



THE 7<sup>TH</sup> INTERNATIONAL CONFERENCE RESEARCH AND DEVELOPMENT OF MECHANICAL ELEMENTS AND SYSTEMS

## ARTIFICIAL INTELLIGENCE IN CAM MODELING OF ASSEMBLY OPERATIONS OF TANK WAGONS

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**Abstract:** Virtual product design represents a technological key for reduction of costs arising from the errors generated in the processes of engineering design during lifetime. 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. Procedures include shape and feature recognition using a model-based CAD (computer-aided design) analyser, data structure and data modeling, knowledge-based representation, and inference processing through a set of heuristics and rules. The main tool here is an object-oriented concept as a means for managing geometrical data, topological data and abstraction. 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 wagons.

**Key words:** Artificial intelligence, CAD, CAM, assembly

### 1. INTRODUCTION

Assembly processes during the lifetime of a product 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.

Design of a virtual product represents a technological key for reduction of, primarily, costs that have arisen from design failures in simultaneous engineering. Within generation of a product model, the mentioned aspect is noticeable in the relation between product design in CAD and assembly operations in CAM, where the virtual

environment is based on avoidance of utilization of expensive production systems.

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 lifetime [1].

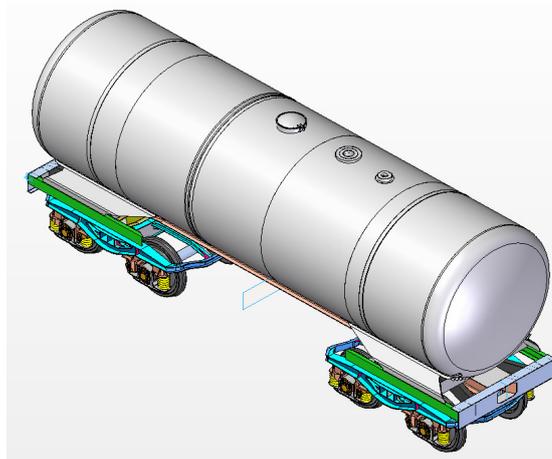


Fig.1: A model of a tank wagon

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.
- *KBS for interface with assembly CAD*. DACON, Design for Assembly Consultation provides a CAD interface for drawing assembly components after they are designed with expert analysis.
- *KBS for interface with facility design*. FADES, Facility Design Expert System provides economic analysis and selection of assembly technology.
- *KBS for assembly and manufacturing design*. ADAM or Assisted Design for Assembly and Manufacture, generates advice on reducing the number of components, rationalizing the assembly and insertion guidelines. Some authors 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.

More recent approaches have integrated design optimization, and application of virtual reality, computer supported distributed collaboration design methods, including agent-based design methods [2].

## 2. 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 assembling and disassembling significantly influence the costs in product lifetime, which requires the application of design solutions that provide efficient assembling. The complexity of assembling 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 assembling of components during product design in the CAD environment by applying virtual tools for

assembling. 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.

