ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume XI (XXI), 2012, NR2

ADVANCED CAD CAPABILITIES APPLIED FOR INTEGRATING FLEXIBLE ENGINEERING DESIGN WITH FLEXIBLE MANUFACTURING

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Keywords: CAD, engineering design, flexible manufacturing, industrial robot, electromagnetic gripper.

Abstract: The paper discusses some possibilities to apply advanced capabilities offered by CAD software solutions in order to develop flexible and sustainable engineering product designs and not at last, their further integration within flexible manufacturing. The included case study refers to the use of advanced assembly modeling facilities from SolidWorks and embedment of outsourced CAD models for the development of a particular multiply configured flexible design model for an electromagnetic gripper, intended to equip ABB industrial robots. The model is further on integrated within RobotStudio applications.

1. GENERAL FRAMING OF THE APPROACH

The paper discusses some possibilities to apply advanced capabilities offered by CAD software solutions in order to develop flexible and sustainable engineering product designs and not at last, their further integration within flexible manufacturing.

1.1. INTRODUCTION

The compulsory need of performing within a strongly competing market environment and lately within a climate of global financial crisis represents a present reality for each enterprise, starting with the SME-s and finishing with the subsidiaries of great international corporations and of course for each of the research or educational institutions.

The main purpose of any company or enterprise is to make money by satisfying clients with its products or services and for accomplishing this purpose, in all its business processes, any company or enterprise has to deal with the following four main factors: resources, suppliers, clients and products or services, [8]. More than that, the conditions of passing from the Information Age towards the Relationship Age determine all the organizations to permanently focus on their relationships and information exchange with partners, suppliers, customers, employees and investors, [5], [9].

Within the nowadays continuously and fast changing market environment, we must agree the idea that one company’s performance, on which its survival is finally based, is in a good part determined by its own ability to rapidly introduce new products or services able to meet changing market demands. Each service or product provider must be agile and achieve short delivery times, as long as most of the customers ask for specific, individually developed solutions. In relation to these we can overtake the affirmation of D. Tate which stipulates that the goals which companies set are not, nor should they be, fixed for all time. What constitutes a competitive performance in terms of development time today can be out-of-date tomorrow, [16].

On the other hand, since the achievement of sustainable development has definitely become a global goal and a real challenge, from the industrial point of view it is widely accepted that for accomplishing such a crucial goal, there must be started from a sustainable manufacturing.

1.2. NEED OF INTEGRATING FLEXIBLE ENGINEERING DESIGN WITH FLEXIBLE MANUFACTURING FOR SUSTAINABLE PRODUCT DEVELOPMENT

Economical progress, which supposes qualitative changes on the content of the production factors and of the relationships from the economic life, in order to adapt to the demands of the social progress, is possible only through technical progress.

The most dominant component of the technical progress is lately represented by the continually renewing technologies and especially by the IT solutions which have brought radical changes in the global ways of thinking and visions about products, manufacturing processes and systems, business environment and not at last about our living environment, [7]. In such conditions, more and more industrials, researchers and academia have been forced to adapt their professional activities to Integrated Product Development (IPD), to Integrated Engineering and to Integrated Manufacturing.

Integrated Product Development, which represents a concept sometimes named Simultaneous Engineering or some other times is called Concurrent Engineering, is widely accepted as an effective instrument to achieve Sustainable Product Development, mainly by achieving Sustainable Design.

Optimizing product design processes has become in such conditions one of the main objective and strategic target of industrial, research and academic engineering activities. Lower costs and shorter development times are the essential effects of implementing better product design processes, by saving overhead and using engineering and production resources more efficiently and by getting products to market before trends and customer tastes change, as it is described by Reitman and Simison, [14].

Scientific and technical progress have provided design theories and methods as valuable instruments for companies which target in their product development processes objectives like the following, [16]:

- to reduce use of product development resources (time, money, etc.);
- to improve product functionality;
- to improve product reliability;
- to reduce product life-cycle costs;
- to reduce manufacturing cycle time.

