

# Applications of virtual reality technologies in design and development of engineering products and processes

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## 1. Introduction

Virtual reality (VR) technologies support and accelerate product design, facilitate actualisation and delivery of ideas, and are highly helpful for discussions and collaboration [1]. It is known as a new dimension in man-machine communication that combines real-time (3D) computer graphics direct intuitive interaction in 3D space [2]. They are one of the main mechanical engineering tools helping to obtain better results designing new and improving already designed products [3, 4]. Significant benefits on efficiency and flexibility of processes as well as functionally of products serve as the reference point for using such technologies in other engineering operations [5, 6]. Short production terms, often being the case even manufacturing complex products, make manufacturers to involve engineers of various specialisations. In such situations, quick, creative, and integrated activities are needed in order to find and integrate efficient solutions. The use of virtual technologies in various product design or manufacturing stages requires various abilities and skills, such as the understanding of what is requested, using computer and software, converting and processing data, understandable presentation of the information; also insight, experience, curiosity, and talent. The better the engineer at each stage of the chain understands what is requested from him/her and the more understandably he/she delivers his/her requests, the smoother the following stages of product design go. This is also applicable to the ability of collecting data that later will be used for designing virtual 3D prototypes and further development of the products; and skills of creating and improving virtual 3D prototypes that later will be used for designing CNC and other programs and preparing questions and proposals. The most important aspects of the application of VR technologies [7, 8] discussed in the article:

**Novelties:** the article describes the method which allows accelerating many stages of product design, development, and manufacturing; putting into effect solutions that can hardly be actualised using classical methods. This method originated from multiple attempts to use VR technologies in the area of products design and develop in Mechanical Engineering Company; the result was achieved due to contact development of mechanical processing technologies, tight collaboration supported by an IDEF0 diagram of corporate specialists and divisions, and goodwill cooperation between the manufacturer and the client [9].

**Scientific value:** cross-disciplinary communication enables developing new information, transferring and accepting knowledge and experience, acquiring and im-

proving skills, accumulating experience and so on. Practical value: improved technical communication and more rapid generation of alternative ideas. Designing spherical elements and implementing them into the existing 2D drawings is complicated and time consuming process. It requires the creation of additional technologies that extend the time and increase the cost of production. Besides this, the 2D technology requires using several reference points that influence manifestation of setting (measurement) errors.

## 2. The improvement of technological process using VR

### 2.1. The relationship between physical and virtual prototypes

The usability of the user interface is a key aspect for the success of several industrial products. This assumption has led to the introduction of numerous design methodologies addressed to evaluate the user-friendliness of industrial products. Most of these methodologies follow the participatory design approach to involve the user in the design process [10]. 3D prototypes may be successfully used in various stages of product design and manufacturing: rapid design and improvement of work pieces; rapid design and improvement of surface geometry and preciseness; rapid generation of alternatives that would improve the structure and workability of the part or product; better cooperation between the manufacturer and the customers, the manufacturer and the consumers, and between various departments of the manufacturer. Virtual 3D prototype may be improved at any time by using software. The technological solution is implemented into a product at early production or design stages. The improved prototype is transferred to the programmer, who creates CNC program for mechanical processing of the product. Surface and geometry of the product remain unchanged, but there's achieved enhanced workability of the product. Simpler processing technology and reduced technological tooling reduce mechanical processing time thus enabling manufacturers to offer customers more competitive prices.

In a proposed case the manufacturer obtained primary 3D prototype from the customer (Fig. 1). It was a welded structure consisting of various length square tubes with wall thickness 3mm and plates of different geometrical forms and sizes. The plates were located at various original and complicated angles facing each other. Most of them should be mechanically processed aiming to obtain surfaces and holes of certain preciseness (tolerance T, Table 1). The development of the product, using VR technology, consists of the following stages:

- the evaluation of geometrical, constructional and mechanical processing possibilities of the product;
- development stage;
- creation of the CNC numerical control program.

