Virtual Manufacturing – Navigation System
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Abstract—the constantly increasing complexity of products, their manufacturing processes, and minimal resources are reasons to control and manage the manufacturing effectively. Manufacturing simulation and digital engineering tools and procedures have a positive impact on the manufacturing industry. Materials, energy and unneeded processes can be spared, especially in the construction of production plant and manufacturing lines. This paper presents and describes a Navigator System, which controls and manages the virtual manufacturing processes effectively and thoughtfully to avoid the errors that occur in the real production. The Navigator System can be described as composite system from integrated external applications (software). The virtual manufacturing processes of products are operated by the external application inside the navigator system. The digital representation of a product and its digital manufacturing system, in which the digital product is created, is the result of this research.

Index Terms — Virtual manufacturing process, Navigator System, digital manufacturing system, manufacturing simulation, external applications, digital factory

I. INTRODUCTION
The current requirements of the market, such as variants, flexibility, short product life cycle, etc. put the manufacturing companies against new and growing challenges, so that they continue to maintain their success and competition. This can result in a scientific and practical planning of factory and production. This planning is optimized by the simulation. Manufacturing simulation, digital engineering tools and procedures have a positive impact on the manufacturing industry [1]. Herewith, the unneeded processes can be eliminated, which can be discovered later without the simulation. Materials and energy can also be spared, especially in the construction of production plant and the manufacturing lines.

The virtual manufacturing processes of products, in particular, can be controlled and regulated by the manufacturing simulation. In this article, a method for controlling and regulating the virtual manufacturing processes is shown by means of a so-called Navigator System. The virtual manufacturing processes are concerned with the steps from design to end product.

II. MOTIVATION-PROBLEM-OBJECTIVES
The current and future products (e.g. mechatronic devices) are often based on the interaction of mechanics, electric, electronics, control engineering and software engineering. These products are characterized by complex components and functionality (mechanical, electrical, electronic). Consequently, the development of this products and their production processes can be increasingly complex [2]. The production of such products is not economical or manageable according to the classical approaches. New technologies are increasingly used for the planning and development of such products, for example, the approach of digital factory with its tools [3].

The virtual manufacturing process of a product can be embedded or integrated in the concept "digital factory", which will be carried out by several and different tools from different software vendors. Most existing tools for the manufacturing simulation have been developed as individual solutions (so-called island solutions) and are used in practice. These individual solutions are suitable for particular tasks, for example, the assembly simulation of products [4]. Current systems in use, which are capable of executing multiple and single tasks.

When the stand-alone solutions are used for virtual production processes, they develop several problems, such as unfavorable data exchange, frequent error occurrence, etc. This results introduce the products at later time points in the market. Consequently, the competitive producers suffer. Therefore, they need to improve the data exchange and to navigate among the used tools using different sources in order to improve or optimize the control and regulation in the virtual manufacturing process.

The solution to this presented problem is a tool-composite, in which the needed tools are integrated and connected in a certain form for the implementation of virtual manufacturing processes.
In addition, this tool composite contains an integrated, common and central product database. Furthermore, the connection and navigation under each tool are based on a graphic method without media breaks.

III. PRINCIPLE AND METHODS
The manufacturing systems are actually subsystems of the factory, their planning is carried out in the context of factory planning. For such planning, there are various methods which do not meet today's requirements based on the planning of the duration and the frequency. Therefore, a computer support is required in all the processes of the factory planning. Consequently, it is possible to achieve a rapid implementation of the customer requirements and the new product's ideas to remain competitive. By this planning, the following methods are used for process modeling.

IV. METHODS - PROCESS MODELING
Manufacturing systems can be shown and described by the modeling with different methods which are close to reality. Graphic arts-based methods are very suitable for modeling of processes like “product make” and “product mount”. With the process modeling several aims can be achieved, e.g. avoidance of process loops and of media breaks as well as the regulation of dependence of the processes among each other [5].

Several graphic-based methods are used for the modeling of virtual manufacturing processes. A comparison between the mentioned graphic arts-based methods shows that the SADT (Structured Analysis and Design Technique) method is suitable for the modeling of the manufacturing simulation process due to several reasons: the clarity, the return (back coupling), the navigation and the refinement up to defined level of detail. [6]

V. SADT - METHOD AND VIRTUAL MANUFACTURING PROCESS
The figure 1 shows the process chain “virtual manufacturing” in an SADT-diagram. All the main areas and sub-processes parts manufacturing, assembly and final inspection / testing are available, which are sequential or parallel, or even timed to arrange overlapping [6].

The data from the design and development is to be regarded as INPUT, which is processed within the virtual manufacturing process by means of specific tools. It issues the data as OUTPUT for virtual manufacturing. The concrete detailing or virtual manufacturing is represented in Figure 2. It can be seen that the input data is processed within the activities (sub-processes of virtual manufacturing) by the resources (software, methods, personnel). And then the processed data is issued in the output data.

Figure 1: SADT-diag. “Virtual Manufacturing”

Furthermore, the activities of data control, conditions and circumstances to control the functions are determined [6]. In this case, the input data is the basis for the virtual manufacturing like 3D designs and technical drawings, which are processed by the resources for the virtual manufacturing of the parts. In the sub-process “virtual assembly” the virtually finished parts can be mounted. This is done either manually by a human model or automatically by robot model. A hybrid virtual assembly can also be used by specific software. The mounted digital products or assemblies are as a result of the virtual assembly. In the last step of the virtual manufacturing, the finished digital products are tested virtually for their ability to function.