Regarding the efficiency and effectiveness of design activities, there are specialists who, based on research statistical data, announce that up to 90% of all design activities developed by companies are based on variants of existing designs, [2]. The same source nominate that, according to an industrial survey, less than 40% of the interviewed companies use initial CAD models for downstream applications and less than 15% for adaptive design.

An effective solution able to increase the overall design productivity and to eliminate non value added costs, mainly by reducing the amount of CAD model rebuild for downstream applications or for adaptive design, is represented by the PLM systems. PLM systems come to help in solving complex problems of internal and inter-organizational collaboration for product development. The implementation of a PLM solution, respectively of a system of product information management, in a company new product development activity bring a set of advantages such as: the productivity of the design/calculation process is improved; an innovative content of the products is determined; the time for realizing a new product (Time to market) is reduced; the design and manufacturing accuracy is improved; data security is provided; a better control upon changes is provided.

PLM systems and the highly integrated CAx systems from the new generation of IT engineering solutions allow the use of the initial CAD product model as an invariable master model and to propagate it within different further integrated specific engineering applications, as partial models of the same product (FEM models, models for testing and validation, manufacturing models, DMU models, models for presentation, marketing and selling).

For achieving their objectives of continually improving their performance and capabilities in product design, in relation with the product life cycles ever shortening, companies need well skilled human resources.

In this sense, there exists a permanent concerning in providing the increase of development, creativity and competitiveness for the organizational culture within engineering education in general, but also for the human resource, engineering and research-development departments from productive enterprises, [10].

The role of the institutions of engineering education is very important in the process of implementing and developing integrated engineering design, product data management and integrated manufacturing skills within human resources, starting from considering an educational institution as part of the basement for human and professional development, and considering the main purpose of engineering education being to provide adequate competences to the graduates for assuring later professional independence and performance. More than that, engineering education as process and institution should also be considered a part of the further stages in the professional development of human beings, considering here the lifelong learning process, [13].

As consequence, the need for aligning the educational programmes for engineering qualifications to the demands of social and economical development of regional, national or European labour market becomes vital and the development of specific engineering skills for the graduates in integrated engineering design, integrated and flexible manufacturing, industrial robotics etc. should be realized in collaboration with employers and stakeholders.

2. APPROACH OUTLINING

The scientific approach upon applying advanced CAD capabilities for integrating flexible engineering design with flexible manufacturing, which makes the object of the present paper, represents a collaborative team work of specialists from "Gheorghe Asachi" Technical University of Iaşi and from Totalgaz Industrie SRL Iasi, the productive enterprise being interested in the implementation of integrated flexible manufacturing and of industrial robots applications, mainly in manufacturing welded product and structures and owning a very well trained and developed team in integrated engineering design.

Considering the particular experience of the authors in the field of integrated engineering design, SolidWorks is first of all briefly presented and analyzed as valuable instrument for flexible engineering design and a set of advanced capabilities of the considered CAD solution are further on discussed, in relation with the possibility of integrating the product model development with the principles of axiomatic design. The decomposition rules are mainly targeted, as being considered very important in generating valuable flexible structure of product design model.

The further on included case study refers to the use of advanced assembly modeling facilities from SolidWorks and embedment of outsourced CAD models for the development of a particular multiply configured flexible design model for an electromagnetic gripper, intended to equip ABB industrial robots. The model is further on integrated within RobotStudio applications.

3. APPROACH DEVELOPMENT

The design model for a product is defined by the product structure, product components and by the relationships between product components, included in the model database and also their belonging to sub-assemblies and to the product assembly.

The presented approach refers to SolidWorks, used as a CAD solution which provides dynamic generation of the product model structure.

3.1. SOLIDWORKS AS INSTRUMENT FOR FLEXIBLE ENGINEERING DESIGN

SolidWorks represents, through the capabilities provided by the embedded specific modules and functions, a complete engineering and industrial design solution, making possible the effective product model development with high accuracy and flexibility, without the need of appealing other software instruments.