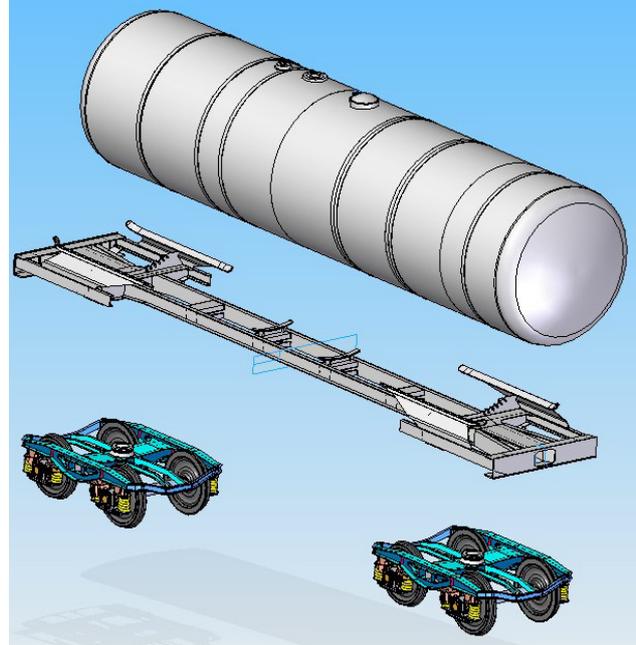


Fig.2: The main elements of the assembly of a tank waggon

### 2.1. 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.

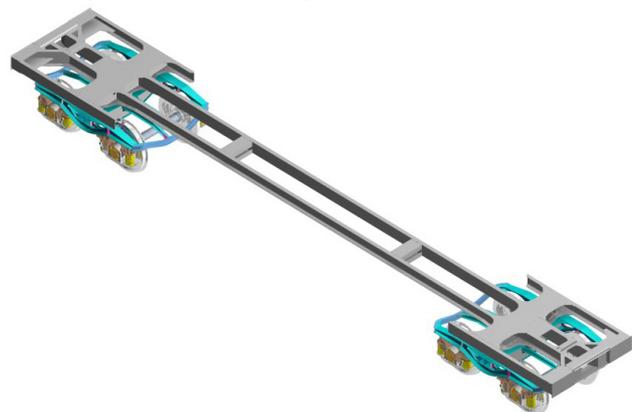
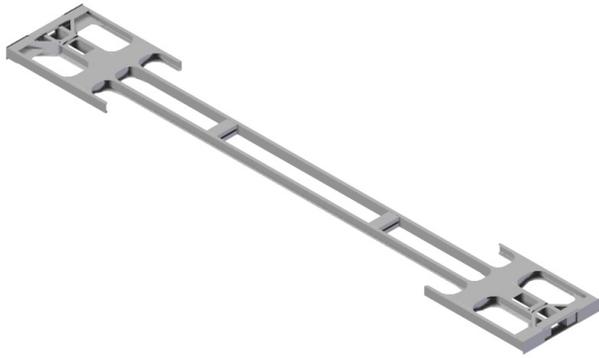
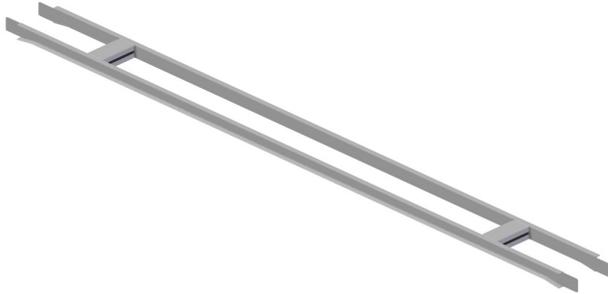


Fig.3: The assembly of the underframe and the bogie

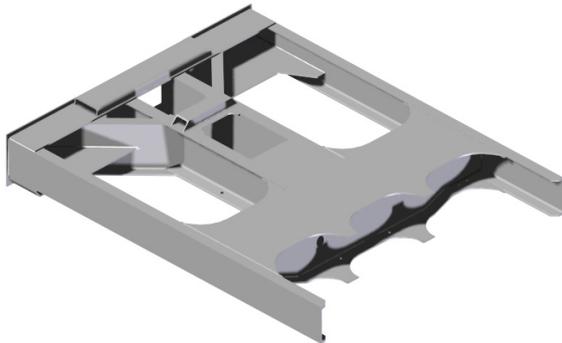


*Fig.4: A model of the underframe*

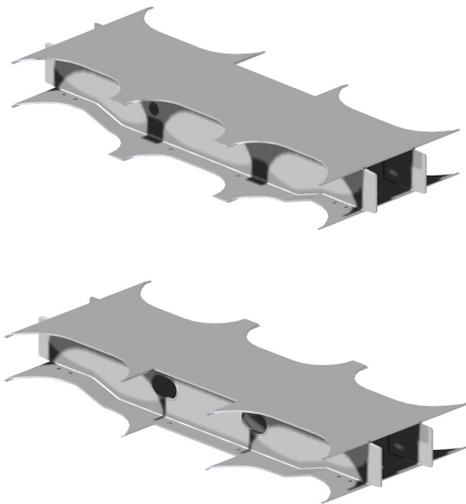
The underframe consists of several subassemblies. The main subassemblies are presented in the following figures.



