International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:7, No:3, 2013

An Approach for Optimization of Functions and Reducing the Value of the Product by Using Virtual Models

A. Bocevska, G. Todorov, T. Neshkov

***Abstract*—**New developed approach for Functional Cost Analysis (FCA) based on virtual prototyping (VP) models in CAD/CAE environment, applicable and necessary in developing new products is presented. It is instrument for improving the value of the product while maintaining costs and/or reducing the costs of the product without reducing value. Five broad classes of VP methods are identified. Efficient use of prototypes in FCA is a vital activity that can make the difference between successful and unsuccessful entry of new products into the competitive word market. Successful realization of this approach is illustrated for a specific example using press joint power tool.

***Keywords*—**CAD/CAE environment, Functional Cost Analysis (FCA), Virtual prototyping (VP) models.

I. Introduction

THE current trend forces companies to produce low-cost and high-quality products in order to maintain their competitiveness at the highest possible level, which arises due to rapid technological developments. There is no doubt that, reducing the cost of a product at the design stage is more effective than at the manufacturing stage. Therefore, if the product manufacturing cost can be estimated during the early design stage, designers can modify the design to achieve proper performance as well as a reasonable cost at this stage.

Functional Cost Analyze (FCA) of Functional Value Analyze (FVA) is a value engineering method that aims to increase the difference between the cost and value of a product [1]. The cost is amount that is incurred in the production and delivery of the product. What the product is worth in the eye of the customer is considered the value. When completing a FCA this definition is extremely important. The design team may not perceive a certain product feature to be valuable, however it is important to the customer, than that feature must be regarded as valuable.

In this respect, physical prototyping can prove to be very lengthy and expensive, especially if modifications resulting from design reviews involve tool redesign.

Despite reliability and high accuracy of CNC, its increased time and cost over other available processes have discouraged its use, although high-speed CNC machining attempts to improve shortcomings of CNC by decreasing machining cycle times and increasing material removal rates [5]. The availability and affordability of advanced computer technology has paved the way for increasing utilization of prototypes that are digital and created in computer-based environments, i.e. they are virtual as opposed to being physical.

Andrijana Bocevska is with Faculty of Technical Sciences, University "St. Kliment Ohridski", Bitola 7000, Macedonia, (e-mail: abocevska@yahoo.com).
Georgi Todorov is with the Faculty of Industrial Technology, Technical University, Sofia 1797, R. Bulgaria, (e-mail: gdt@tu-sofia.bg).
Todor Neshkov is with Faculty of Mechanical Engineering, Technical University, Sofia 1797, R. Bulgaria, (e-mail: tnesh@tu-sofia.bg).

The main aim of this paper is to present a new approach which define performance of Functional cost analyze based on virtual prototypes in CAD/CAE environment, while using all of their advantages and specific techniques. The proposed approach is illustrated with an industrial example.

II. Functional Cost Analyses based On Virtual Prototypes

A. Virtual Prototypes

Virtual prototyping is an aspect of information technology that permits analysts to examine, manipulate, and test the form, fit, motion, logistics, and human factors of conceptual designs on a computer monitor. Pratt [4] states that almost any form of computer model will serve for some purpose as a virtual prototype. Based on the modeling objectives and purposes, five broad classes of VP methods are identified:

1. Visualization Models

Visualization models are used for examination of form as well as appearance. These models play a crucial role in communication of product information between a variety of users including marketing people, customers, managers, product development teams and engineering and even repair and maintenance personnel. Visual appearance also serves as an attraction factor. Modern visualization software can simulate interactive navigation capabilities through complex assemblies of any size to enable effective and accurate visual inspection.

2. Fit and Interference

Fit and interference assessment is generally an iterative, time consuming and error prone process that would benefit from being replaced with VP using three dimensional models. Using VP, the product can be evaluated automatically with great accuracy and speed, resulting in a listing of all the interference's. It is also possible visually to inspect the virtual prototypes, where clearances and interfering areas of the CAD model can be highlighted with different colors. Visual inspection of a digital three-dimensional increasing the power of VR with new haptic applications and interfaces may provide a solution through simulating sense of touch.