Practically, SolidWorks together with being economically accessible also for SMEs, stands up as an easy to assimilate and to use package of software applications designated to solve mainly the following categories of functions and activities, [17], [18]:

- Mechanical Computer Aided Design (MCAD);
- Product Design validation;
- Product Data Management (PDM);
- Design communication;
- CAD productivity.

3.2. IDENTIFYING ADVANCED CAD CAPABILITIES USED FOR RESEARCH APPROACH DEVELOPMENT

As long as the beneficiaries usually need and demand individually developed product solutions and the suppliers of outsourcing components very often introduce changes in their deliverables, the process of product development imposes modifications of product structure, starting from simple changes of aspect, shape and dimensions of some components and up to structural product modifications.

When a product is already designed and sometimes even realized and the customer requires claim different shaped or dimensioned variants, multiply configured flexible design models are recommended to be developed on the principle of product families and part families. Such flexible product design model can be realized by orienting in two directions, [11], [12]:

- changing of some characteristics of product components;
- changing of product structure

An important idea in the presented research was to approach the possibility of integrating the product model development with the principles of axiomatic design.

Specialists affirm that axiomatic design can be applied in all design fields, [4], being characterized by its generality, its rules being the same and the guidelines on how to make being given by the design axioms. The basic two axioms of axiomatic design, stipulated by Suh, state that a good design must maximize the independence of the functional elements and minimize the information content, [15].

Axiomatic design approach has common elements with systematic approach: both deal with functions; the nature and the definition of functions are the same; in both situations, there must be thought in terms of functions and not in terms of solution, [4].

While developing the research approach on integrating the principles of axiomatic design within activities of multiply configured flexible design model structuring, the decomposition rules have been mainly targeted, as being considered very important in generating valuable flexible structure of product design model. In this direction, the two functional requirements (FRs) stipulated by Brown, [3], as being applicable to all manufacturing problems from the details of the process to the abstraction of manufacturing systems, respectively FR1 – maximize the value added to the product and FR2 – minimize the cost in the production process, have been considered.

In order to achieve the targeted objectives of the decomposition as crucial element for the optimization of product model structure, it is important in the design stage to know some technical elements such as:

- the functional role of the components which have to be grouped in sub-assemblies for optimizing the functioning conditions;
- the mounting technology and its importance upon the product's functional qualities;
- the constraints imposed by components positioning in the assembly;
- the mobility degrees of the components in the assembly.

For solving the task of developing multiply configured flexible design models there has been overtaken the idea to start from a rough structure or analyzing similar known systems in order to find possible variants to satisfy the considered functions. This kind of approach is useful in axiomatic design, where the designers have to take into account all alternatively possible variants to satisfy the functions, [4].

In the sense of supporting the above presented considerations, a set of advanced capabilities of the considered CAD solution have been identified as being useful for the research approach development. These are as following [17], [18]:

- Large Assembly Management Tools;
- Data Translation, respectively file converting from and to different data formats;
- Design Reuse tools;
- Automate generation of assembly structure, respectively of Bill of Materials (BOM);
- Design Automation of Repetitive Tasks;
- Feature Recognition within collaborative product model development with partners using other CAD systems or in outsourcing design activities, with the aid of the instrument *FeatureWorks®*;
- Instantaneous access to virtual libraries of standard components (*Standard Hardware Libraries*) with the aid of instruments such as *SolidWorks Toolbox* and *3D ContentCentral*;
- Productivity Tools such as *SolidWorks Utilities* and *FeatureWorks*;
- Automation of the process of modelling of routed systems as piping, electrical harnesses etc. with the aid of the instrument *SolidWorks Routing*.