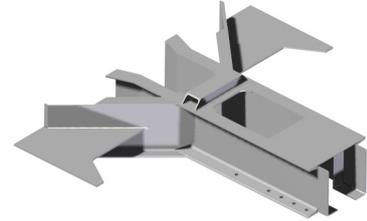
*Fig.5: The central/medium girder*



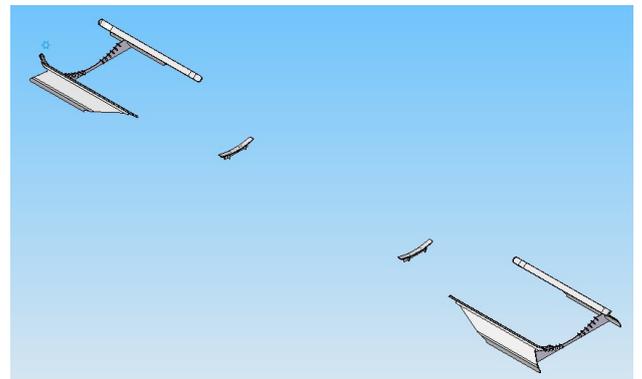
*Fig.6: A model of subassembly of the cross bearer, headstock and side members*



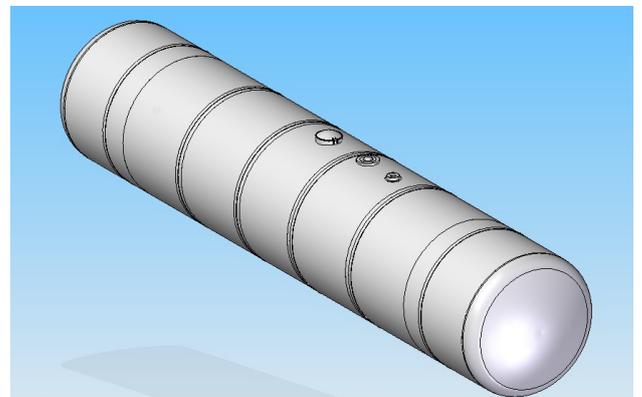
*Fig.7: A model of the cross bearer*



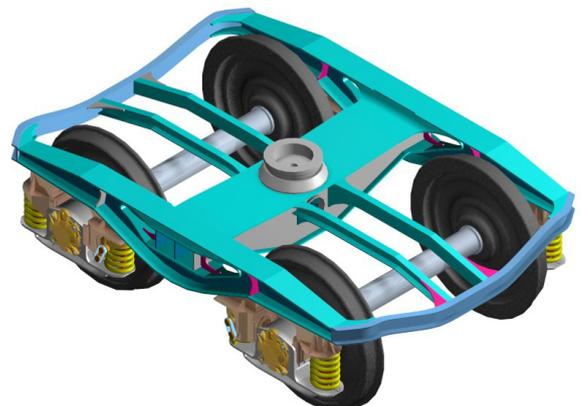
*Fig.8: A model of the headstock with the beam*



*Fig.9: Connecting elements between the tank and the underframe of a tank wagon*



*Fig.10: A model of the tank*



*Fig.11: A model of the bogie*

### 3. 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. In 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. [2].

#### 3.1. 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.

### 4. ASSEMBLY PROCESSES

#### 4.1. 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 wagons 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 wagons 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 wagons.

### 5. CONCLUSION

The development of complex products such as tank wagons 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.

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