The examination of 3D prototype is presented on the monitor. Making decision on the improvement of the prototype is proposed, aiming to improve workability of the product. Such improvement enables to maintain customers' requirements after implemented changes. Deciding on what actions shall be taken in order to implement the idea and performing them. Choosing necessary 3D and 2D CAD software and measurement tools for the implementation of idea is discussed.

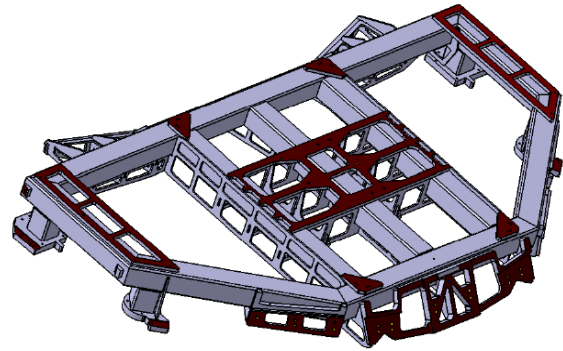


Fig. 1 Primary virtual 3D prototype of the product

Table 1

Geometrical and mechanical characteristics of the product

Element	Position of the element in rectangular coordinate system	$T$	Mechanical operations
$\varnothing 6H7$	$\perp / \parallel$	+0.015 0	centering, drilling, reaming, broaching
$\varnothing 8H7$	$\perp / \parallel$	+0.015 0	centering, drilling, reaming, broaching
$\varnothing 10H7$	$\perp / \parallel$	+0.018 0	centering, drilling, reaming, broaching
M8	$\perp / \parallel$	$\pm 0.2$	centering, drilling, tapping
M10	$\perp / \parallel$	$\pm 0.2$	centering, drilling, tapping
M12	$\perp / \parallel$	$\pm 0.2$	centering, drilling, tapping
Milling surface $R_a 3.2$	$\perp / \parallel$	$\pm 0.2$	Rough milling, smooth milling
Milling surface $R_a 3.2$	$\angle 10^\circ / \perp$	$\pm 30'' / \pm 0.1$	Rough milling, smooth milling
Milling surface $R_a 3.2$	$\angle 22^\circ / \angle 80^\circ$	$\pm 30'' / \pm 0.1$	Rough milling, smooth milling
Milling surface $R_a 3.2$	$\angle 82^\circ / \angle 89^\circ$	$\pm 30'' / \pm 0.1$	Rough milling, smooth milling
Milling surface $R_a 3.2$	$\angle 55^\circ / \perp$	$\pm 30'' / \pm 0.1$	Rough milling, smooth milling

## 2.2. Digitization of physical model

This method was necessary since CNC machine was capable of processing elements not larger than overall dimensions  $1700 \times 1000 \times 350$  mm. Sometimes the manufacturers get orders exceeding the capabilities of CNC machines. In such case inquiry or even order must be cancelled facing technical capabilities of the manufacturer. Cancellation of inquiries and orders may lead for losing customers. In order to retain competitiveness manufacturer must put in one's best efforts as possible performing gotten orders. In the described case, the overall dimensions of the product were  $2100 \times 1400 \times 206$  mm. Such welded structure is processed applying tool machine with bigger work table but less possibility of spindle positioning the tilting and turning in respect to coordinate system of machined welded structure. In such cases, manufacturers used to produce specific technological tooling that served as a starting point or a compensation of tilting or turning of the element or

spindle. The production of such technological tooling required additional time, machinery, high quality specialists, materials, and energy. In addition, such technological tooling might not be enough for establishing one reference point and machining the welded structure because the manufacturers must use several reference points making more complicated chain of measurements and increasing the probability of setting errors. Designer's input to the improvement of the product depends on his/her knowledge of manufacturing technology and design skills. In a development stage, the main designer's output is an alternative 3D prototype. Virtual 3D prototype of the product becomes the intermediary between the customer, the designer, the technologist, and the operator. The described method has been developed aiming to improve mechanical processing technology, saving expenses of producing additional technological facility, and reducing the number of actual production actions and the number of reference points thus avoiding the errors. Product development diagram, gener-

alising the applied method, is delivered in (Fig. 2.)