3.3. CASE STUDY PRESENTATION

The case study selected for exemplifying some possibilities to apply advanced capabilities offered by SolidWorks as CAD software solution, in order to develop flexible and sustainable engineering product designs refers to the development, on the principle of parameterized product families and part families, of a particular multiply configured model for an electromagnetic gripper, intended to equip ABB industrial robots.

The further integration of such engineering design activities with flexible manufacturing is exemplified by the integration of the developed flexible design models within RobotStudio applications of modeling, simulating and programming manufacturing flexible working stations with ABB industrial robots.

Analyzing similar known systems of electromagnetic grippers, the study started from establishing a rough structure able to satisfy the considered functions, respectively to grip different metal loads and to be adaptable to different ABB robots.

That rough structure involved to find and to optimize variants for the following:

- solutions for attaching the gripper on the robot's end flange element;
- solutions for the gripper frame;
- solutions for the electromagnets supports;
- solutions of electromagnets.

A primary model configuration developed for such an electromagnetic gripper is shown in Fig. 1.

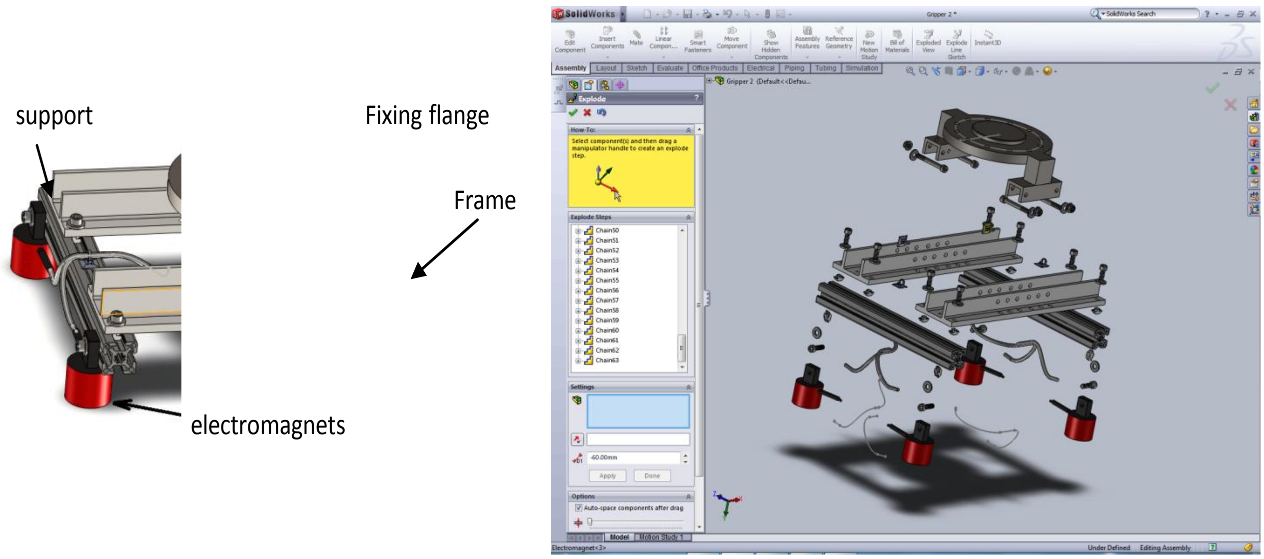

Fig.1. Primary model configuration developed for the electromagnetic gripper

By changing the solution for attaching the gripper on the robot's end flange element, the solution for the gripper frame and the solution for the electromagnets supports, a developed solution of electromagnetic gripper was modeled, as in Fig. 2.

