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Assembly plans generation of complex machines based on the stability concept

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Abstract

Assembly Sequence Planning (ASP) is one of the well-known optimization problems in the manufacturing industry. It represents a great deal of interest over the past three decades. This paper aims to present a method for generating ASP, taking into account the stability assignment during assembly's operations. The developed method uses the topological and geometrical assembly constraints extracted and generated from CAD system (assembly constraints, mass and center of gravity of components, interference and contact matrices), to guarantee the generation of a feasible ASP. The main contribution of this research is the development of a method which respects the stability assignment of heavy machines during the assembly's operations. Also, it reduces the design costs and minimizes the time of replacement or repair of failing components of industrial equipments, which has become complicated task given the complexity of today's mechanisms. A validation example is used to highlight the advantages of the proposed approach.

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*Keywords:*ASP; Stability; Contact matrices; Centre of gravity; Mass; Assembly Constraints; Interference matrices.

1. Introduction

Despite the multitude of functionalities offered by the actual CAD/CAM softwares, the generation and the simulation of Assembly/Disassembly Sequence Plan (ASP/DSP) remain an actual issue. In fact, the identification or the optimization of ASP/DSP depends on many criteria. Researchers have developed different approaches in order to automatically generate feasible and optimal sequences.

Those approaches, which improve the product design and the maintenance operations, take into account several parameters such as feasibility [1-8], subassembly identification [9-10], assembly directions [11], tool operational space [12], assembly coasts [13] etc. Also, and to optimize ASP/DSP of a mechanical product, authors adopted intelligent methods such as the genetic algorithms [14-16] and the ant colony optimization [17-18]. The obtained sequences can be simulated interactively using the augmented virtual reality [19].

Contrariwise, the stability criterion, during assembly/disassembly process has not been well treated in the literature. The stability of a mechanical assembly is an important aspect, not only for operator security, but also, for many mechanisms which needs stability during the mounting phase (e.g. Wheel Loader, truck, etc.). Laperriere and Lavoie established an approach using a graph-theory to calculate the stability degree of subassemblies formed during ASP generation [20]. In this approach, the stability is estimated using freedom matrices. Smith et al. developed an ASP approach which respects the mechanism stability [21]. This approach, based on genetic algorithm, used three matrices such as connection, support and interference-freeness matrix to carry out ASP. Bahubalendruni and Biswal established a method, which tests automatically the stability between parts, using mechanical equilibrium conditions, part surface features and contact between parts [22]. Kumar et al. proposed a method to identify the stable configurations between parts of an assembly [23]. The stability predicate information, are automatically obtained, through a CAD interface.

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As could be seen, it is clear that ASP/DSP approaches based on stability concept were not well considered in the literature. In order to improve the security aspect, especially for heavy machines, the stability criterion should be taken into account in the ASP/DSP generation.

The aim of this paper is to develop an ASP approach based on stability criterion from product CAD model. For better discussing and explaining all the steps of the proposed approach an illustrative example is treated in all sections of this paper.

Nomenclature

AP	Assembled Parts
ASP	Assembly Sequence Planning
DSP	Disassembly Sequence Planning
CG	Centre of Gravity
CAD	Computer-Aided Design
CAM	Computer-Aided Manufactory
[CMk]	Contact matrix according to k-axis
d_k	Distance between the GC of the initial parts and each component in {Pk}
d_{mi}	Minimum distance
m_k	Mass of a component in {Pk}
g	Gravity
{Pk}	Set of closet component to Pref
Pref	Initial part
WACG	Weight Average Centre of Gravity
WM	Weight Moment

2. Developed Approach

The developed approach is composed by three main steps (Fig.1):

- Assembly information.
- Algorithm of assembly sequences generation.
- Collision test.

