INTELIGENT CAD DESIGN AND ASSEMBLY PLAN OF MILLING HEADS

Nemanja ILIĆ
Marina PLJAKIĆ
Aranđel BABIĆ

Abstract: *The main difficulty in the overall process of optimal assembly plan generation is the great number of different ways to assemble a product (typically thousands of solutions). This problem confines the application of most existing automated planning methods to products composed of only a limited number of components. Automatic assembly design and planning has been recognised as an important tool for achieving concurrent product and process development, thus reducing manufacturing costs. AI techniques such as knowledge-based DFA expert systems, fuzzy logic, neural networks, genetic algorithms, case-based reasoning, and their hybrids may be used for assembly planning. AI techniques should be a tool for creating a system which will be able to provide users with suggestions in order to improve a design and also to help obtain better design ideas. In this paper will be presented an assembly plan for milling heads in processing of road and railway infrastructure facilities.*

Key words: *CAD, Artificial intelligence, Assembly plan, Milling heads*

1. INTRODUCTION

In industrial manufacturing, process planning for assembly is very important phase in product development. In case of variant design of complex products (many variants of the same product), planning of assembly, and also disassembly or maintenance, is still very complex. Computer aided assembly planning is one of a solution to reduce the effort necessary to produce assembly plans while improving their quality and production cost.

Therefore, in recent years more and more attention is paid for creating an optimal assembly plan with computer support.

In this process may occur some problems based on product complexity with large number of components and more possible ways that assembly process can be performed. Assembly plan consists of three phases:

1. determination of all possible ways,
2. choosing the most suitable assembly plan,
3. distribution of assembly operations.

Biggest problem is combining of possible ways. Number of feasible assembly plans is very large. Ideal product is one that has no assembly restriction. In most cases of assembly plan designing is necessary to take into account all feasible plans. In some methods for reduction of numbers of possible assembly plans are introduced restrictions based on geometry or on element stability in assembly structure. However, introducing too many restrictions and the possible rejection of most of the plan assembly, can lead to the rejection of solutions that can later turn out to be interesting.

2. ARTIFICIAL INTELIGENCE IN PROCESS OF ASSEMBLY PLANNING

Integration of product development processes and assembly plan generation is based on application of artificial intelligence methods. There are large number of AI methods that can be used in the design and planning of products and assemblies, such as: expert systems, fuzzy logic, neural networks, genetic algorithms, case-based reasoning. A complete AI based integration of product design and assembly process planning is still complicated by the complex interactions and domain knowledge between the technical, economical and ergonomic aspects of design and planning. Main aspects are technical and economical and they need to be integrated. Figure 1. show scheme of this integration. To ensure this integration next steps must be taken into the consideration:

1. Assembly design (conceptual design, preliminary design, detailed design, assemblability analysis and evaluation).
2. Assembly process planning.
3. Assembly system layout and design.
4. Assembly simulation.
5. Econo-technical and ergonomic analysis and evaluation.

Then, an AI protocol based on intelligent methodology is proposed for the assembly oriented design and planning scheme shown on figure 2. This protocol is composed by of one or more individual intelligent technologies to form a distributed or hybrid intelligent scheme. Possible development and applications of the above intelligent design methodology are:

1. Conceptual and preliminary design products.

2. Checking/rectifying design of products.
3. Optimisation of assembly tasks.
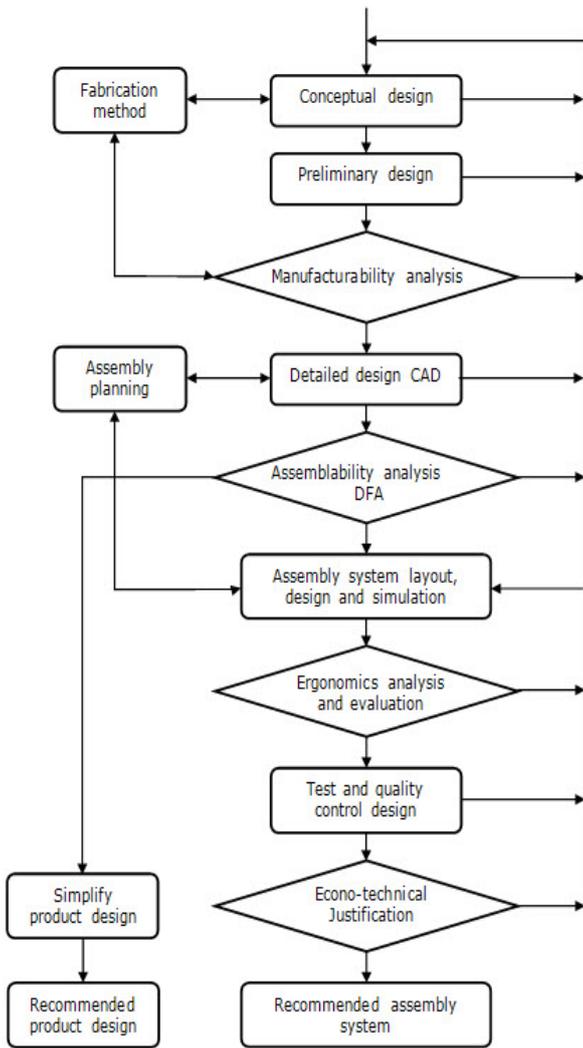4. Optimisation of manufacturing/machining.

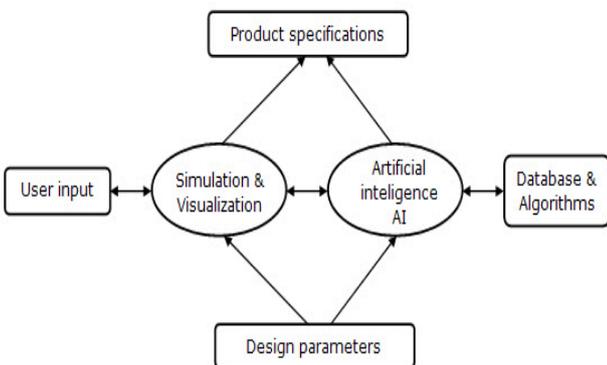*Fig.1: Integration of assembly design and planning*

Fig.2:Assembly design and planning scheme

3. ASSEMBLY CONSTRAINS

An operation is said to be feasible if it respects the assembly constraints coming from product, assembly process or assembly facility.

Assembly constraints take into account the assembly operation (for example geometrical feasibility or stability of subassemblies..) or the process of optimal plan selection (for example minimizing time or maximizing the number of subassemblies). The nature and weight affected to a specific criterion are sensitive as they can lead directly to eliminating entire groups of assembly solutions.

3.1. Constrains on the level of assembly operations

These are fundamental constrains. Most common of them are:

• geometrical feasibility: is the strongest constrain, there must be possibility for mating components,

• assembly tool access: requires that sufficient space be available for the tool used to assemble.

• minimizing difficult assembly operations: avoid awkward operations,

• stability: mean that all subassemblies must be in stabile state.

3.2. Constrains on the level of assembly plan

This type of constrains is used during selection of best assembly plan. Some of them are:

• minimizing the time needed for assembly process,

• minimizing assembly process costs,

• minimizing numbers of inserting directions in assembly process,

• maximizing number of operations performed in parallel directions,

• minimizing number of different tools for performing assembly operations.

These constrains are used as a filter during process of assembly plan generation. If these constrains are failed to comply, the user can take into account all the "families" of the possible plans.

4. ASSEMBLY PLAN GENERATION

Many computer assembly planners have been developed in the past for mechanical products. The techniques used for their development are classified into four categories:

1. algorithmic,
2. integrated interactive/algorithmic,
3. knowledge-based, and
4. case-based.

Assembly plan has a very big influence on design of an assembly system, assembly costs, and assembly equipment. Selection of the best assembly plan is very importante activity.

4.1. Algorithmic Approach

The algorithmic approach organizes planning knowledge in the form of algorithms, which are implemented using a languages like C or Java. This approach has been utilized in both assembly and disassembly planning. In either

case, geometric reasoning is often applied to verify the ability to assemble or disassemble based on various criteria such as accessibility, interference, blocking, structural stability, etc.