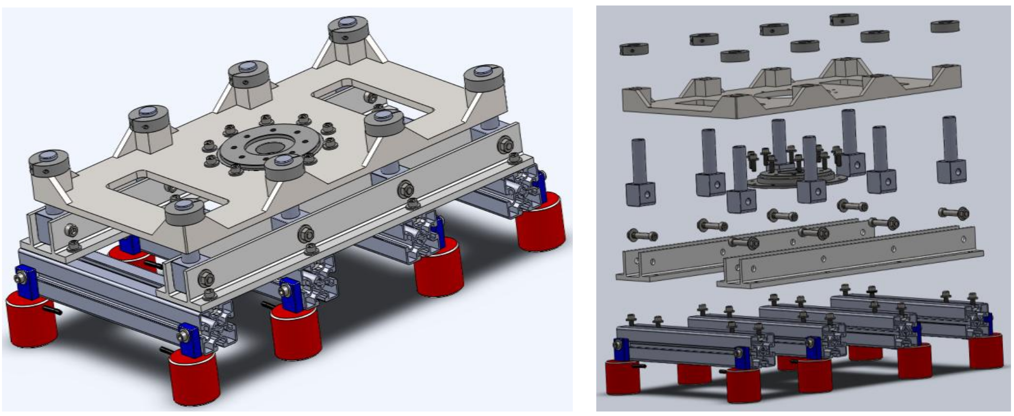

Fig.2. Developed solution of model configuration for the electromagnetic gripper: assembled and exploded views

Working further on based on the principle of parameterized product families and part families, the model of the electromagnetic gripper has been multiply configured respectively 6 different configurations have been developed, (see Fig. 3): Gripper with 4 electromagnets for a load of 40 kg; Gripper with 4 electromagnets for a load of 60 kg; Gripper with 8 electromagnets for a load of 80 kg; Gripper with 8 electromagnets for a load of 120 kg; Gripper with 16 electromagnets for a load of 160 kg; Gripper with 16 electromagnets for a load of 240 kg.

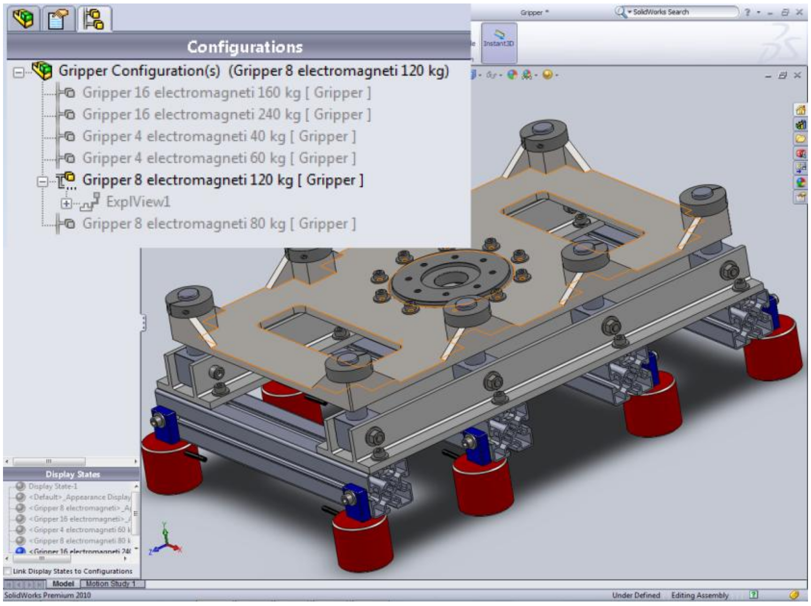

Fig.3. Multiple configurated assembly model for the electromagnetic gripper

The solid models for electromagnets, for the U profiles and for the extruded profiles used in the developed configurations have been imported from outsourced models libraries, respectively from *Design Library – 3D Content Central – Supplier Content – All Categories*.