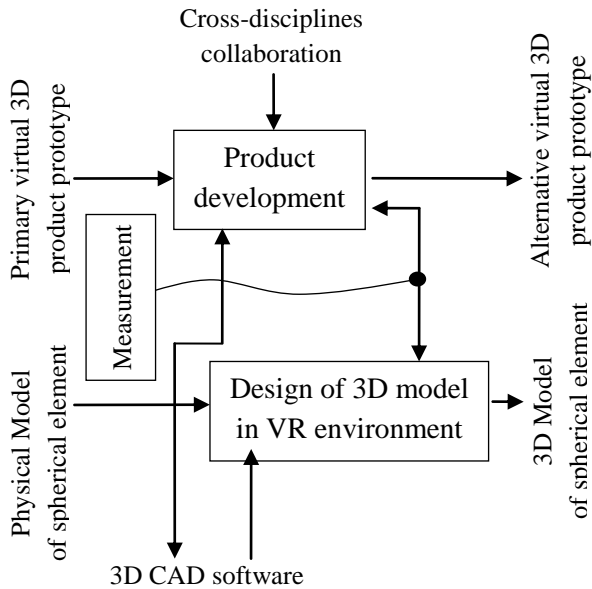


Fig. 2 IDEF0 diagram of 3D model generation in VR environment

Aiming to improve the workability of the product, spherical element, delivered in (Fig. 3), was used. That tooling is fixed in a rectangular tube. As technological fixing feature for spherical element a M6 3 mm depth hole is used. Spherical elements perform significant roles in manufacturing of the products with prevailing precise and geometrically intrinsically to each other located surfaces. This element combines its mechanical functions with the idea of a technologist improving the workability of the product and creating better opportunities to design CNC program for manufacturing of the product reducing the amount of technological tooling and the probability of setting (measurement) errors. Aiming to develop 3D prototype delivered by the customer to the level that satisfies the requirements of a production technologist and programmer, the designer created virtual 3D prototype of a spherical element (Fig. 4).

Virtual 3D CAD prototype of the spherical element has been created on a basis of the sketch in communication with 3D design program (Fig. 5). Data for the sketch Table 2 was obtained having measured physical model of the spherical element in a measurement laboratory. The process of developing a 3D prototype of the



Fig. 3 Physical model of spherical element

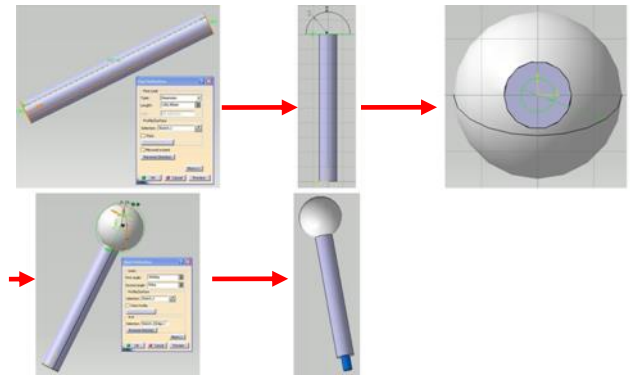


Fig. 4 Design steps of virtual 3D model of spherical element

spherical element had to involve a specialist of measurement laboratory who had to measure physical model of the spherical element and design the sketch with required dimensions.