4.2. Integrated Interactive/Algorithmic Approach

This approach normally uses a combination of interactive and algorithmic programs. The interactive program is used to capture some constraints on assembly plans from users. It is argued that interaction with users is needed because some constraints on assembly plans are not well understood to encode in a computer program, and other constraints are too computationally expensive to evaluate under current methods. The information (relations) captured by the interactive program together with information about other constraints is subsequently utilized in planning to generate all valid assembly sequences. The planning knowledge is organized in the form of algorithms just like the algorithmic approach.

4.3. Knowledge-Based Approach

This approach generally models actions in assembly processes by production rules in the form of IF_condition_THEN_action_. The condition part may consist of a single fact or a conjunction of several facts in assembly planning, either supplied by the user or induced by the inference engine. They form conditions of the rule, and only when those conditions are satisfied can the rule be fired. In a similar way, the action part models the action taken during an assembly process. The actions can be a mating between two components, a change of fixture or tool, etc. A rule-based system could also include procedural knowledge as part of the knowledge.

4.4. Case-Based Approach

Unlike the other approaches, which all attempt to generate assembly plans from scratch, the basic idea of CBR is to derive a solution to a new problem effectively and efficiently by referring to the solution of a similar previous case and then adapting its solution appropriately to fit the new problem. The CBR approach comprises four major steps: case representation, case retrieval, case adaptation, and learning.

The representation of cases is essential because it determines what the case memory can be used for, how cases can be retrieved, and whether there is enough information for case adaptation. Given a new case, the aim of the case retrieval process is to identify the most similar cases. The retrieval technique depends on the structure of case memory and the associated index scheme. The index schemes makes the retrieval process more selective and reduces the effect of the memory size. Case adaptation involves taking a selected case, making changes to the case, and labeling the revised case as the new solution. Learning in CBR is achieved simply by storing an old case in the case base.

5. ASSEMBLY PLAN OF MILLING HEAD SYSTEMS

Milling head systems are systems consisted of several subassemblies, shown on figure 3. Each subassembly can be further divided into next level of subassemblies. For example, milling head subassembly, is consisted of cutting tool subassembly and drum construction.
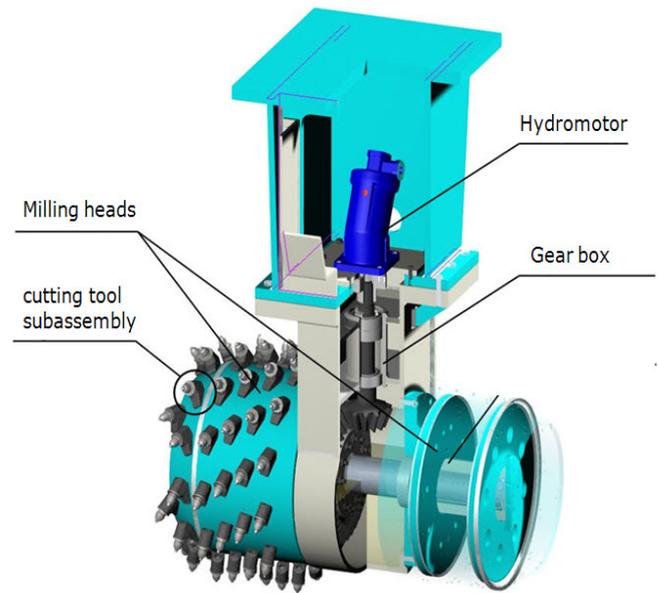

Fig.3:Milling head system subassemblies

Milling head subassembly is shown on figure 4., where can be seen all elements included in hierarchical structure. Bill of material is shown in table1.
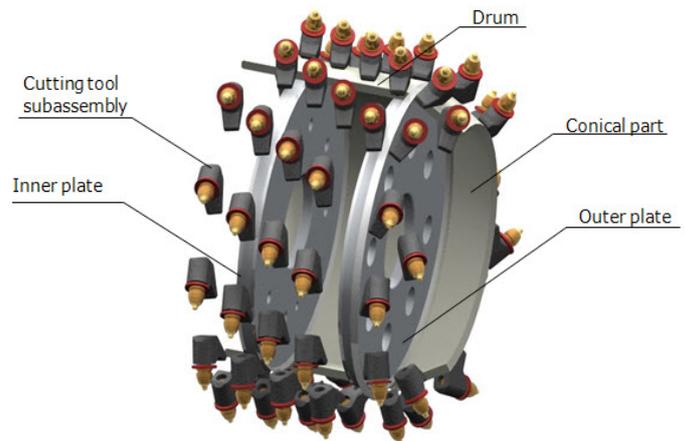

