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Systematic Design according to VDI and integrated Computer Aided Engineering in Agricultural Technology

At present there is an increasing boom in the industrial sectors of agricultural engineering and renewable energies. Innovation stress and short product life cycles require clear systematic procedures in the early design phase. In addition, the application of integrated computer-aided tools could support problem solving. The development of a mixing and transporting robot for solar biomass dryers exemplifies the potential of that integrated design process.

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Literature

Literature references can be called up under LT 07312 via internet http://www.landwirtschaftsverlag.com/landtech/local/fliteratur.htm.

The sector of agricultural engineering and utilisation of biomass are presently characterised by an increasingly shorter development cycle and a more complex technology of products. At the same time, the customers ask for more individual products and a balanced price-performance ratio. The globalisation of markets causes high innovation pressure in Europe. Considering also the relatively high personnel costs, user-friendly design- and creativity methods can support the engineers to manage these challenges. To meet targets such as quality improvement, cost reduction and time saving, the VDI-guidelines for systematic development and design of technical systems and products offer a comprehensive method. At present, the VDI-guidelines offer just a fragmentary answer to the question how classical design methods could be combined with modern computer-aided engineering tools. Applying CAx-technologies - the "x" represents a great possible field of application - digital mock-ups can be established, interactively configured and simulated to investigate their functions and properties. Thus, machines and constructions can be evaluated and modified already during the early design phase. In that case a physical construction of the product is not required. Due to the mainly general and abstract procedure of classical design methods they have not arrived on the application field of engineering agricultural products and systems. At the moment, merely major manufacturers of farming equipment apply integrated 3D-software in design and simulation of their products.

In a R&D-project of the Universität Hohenheim and the industrial company Thermo-System, classical design methods were combined with latest computer aided tools. The results of that project are partially exemplified on the development of a mixing and transporting robot for solar biomass dryers.

VDI-guidelines for systematic design and evaluation

The VDI-guidelines for systematic design of technical systems offer a comprehensive library of methods for all development phases. They are published by the "VDI Society for Development, Design and Marketing". The superior guideline VDI 2221 "Systematic approach to the development and design of technical systems and products" shows the general procedure in development and design [1]. The guideline VDI 2222 sheet 1 "Methodical development of solution principles" deals with the design steps of the superior guideline VDI 2221 in a supplementary and more detailed way [2, 3]. The guideline VDI 2223 "Systematic embodiment design of technical products" contains methodical support especially to the process of form design [4]. The guideline VDI 2225 "Design engineering methodics – Engineering design at optimum cost" provides a methodical platform for the evaluation of solution alternatives [5, 6, 7, 8]. This guideline is divided into four sheets: Sheet 1) Simplified calculation of costs; Sheet 2) Tables for engineering design at optimum cost; Sheet 3)