3. Testing and Verification of Functions and Performance

Prototypes are used frequently to verify the functionality and performance of various features of a new product during its development phase. Virtual prototyping relies on three-dimensional solid models to create accurate models that are complete and comprehensive in terms of both detailed geometrical (e.g. center of gravity, surface, volume) and non-geometrical (e.g. properties such as density, stiffness, etc.) data. The resulting wealth of information satisfies the data needs of advanced CAE tools for carrying out extensive and specialized tests and analysis. As for the test data, they may be either simulated or collected from previous physical testing of finished products. Finite element analysis is the most accepted and widely used VP tool. It calculates the relations between material properties and structural performance to predict the behavior of a structure with respect to virtually all physical phenomena [3]. The motion of any mechanical assembly may be modeled, evaluated and optimized in two or three dimensions. The two main types of motion simulation are:

1. Kinematics performance. Velocity, acceleration, position, displacement and rotation are determined without considering the mass or force properties. 2. Dynamic motion. The main difference from kinematics simulation is that dynamic analysis considers additionally both the mass and the forces associated with the constituent elements of an assembly. The underlying method for calculation of the dynamics of forces and motion is the 'numerical method' [2] which is used to approximate the motion of mechanical systems by solving differential equations

4. Manufacturing Evaluation

Ideally, virtual prototyping should comply with the requirements of concurrent engineering (CE), as opposed to sequential engineering, and must therefore allow simultaneous product exploration and collaboration by various engineering teams. Prototype evaluation should include prediction and simulation of manufacturing processes and production planning both during the conceptual design when design data are incomplete and during the later stages when the design has matured after several design iterations. The risks of transition to full production can be reduced by integrating virtual design and testing with manufacturing simulation. Tseng et al. [6] report an example of VP design environment implementation where, through capture and utilization of information generated during the design phase, data for manufacturing and production and assembly planning are simultaneously generated.

5. Human Factor Analysis

Software tools for virtual prototyping can be used to evaluate alternative options when designing. Moreover, the integration of virtual prototypes with virtual reality gives the user the opportunity to interact with realistic three-dimensional models. On that way, physical objects behavior can be better represent during simulated conditions and physical laws.

B. Functional Cost Analyze Based On Virtual Prototype

Features of the FCA and virtual prototyping can become a significant advantage in development of new products. The approach for making FCA based on virtual prototype emerged as one of the most effective means to generate an adequate assessment of functionality and value of the product Fig. 1.

Step 1: Create a List of Components

Virtual prototype that is available at the earliest design stage contains all the necessary information to compile a list of individual components. In this case falls to the need of analyzing similar products and data mining of drawings and other documentation of competitive solutions.

Step 2 - Determine the Value of Components

This step can be regarded as the most important in terms of accuracy at the time of implementation of analysis, and but also represents the core of FCA. This step determines how close a product is to the expected characteristics.

There are several approaches to realize this step:

– Assessment based on similar existing components - this approach works with a various number of approximations and provides not very precise and reliable results.

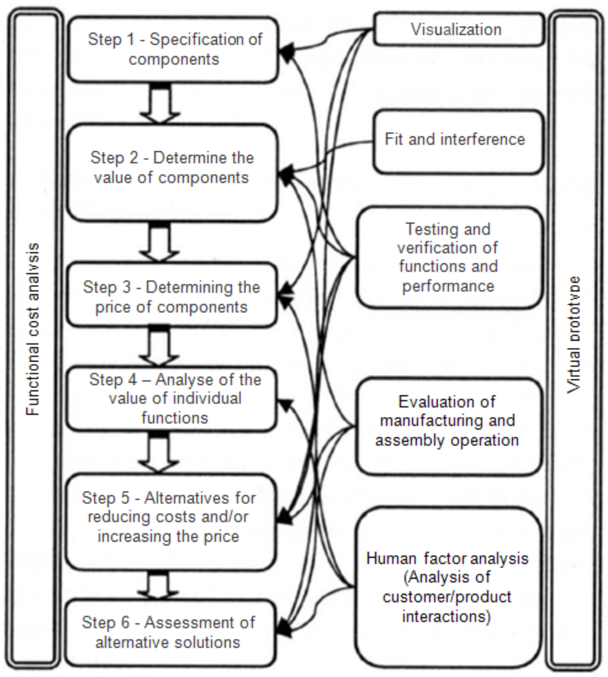

Fig. 1 Applicability of properties of VP in the course of FCA

– Expert evaluation - this approach is more imprecise and carries greater risk to differences between experts and the actual assessment.
– Evaluation based on virtual prototype - this is the right approach, since the virtual prototype contains all the

necessary information to produce an accurate value evaluation. Geometric information (volume, specification of material) gives a required volume of used material, while tolerances and precision requirements along with geometric information allow estimating the cost of production.

– Assessment based on information from suppliers
– This is possible when virtual prototype and its attributes exist such as visualization, geometric information and more. Virtual prototype allows fully comprehensive information, based on which suppliers can define value of individual components.

Step 3 - Determining the Price of Individual Components

Step 4 – Analyze of the Value of Individual Functions

These steps are combined as value of the functions defined in the previous steps of FCA. Both steps in general represent attributes of virtual prototypes related to the analysis of interaction between product and customer.

