generating distributed support to the production of components. Artificial intelligence is one of the most significant impact on improving the CAD/CAM technology and will continue to be an effective tool in their development. Namely, how many parameters the planning process based on long experience in manufacturing, they can not be mathematically modeled. It is expected that great ability of artificial neural networks are extensively applied in the development of intelligent CAD/CAM systems.

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