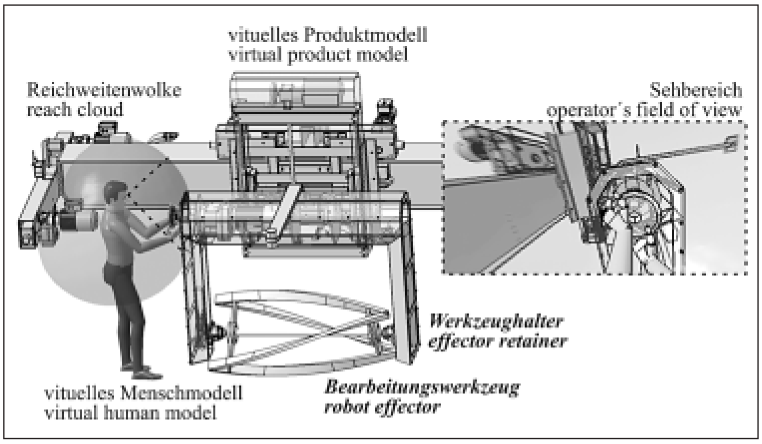

Fig. 1: Virtual product model of the mixing and transporting robot

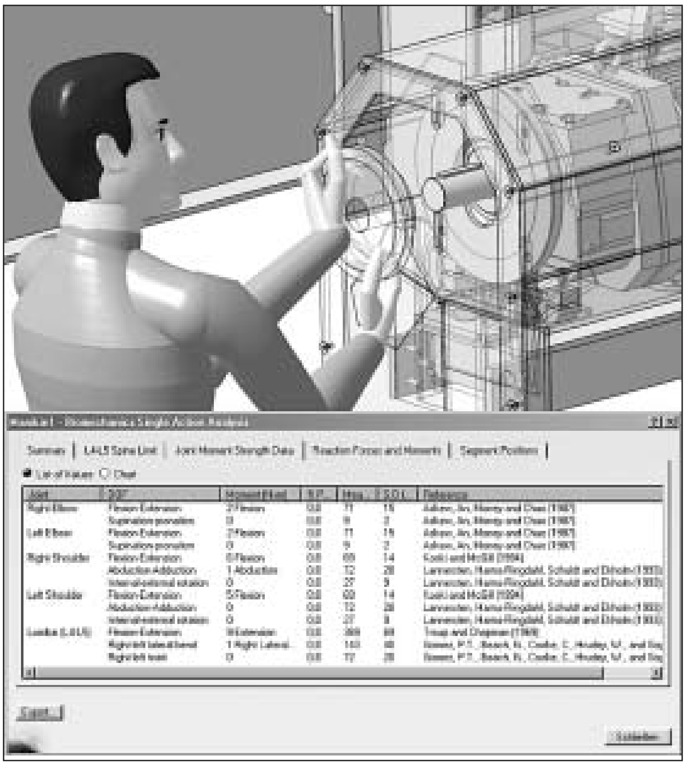

Fig. 2: Assembly simulation with analysis of the biomechanical stresses

Valuation of costs; Sheet 4) Dimensioning. In addition, the VDI Society for Development, Design and Marketing offers further guidelines which deal with more specific fields of systematic design [9, 10, 11, 12, 13, 14].

The recommended design procedure in the superior guideline VDI 2221 is divided into seven design steps: (I) Clarification and definition of the problem. (II) Determination of functions and their structures. (III) Search for solution principles and their structures. (IV) Dividing into realisable modules. (V) Form design of the most important modules. (VI) Form design of the entire product. (VII) Compilation of design and utility data. The VDI-guidelines provide for each of the seven design steps various methodical support.

CAx using CATIA - an integrated engineering tool

To develop the mixing and transporting robot the CAE-software CATIA was used. CATIA (Computer Aided Three-Dimensional Interactive Application) is a CAD-software of the French company Dassault Systèmes, which was primarily developed for aircraft construction. Actually, the software is also getting established in the field of mechanical and vehicle construction. Using CATIA, it is able to generate product data, develop three-dimensional design models and finally derive two-dimensional production drawings. The software consists of various modules such as part design, surface modelling, drawing creation etc. Some of the other modules are listed below:

- FEM structure analysis
- Collision analysis on the virtual product model
- DMU assembly & fitting simulation
- DMU kinematics simulation
- NC manufacturing & machining simulation
- Electrical engineering & cable harness simulation

„Mixing and transporting robot“ for solar biomass dryers

The design steps I to IV were realised according to the VDI-guidelines. This work resulted in two competing concepts for the robot with 4 and 5 degrees of freedom, respectively. These concepts were technically and economically evaluated, in order to release the preliminary design for the further detail design. The results of that process were published in [15, 16]. The virtual 3D product model of the released concept is shown in *Figure 1*. The machine components are parametrically connected by specific relations. The material characteristics are specified and registered in a database. Thus, geometric engineering and finite elements structure analysis could be simultaneously done to optimise the topology of parts.

CAE in the concept design phase: Example „Product Function Optimisation“

The strong and the weak points of the components of the robot were identified during manufacturing and the initial pilot tests with the first prototype. Using the module CATIA Product Function Optimiser, the strong and weak points were merged to a function structure plan and linked by hyperlinks to the 3D engineering data set. The parts were combined with the parameters costs, function rank and problem rank in a database. Hence, the mixing and transporting robot was completely described by a virtual product with respect to its functional and physical features. Different optimisation strategies considering targets such as "reduction of costs" and "problem recovery" lead to a second prototype of the robot, which was placed on the market at the meantime.

CAE in the detail design phase: Example „Human Activity Analysis“

One of the targets for the further detail design was to ensure rapid manufacturing and easy servicing of the robot. In the first step the translation volumes of the parts during the assembly process were computed. Thus, any collisions of the parts were eliminated. In addition, biomechanical analysis was done for handling several selected wearing parts. The virtual product model and a virtual human model were combined to one system in order to simulate the human interaction with the robot components. The reach cloud of an adult, male 50-percentile European during servicing the driving elements of the robot tool is shown in *Figure 1*. On the right side of Figure 1 a snapshot of the operator's field of view during replacing the chain wheel is shown. Further investigation focused on evaluation the free space to install the chain wheel ambidextrously and safely. In addition, a motion study of the limbs and the whole body was done. *Figure 2* shows a detail of the assembly of the chain wheel. The bottom part of Figure 2 shows the appropriate biomechanical analysis of the elbow, shoulder and spinal column respectively. The analysis contains the computation of the motion path of the limbs as well as the computation of the mechanical moments and reaction forces.

Conclusions

The generally described systematic approach according to the VDI-guidelines is well suited to identify the project goals, search for solution principles and evaluation of several competing concepts in the early design phase. Integrated CAE systems such as CATIA present a complete and open platform for a continuous product development from function modelling and simulation to manufacturing. The combination of those tools leads to a reduction of development time and costs. Furthermore, it supports innovative solutions and ensures a traceable documentation of the product development.