Virtual prototypes combined with the means of virtual reality may be used to obtain feedback from customers or simply to analyze the values of individual functions. Opportunity to review the functionality in near real conditions provides comprehensive information on how a product is perceived by the customer.

Step 5 - Alternatives for Reducing Costs and/or Increasing the Price

This is another important step in FCA in which virtual prototype has successful application. Virtual prototype of a conceptual model can be easily modified to create different variations. Furthermore, modern VP can be fully parameterized, allowing individual parameters to be changed, with purpose to define a variant with the best functionality. All five attributes of the virtual prototype are related to this step - visualize new solutions, geometric verification of their implementation, functional analysis – main subject of FCA, manufacturing simulation - mostly related with the next step 6 - the price of alternative solutions and analysis of the human factor - which is an important element in making final decision.

Step 6 - Assessment of Alternative Solutions

Application of VP in this step is similar to that in step 1. Here the information that VP has is used to assess newly developed alternative solutions. VP also allows parallel storing of all generated variants until final decision, which variant will be use. This enables generating of multiple solutions that can be offered together at the market, which helps greater flexibility to be achieved.

III. Example of Using Virtual Prototype in FCA

Successful realization of previously mentioned approach regarding implementation of functional value analysis based on virtual prototype is illustrated for a specific example using press joint power tool. This type of instrument is characterized by a specific design as they require transforming rotary movement of electric motors in translational movement of working instrument. There are additional requirements such as compact and ergonomic design and cost-effective realization.

A comprehensive function cost analyze of existing solution is realized. The analyze is based on a virtual prototype which has relatively high accuracy of the results.

To accomplish analyze focuses on press joint power tool value reduction while maintaining their existing functionality. A detailed review of the value of each component also is performed. For this purpose the components are grouped in seven basic groups: Completed shaft I, Complete shaft II, Screw nut gear, Reduction gear housing, working instrument, electromotor, and other, Fig. 2. The value of each group is evaluated and illustrated graphically in Fig. 3. Final calculated cost of existing solution is 54.2 euro. Based on the studies, following conclusions are made:

- The main cost element is electric motor. This component also is used in other existing products and its value can be hardly reduced.
- The next element is reduction gear housing, whose geometry can be optimized with the reduction gear simplification.
- The third element is screw nut gear, whose value reduction can also be difficult to obtain.
- Working instrument and other components constitute a small part of total costs and his reduction will lead to non significantly reducing of total value of product.

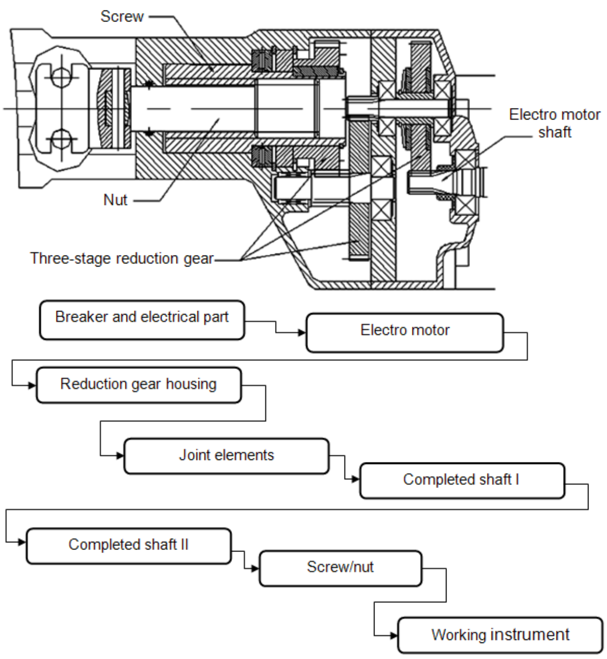

Fig. 2 Original design of considered press joint power tool

- Three-stage reduction gear has a value close to screw nut gear and his simplifying as well as reducing the number of elements would significantly reduce the whole product value.

Finally we can summarize that the three-stage reduction gear which was used can be optimized by choosing an alternative mechanism for transmitting movement while maintaining the required torque/pressure force. This is the main goal of the accomplish optimization.