Fig.4:Milling head components

Table 1: Bill of Material of milling head subassembly

Part. No	Part name	Part code	Quantity
1.	Toolholder	Mh01-1	64
2.	Tool	Mh01-2	64
3.	Drum	Mh01-3	1
4.	Conical part	Mh01-4	1

5.	Inner plate	Mh01-5	1
6.	Outer plate	Mh01-6	1

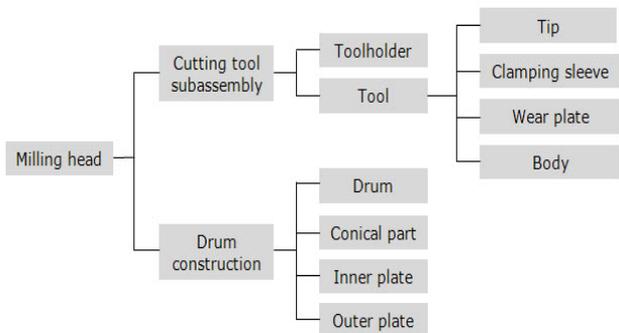Hierarchical structure of milling head is shown on next figure 5.

Fig.5:Milling head hierarchical structure

Cutting tool subassembly consists of several components shown on figure 6. Main parts are tool holder and a cutting tool. Cutting tool and it's elements are also shown on this figure. Depending on milling head system type, different number of these cutting tools can be used (42,54, 66 or even more) on a single milling head. Cutting tools are considered as assembled because they can be bought as a spare part.
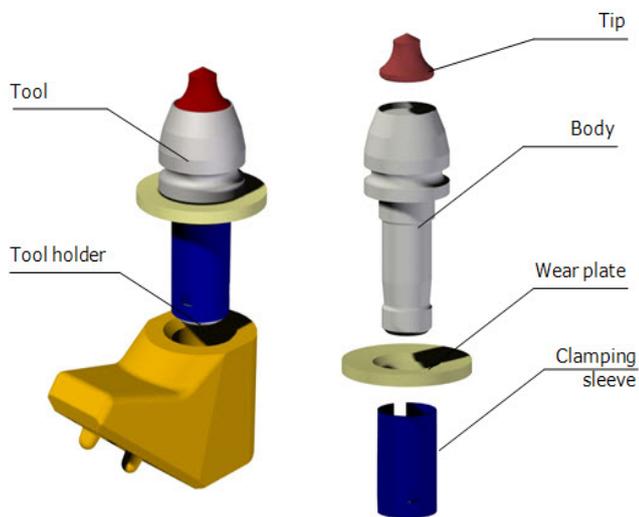

Fig.6:Cutting tool components

Assembly plan, shown in Table 2., of milling head consider no technological constraints, while the other, shown in Table 3. does.

Table 2: Assembly plan that consider no technological constrains

Operation No.	Description
Step 1.	Positioning part 3.
Step 2.	Positioning part 5.
Step 3.	Positioning part 6.
Step 4.	Positioning part 4.

Step 6.	Performing welding operation according to information W1
Step 7.	Performing welding operation according to information W2
Step 8.	Performing welding operation according to information W3
Step 9.	Positioning part 1
.	.
.	.
.	.
Step 73.	Positioning part 1.
Step 74.	Performing welding operation according to information W4
.	.
.	.
.	.
Step 138.	Performing welding operation according to information W4
Step 139.	Positioning part 2.
Step 140.	Performing axial force to push part 2 into part 1
.	.
.	.
.	.
.	.
Step 268.	Positioning part 2.
Step 269.	Performing axial force to push part 2 into part 1

First assembly plan consider no technological constrains. In this case, first all components need to be positioned (drum, inner plate, outer plate, conical part). Then welding operation need to be performed.