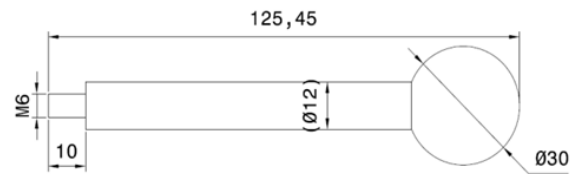


Fig. 5 Sketch of spherical element after measurement

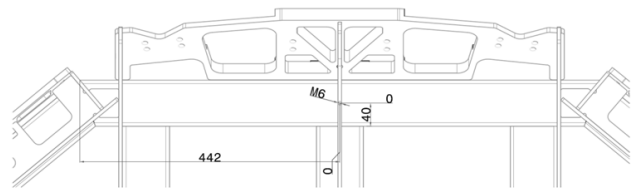


Fig. 6 Sketching of spherical element positioning in primary model of a product

Virtual 3D spherical element was integrated in a VR into virtual 3D model, sent by the customer, making an additional M6 3 mm depth hole. The location of the technological feature was selected by the programmer employing his/her knowledge on the manufacturing technology and properties of the machinery that will be used for mechanical processing of the developed product. The sketch with required dimensions was delivered to the designer (Fig. 6). The sketch involved the indication of the type and the location of the hole in a primary model of the product. Then the designer employing his design skills integrated the hole to the virtual 3D prototype (Fig. 7).

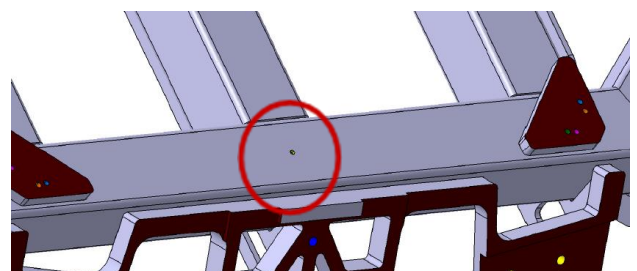


Fig. 7 Appointment of spherical element positioning in the 3D model



Data for integration of spherical element into primary product

Element	Length $L$ , mm	$T$	Width $W$ , mm	Diameter $D$ , mm	$T$	Coord. $x$ , mm	$T$	Coord. $y$ , mm	$T$
Sphere	125.45	$\pm 0.2$	-	30	$\pm 0.02$	(442)	$\pm 0.2$	40	$\pm 0.2$
Hole	3	$\pm 0.2$	-	M6	$\pm 0.2$	(442)	$\pm 0.2$	40	$\pm 0.2$

After the improvement of virtual 3D prototype, integrating an additional spheric element (Fig. 8), new projections of the product in 2D environment were made. This data was used for the development of CNC program to produce an actual product (Fig. 9).

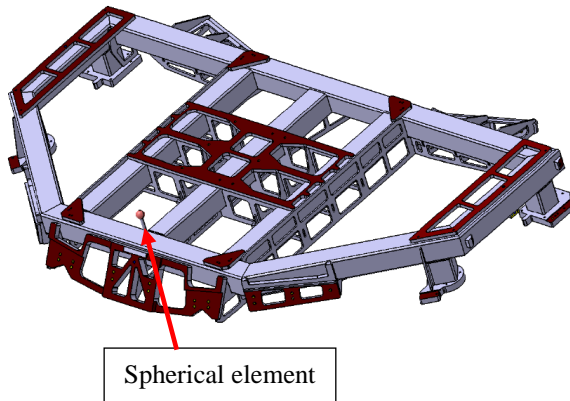


Fig. 8 Alternative virtual 3D product prototype

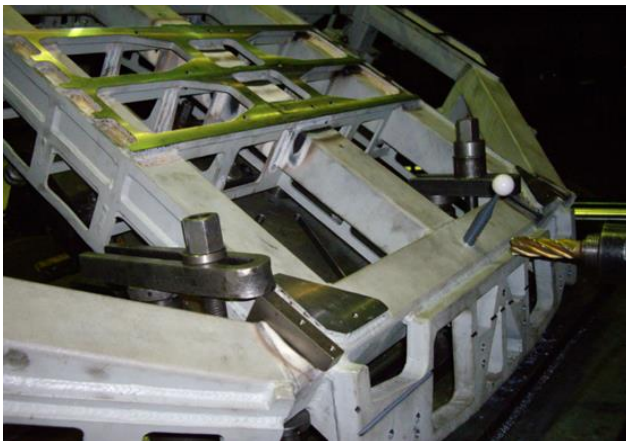


Fig. 9 Actual product

### 3. Conclusions

In response to scientific value: possibility of facing, designing, and integrating virtual prototypes is a good basis for firming already possessed and acquiring new, specific, knowledge on the implementation of virtual prototypes in the area of product design and manufacturing. Such experience also helps to maintain and improve one's innovative, adaptive, and competitive potential.