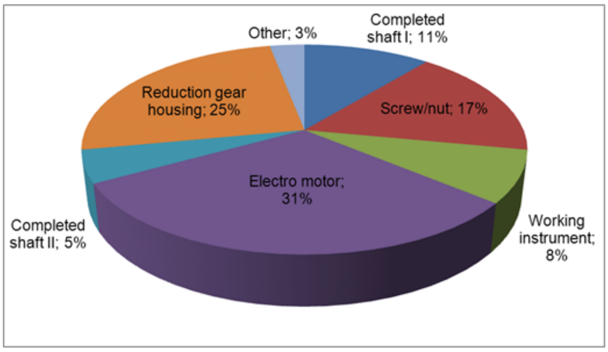

Fig. 3 Distribution of expenditure by basics groups of the existed solution

A new alternative construction of gear mechanism, illustrated in Fig. 4 is developed. The presented mechanism has the following components:

- Two-stage reduction gear with gear ratio I = 18.43.
- Differential screw nut gear with satellite rolls to move linearly screws of 0.66 mm per revolution of the nut.
- A virtual prototype of presented mechanism is developed.

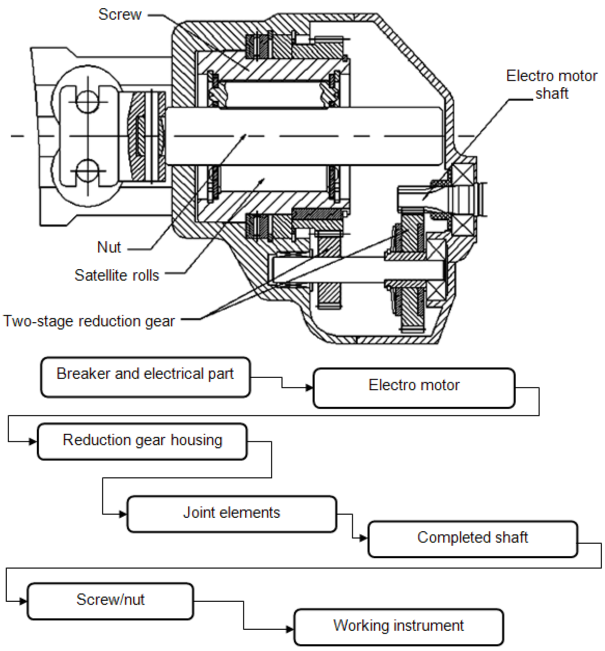

Fig. 4 New design of the gear mechanism

Based on information generated from it, functional value analysis of new solution is performed, again dividing it into separate functional groups. The value of each group is presented in Fig. 5.

Final calculated cost of new solution is 53.1 euro. It is seen that with the new solution reduction of the product value for 1.1 euro is achieved. Applying this in series production will lead to significant costs reduction.

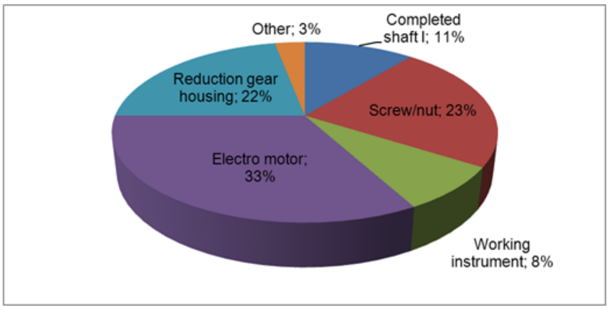

Fig. 5 Distribution of expenditure by basics groups of the new solution

IV. Conclusion

A new developed approach about performing Functional cost analysis with application of virtual prototypes in CAD/CAE environment is applicable and necessary in developing new products. It enables improving the value of the product while maintaining cost and/or reducing the cost of the product without reducing value at early stage of the design. This approach leads to improved product designs and lower costs by identifying or eliminating high cost functions in accordance with customers. Also, it is not necessary to analyze similar products and data mining of drawings and other documentation of competitive solutions, because a list of individual components is based on virtual prototypes. The cost of production can be estimate based on geometric information, tolerances and precision requirements of the prototypes.

References

[1] C. Nigel, “Engineering Design Methods”, John Wiley & Sons Ltd., United Kingdom, ISBN 0-471-92215-3 pp. 123-142, 1989.
[2] G. H. Golub, and J. M. Ortega, “Scientific Computing and Differential Equations: An Introduction to Numerical Methods”, (Academic Press, USA), 1992.
[3] T. Hughes, “The Finite Element Method: Linear Static and Dynamic Finite Element Analysis”, (Dover Publications, USA), 2000.
[4] M. J. Pratt, “Virtual prototypes and product models in mechanical engineering”, In Virtual Prototyping – Virtual Environments and the Product Design Process, pp. 113-128 (Chapman and Hall, London), 1995.
[5] T. Schmitz, M. Davies, B. Dutterer, and J. Ziegert, “The application of high-speed CNC machining to prototype production”, Int. J. Mach. Tools and Mf. pp. 1209-1228, 2001.
[6] M. M. Tseng, J. Jiao, and C. J. Su, “Virtual prototyping for customized product development”, Integrated Mfg Syst., pp. 334-343, 1998.