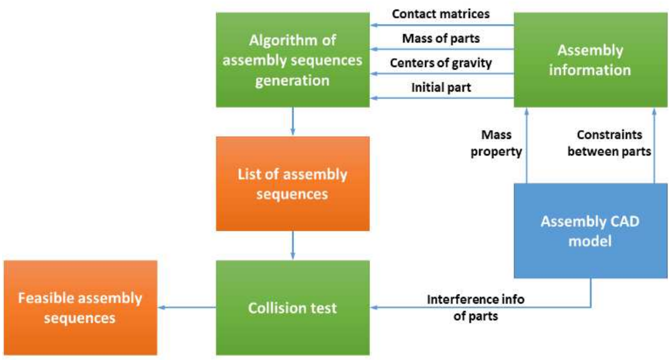

Fig. 1. Developed approach steps.

To demonstrate each step of the developed approach, an illustrative example is proposed. The treated example, which is a “swivel vice assembly”, is composed of 22 parts as presented in Figure 2.

Items	Name
1	Body
2	Jaw 1
3	Clamping nut 2
4	Jaw screw 1
5	Jaw screw 2
6	Jaw screw 3
7	Jaw screw 4
8	Jaw 2
9	Moveable jaw
10	Screw rod
11	Guide strip 2
12	Guide strip bolt 4
13	Guide strip bolt 2
14	Guide strip bolt 1
15	Guide strip bolt 3
16	Guide strip 3
17	Clamping bolt 1
18	Clamping bolt 2
19	Base
20	Clamping nut 3
21	Collar 2
22	Clamping nut 1

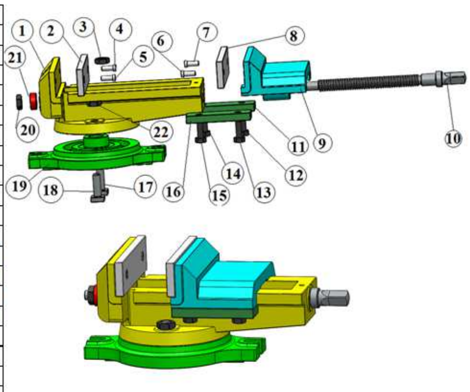

Fig. 2. CAD model and nomenclature of swivel vice assembly.

In order to retrieve the parts’information from the CAD model and to generate an assembly sequence, the following assumption are considered:
Assumption 1. All parts are considered as rigid solid.
Assumption2. The parts are assembled sequentially one by one.

2.1. Assembly information

2.1.1. Collected information

From the CAD assembly model, the developed algorithm collects information from the components and the assembly constraints. As first step, the algorithm extracts the necessary body’s proprieties of each component: the name, the mass and the center of gravity. Those data will serve to identify the precedence relations. The collected data from the demonstrative model’s parts are presented in Figure 3.

Components	Volumes (mm3)	Mass (g)	X(mm)	Y(mm)	Z(mm)
(20)	4542,161	35,428	0	0	5
(12)	7648,852	59,661	0,039	-6,031	12,475
(10)	159084,963	1240,862	0	0,002	250,451
(21)	9088,974	70,894	0	6,5	0
(15)	7648,852	59,661	0,039	-6,031	12,475
(2)	148245,749	1156,316	0	6,968	-1,524
(16)	87364,41	681,442	69,499	20,5	8,188
(11)	87364,41	681,442	69,499	20,5	8,188
(5)	2842,633	22,172	0	-1,906	9,485
(4)	2842,633	22,172	0	-1,906	9,485
(6)	2842,633	22,172	0	-1,906	9,485
(14)	7648,852	59,661	0,039	-6,031	12,475
(13)	7648,852	59,661	0,039	-6,031	12,475
(7)	2842,633	22,172	0	-1,906	9,485
(8)	148245,749	1156,316	0	6,968	-1,524
(19)	976268,923	7614,897	0	-6,93	32,499
(17)	18001,215	140,409	0,278	-8,722	29
(18)	18001,215	140,409	0,278	-8,722	29
(22)	4542,161	35,428	0	0	5
(3)	4542,161	35,428	0	0	5
(9)	898443,377	6513,714	0	74,036	16,907

Fig. 3. Collected data from the demonstrative model parts.