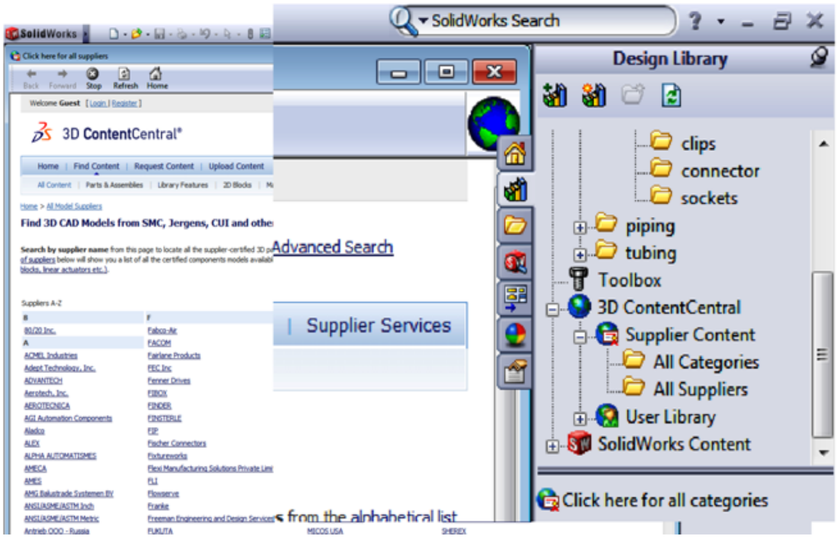

Fig.4. Importing geometry models for metallic profiles from 3D Content Central

Assembling fasteners models have been imported from virtual libraries of standard components, respectively from *Toolbox.*

The defining of different configurations has been done for parts as in Fig. 5 and similarly for sub-assemblies.

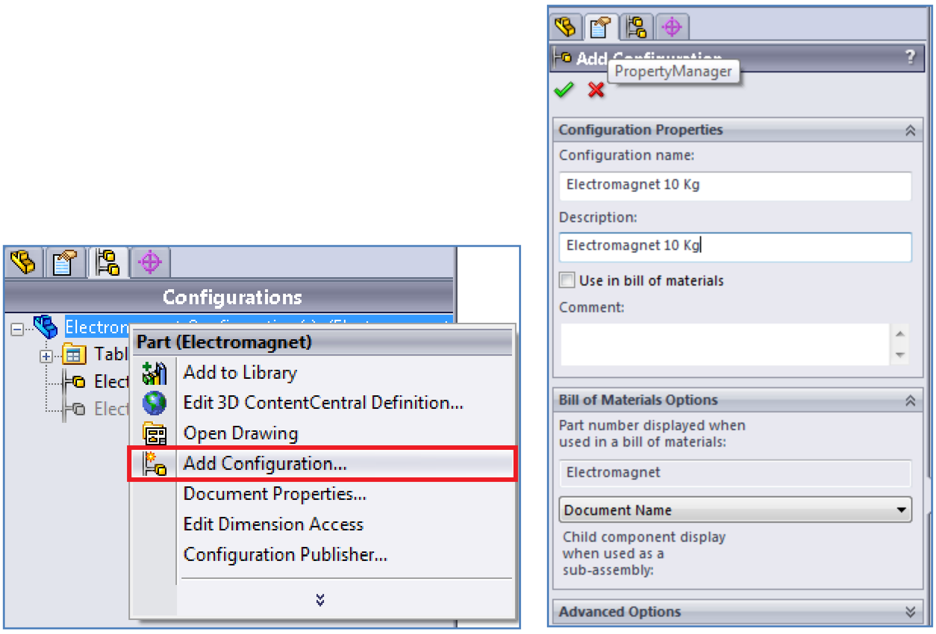

Fig.5. Defining of different part configurations

In relation with the interest of integrating the developed CAD models within applications of modeling, simulating and programming industrial robots, [10], there have been developed several RobotStudio models of robotic workstations.

In Fig. 6, there is exemplified the way a gripper as the one from Fig. 1 is imported within a RobotStudio, [1], application and is attached to an ABB robot.