But there haven't been taken into consideration assembly tool access (requires that sufficient space be available for the tool used to assemble). Welding gun can't access in zone where inner and outer plate need to be welded, shown on figure 7.
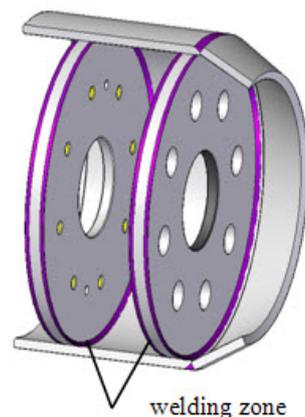

Fig.7:Welding zone where welding gun can not access

After these operations, all tool holders need to be positioned and then to be welded. Also, there haven't been taken into consideration constrains about stability (mean that all subassemblies must be in stabile state). All tool holders can not be in the stabile state, in the same time, figure 8, without performing welding operations.
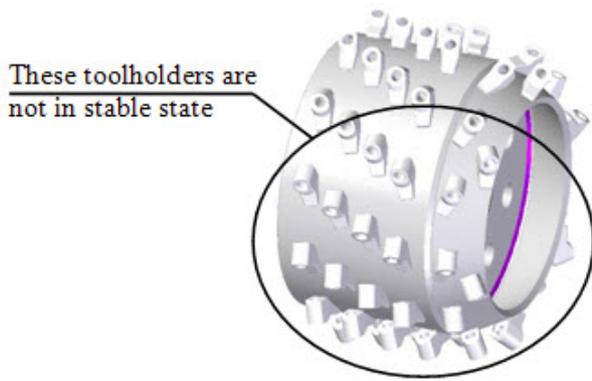
Fig.8:Toolholder which are not in stable state

The second assembly plan take into consideration all the constrains that haven't been taken in previous assembly plan. After milling drum construction parts positioning and welding operations, tool holders are positioned and welded one by one, and all tools are positioned (pushed) in tool holders using a force. View of a welded tool holder and tool in it is shown on figure 9.
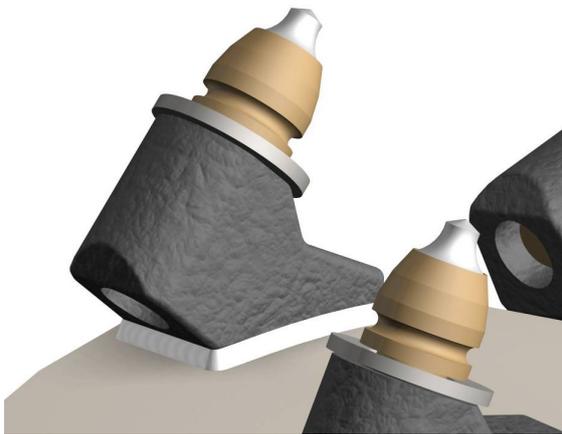

Table 3: Assembly plan that consider technological constrains

Operation No.	Description
Step 1.	Positioning part 3.
Step 2.	Positioning part 5.
Step 3.	Performing welding operation according to information W1
Step 4.	Positioning part 6.
Step 5.	Performing welding operation according to information W2
Step 6.	Positioning part 4.
Step 7.	Performing welding operation according to information W3
Step 8.	Positioning part 1.
Step 9.	Performing welding operation according to information W4
Step 10.	Positioning part 2.
Step 11.	Performing axial force to push part 2 into part 1
.	.
.	.
.	.
.	.