Figure 2: Specification and detailing of virtual manufacturing
The further specification of the virtual manufacturing, in the case of "virtual parts manufacturing" can be seen in the figure 3.

Figure 3: Specification and detailing of virtual parts manufacturing (section)

VI. METHODOLOGY OF THE CONTROL AND THE NAVIGATION

A control system or a navigation system is required for the control and the navigation of the virtual manufacturing sub-processes. It is required to control and navigate the continuous processing of data files, which are generated within the process "virtual manufacturing". This system should have a common infrastructure with a graphical use interface. The designing of the navigator system must meet some requirements, for example: [6]

- Open interfaces for integration of existing tools/systems
- Possibility for management and conversion of all developed data and file during the virtual manufacturing process of product.
- Efficient implementation of external applications (Tools/Programs).
- Representation oriented to user and presentation of the generated results
- Navigate under the various single tools/systems without media break.

Within the Navigator System, the virtual manufacturing processes are connected according to the SADT method (see V.). These processes may be performed by external applications in possible simultaneously or sequentially or in parallel or a time offset.

VII. STRUCTURE OF THE NAVIGATOR SYSTEM

The Navigator System (NS) consists of several components, such as a common, a graphical user interface, a process management system (PMS), and a central product database (CPDB). On the user interface, the data of product and process can be visualized. Also external applications (CAD /CAM systems, simulation programs) can be performed for the virtual process. The process management system (PMS) is the command center for controlling the flow of data within the Navigator System. The central product database (CPDB) is used for storing and archiving of the data of product and process. During the virtual manufacturing process there is a virtual interaction between the system components [6]. The next figure (Figure 4) gives a rough overview of the data flow of the Navigator System and its components.

VIII. PROCESSES WITHIN THE NAVIGATOR SYSTEM

The virtual manufacturing process of a product is carried out with the help of external applications, which make the changes on the STEP product model (single parts, and assemblies, and re-assembly, and finished product). The process within the external applications (Tools/programs) is not important for the Navigator System. This is only for a matter which data (e.g. for NC programming, assembly simulation) are needed to program start.

Figure 4: Overview of the components and data flow in the Navigator System
It is very important to decide, which data need a converter. It is also relevant, that the produced data of the external applications return to the CPDB of the Navigator System after the ending of every application [4].

If an external application (for example, a program of the NC programming) is started in the user interface independent of the required data format, the required data, e.g. current product data (items/manufacturing parts) is sent from the central product (STEP-PM & DBPH) to the external application via the PMS (see Figure 5). The PMS provides on demand by conversion of providing the correct file format (system neutral or native). The produced, processed, and modified data during the execution of the external application can be recycled to CPDB. It can also be done after or during the execution of the external application.

This recycled data will be stored in accordance in the CPDB and is available for other assignment. Furthermore, the generated and modified data in the CPDB can be visualized in the graphical user interface in suitable form by the program internal applications (basic functions) [6].

IX. PRESENTATION OF THE NAVIGATOR SYSTEM

In the graphic user interface the virtual subprocesses of the virtual manufacturing are placed in the main menu. These processes can be displayed in the work area graphically and based on SADT method.

The links to external applications are also placed in the user interface and can be used when needed.

To execute a subprocess of the virtual manufacturing of a product, the corresponding external applications in the user interface are activated by starting the program. External applications are executed in a separate window in the workspace.

The required data and files about the PMs are sent from the CPDB to the activated external applications in the background of the Navigation Systems.

Figure 6: Virtual parts production in NS [6]

X. APPLICATION EXAMPLE

To verify the developed method, the product hydraulic pump is to be manufactured virtually as an example. In this case, various input data is imported from an external data point to the Navigation System via the PMS which is placed in the CPDB accordingly for re-use and archiving. Here, as mentioned above, the navigation is carried out between the processes / sub-processes based on the SADT-method on the common (user interface of the Navigator System).

These processes/sub-processes are executed by external applications without interruptions (media breaks). For this purpose, the impulse "virtual manufacturing" of the product is to be made (hydraulic pump). Here are external applications needed for the sub-processes “virtual part manufacturing, virtual assembly and virtual testing”. The digital components, assemblies and standard parts are to be imported from one or more CAD systems to the Navigator System via an external data interface. For example, only the virtual parts manufacturing for the part, "housing" is performed within the Navigator System.

Figure 5: Data flow - activation of external applications within the NS [7]
To carry out this sub-process "parts manufacturing" in the Navigator System in an appropriate and integrated way, external applications are activated or started in the graphical user interface of the Navigator System, which operate autonomously and without influence from the Navigator System (see Figure 6). These external applications open in a new window with its own menu, for example, the NC process for the housing, the process of modeling virtual CNC machines, etc. Here, the necessary data from the housing, such as 2D drawing, 3D model of the housing, etc. is prepared by the PMS and this is sent to the activated external application. The modified data is sent back by the external application (here the model for machined housing, the NC program) through the PMS to the CPDB to be sorted appropriately. This data is available for further use in the virtual assembly and testing.

Figure 7: NC process of the housing within the Navigator system

REFERENCES

Hashem Badra works a Technical Engineer at a private sector in Gaza. He has a PhD-degree (Doctor-Ingénieur) from the faculty of Mechanical Engineering at Chemnitz University of Technology in the 2012, Chemnitz-Germany. He has 23 years of experience in several fields of Mechanical Engineering on academic, vocational and industrial levels both in Germany and Gaza.

The objectives of Dr.-Ing. Hashem Badra research is to develop in new methods for simulation and modeling of manufacturing operation and planning.

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