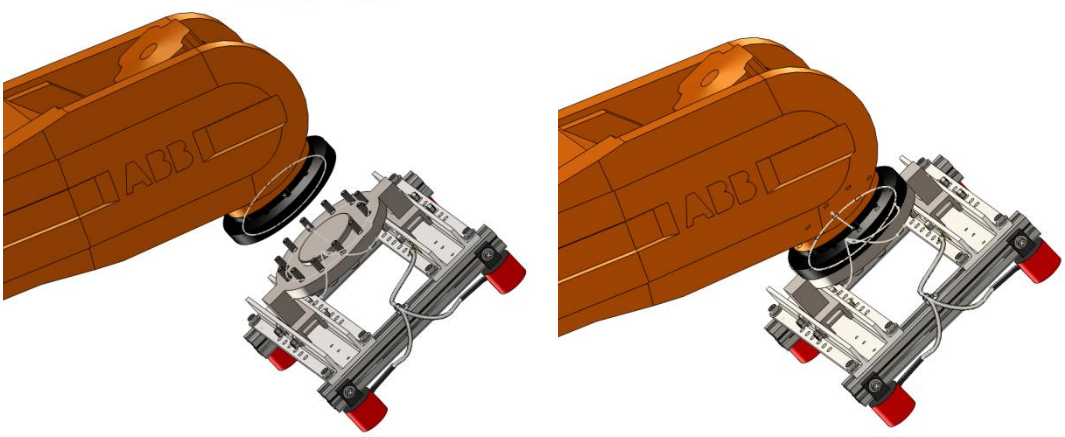

Fig.6. Gripper attached to an ABB robot, within a RobotStudio application

In Fig. 7, there is exemplified a RobotStudio model realized for the manipulation of a metal plate as part of a manufacturing process, using the electromagnetic gripper configuration from Fig. 1 and an industrial robot IRB 6620.

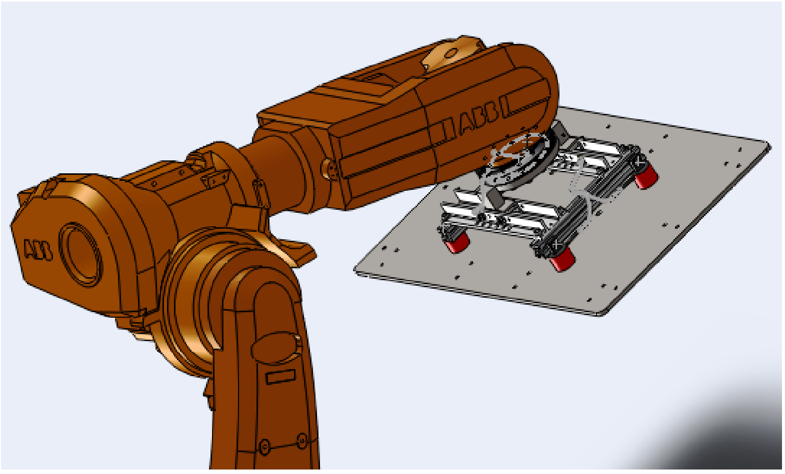

Fig.7. RobotStudio model realized for the manipulation of a steel plate as part of a manufacturing process

4. CONCLUSIONS

Advanced capabilities of integrated CAD software solutions represent a valuable instrument for integrating flexible engineering design with flexible manufacturing.

An assembly or product model is characterized by its structure which contains the component elements, respectively parts and sub-assemblies, the relationships established between them and their grouping on functional or technological criteria.

When grouping some components in sub-assemblies, the structure becomes one of a superior level, easy to use in integrated design and manufacturing.

When a sub-assembly is dissolved or the components at any level are reorganized, the mates and any features referencing the selected components are affected. That is why decisions about hierarchical groupings should be made early in the development of a complex assembly model, in order to minimize the effects on such items.

The good practice premises for efficiently forming engineering skills in CAD, integrated flexible manufacturing and industrial robot programming within a virtual environment are based on the following conditions: adequate level of technical knowledge for accomplishing the tasks for the main steps in the associated; well established motivation of the human resource by co-interesting and highly specialized mentorship.

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