Step 132.	Positioning part 2.
Step 133.	Performing welding operation according to information W4
Step 134.	Positioning part 2.
Step 135.	Performing axial force to push part 2 into part 1

On the next figure 10., is presented milling head at the end of assembly process.
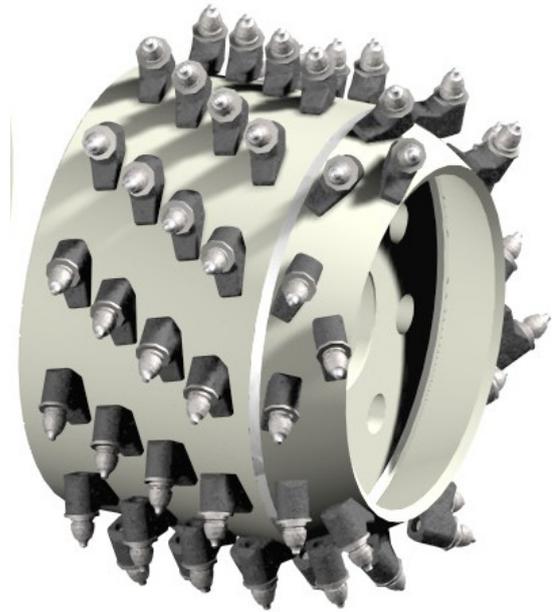

Fig.10: Milling head

6. CONCLUSION

When fully developed, product design and assembly planning can be carried out simultaneously and intelligently in an entirely computer-aided concurrent design system. The design of manufacturable, cost-effective, usable products can therefore be achieved more rapidly and flexibly. Integration of product design and assembly process planning can achieve a better design of a product. Product design in CAD / CAA environment is one of the key conditions that influence the cost savings generated in the process of engineering design during the product life cycle.

In further research need to be developed an algorithm which consider technological constrains, for each assembly plan shown in this paper using some of techniques mentioned above. The aim is to enable that in this way prevent possible errors in the mounting structure of products, to enable the CAD model changes based on assembly relationships and constraints that are generated in the CAA region. In this way, product development time and costs are shortened, while improving quality of a final product.

REFERENCES

[1] Michel MARTINEZ · Viet HUNG PHAM · Joël FAVREL, *Optimal assembly plan generation: a simplifying approach*: Université de Lyon, Bât Nautibus 8, Boulevard Niels Bohr, Villeurbanne Cedex 69622, France

[2] X. F. ZHA, S. Y. E. LIM and S. C. FOK, *Development of Expert System for Concurrent Product Design and Planning for Assembly*: School of Mechanical and Production Engineering, Nanyang Technological University, Singapore; and School of Mechanical Engineering, Nanjing University of Aeronautics and astronautics, Nanjing, China

[3] X. F. ZHA, S. Y. E. LIM and S. C. FOK, *Integrated Intelligent Design and Assembly Planning,* School of Mechanical and Production Engineering, Nanyang Technological University, Singapore; and 2School of Mechanical Engineering, Nanjing University of Aeronautics and astronautics, Nanjing, China

[4] N., ILIĆ, A., PETROVIĆ, A., BABIĆ, M., PLJAKIĆ *Modelling of milling tools in the procession of road and railway infrastructure   facilities*, May 2010, Opatija, Croatia, Zbornik radova, str. 971-975., ISBN 978-953-6272-37-2

[5] A., BABIĆ, N., ILIĆ, M., PLJAKIĆ A., ŽUKOVSKI, *CAD/CAA procedures in designing of cutting subassemblies of wheel excavator system*, IMK–14, Istraživanje i razvoj, Časopis instituta IMK 14 OKTOBAR, Kruševac, broj (16), 4/2010., str.81.-84., ISSN 0354-6829

CORRESPONDANCE

Nemanja ILIĆ, Ph.-D. M.Sc. Eng.
University of Kragujevac
Faculty of Mechanical Engineering Kraljevo
Dositejeva 19
36000 Kraljevo, Serbia
ilic.n@mfkv.kg.ac.rs

Marina PLJAKIĆ, Ph.-D. M.Sc. Eng.
University of Kragujevac
Faculty of Mechanical Engineering Kraljevo
Dositejeva 19
36000 Kraljevo, Serbia
pljakic.m@mfkv.kg.ac.rs

Aranđel BABIĆ, Prof. D.Sc. Eng.
University of Kragujevac
Faculty of Mechanical Engineering Kraljevo
Dositejeva 19
36000 Kraljevo, Serbia
babic.a@mfkv.kg.ac.rs