In response to practical value: the integration of VR technologies enhances the possibilities of manufacturers to implement various technological solutions and make this process faster. It helps to transfer the knowledge acquired into the processes and products as well as provides better opportunities for using the information collected at early stages of product or process development.

Novelties: the applied method connects classical

and VR technologies. The use of VR technologies accelerated the integration of a spherical element into a 3D prototype and the preparation of CNC program.

### References

1. **Paolo Leoncini, Mariano Guida, CIRA Italian Aerospace Research Centre Via Maiorise, Capua (CE) Italy.** 2009. From CAD models to virtual reality simulations: Catia to VR geometry and Dynamics data translation by a VBA plug-in approach. 13<sup>th</sup> International research/expert conference "Trends in the development of machinery and associated technology" TMT 2009, Hammamet, Tunisia, 16-21 October: 613-616.
2. **Jian-Ping Li, Thompson, G.** 2003. Modelling of mechanical failures in a virtual reality design environment. Reliability and Maintainability Annual Symposium - RAMS: 507-512.  
<http://dx.doi.org/10.1109/RAMS.2003.1182040>.
3. **Alcinia Z. Sampaio, Ana R. Gomes, Augusto M. Gomes, Joana P. Santos, Daniel P. Rosario.** 2011. Collaborative maintenance and construction of buildings supported on Virtual Reality technology. The Third International Conferences on Advances in Multimedia: 80-86.
4. **D'Adderio, L.** 2001. Crafting the virtual prototype: how firms integrate knowledge and capabilities across organizational boundaries. Journal: Research Policy-RES POLICY, vol. 30, no. 9: 1409-1424.  
[http://dx.doi.org/10.1016/S0048-7333\(01\)00159-7](http://dx.doi.org/10.1016/S0048-7333(01)00159-7).
5. **Frenkel, J., Schubert, Ch., Kunze, G., Jankov, K.** 2009. Using modelica for interactive simulations of technical systems in a Virtual Reality environment. Proceedings 7th Modelica Conference, Como, Italy, Sep. 20-22: 531.
6. **Kuehn, W.** 2006. Digital factory- integration of simulation enhancing the product and production process towards operative control and optimisation. International Journal of Simulation 7(7): 27-39.
7. **Mujber, T.S., Szecsi, T., Hashmi, M.S.J.** 2004. Virtual reality applications in manufacturing process. Journal of Materials Processing Technology 155-156: 1834-838.  
<http://dx.doi.org/10.1016/j.jmatprotec.2004.04.401>.
8. **Shin, J., Joo, J., Choi, I., Han, S. H. and Cho, H.** 2000. A prototype virtual reality system through IDEF modelling for product configuration and analysis. International Journal of Industrial engineering, 7(1): 15-25.  
<http://dx.doi.org/10.1080/0951192X.2010.518632>.
9. **Cecil, J., Kanchanapiboon, A.** 2007. Virtual engineering approaches in product and process design. International Journal of Advanced Manufacturing Technology, Vol. 31, No. 9: 846-856.  
<http://dx.doi.org/10.1007/s00170-005-0267-7>.

10. **Bruno, F., Muzzupappa, M.** 2010. Product interface design: A participatory approach based on virtual reality. *International Journal of Human-Computer Studies* 68: 254-269.  
<http://dx.doi.org/10.1016/j.ijhcs.2009.12.004>.

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VIRTUALIOS REALYBĖS TECHNOLOGIJŲ  
 TAIKYMAS KURIANT IR VYSTANT INŽINERINIUS  
 GAMINIUS IR PROCESUS

Re z i u m ė

Straipsnyje pateiktas virtualiosios realybės technologijų metodas, pagreitinantis naujų gaminių ir procesų projektavimą. Pasiekama didelė procesų nauda ir efektyvumas bei lankstumas, taip pat aukštas konstruojamų gaminių funkcionalumas, naudojant minėtas technologijas. Šiame straipsnyje aprašytas metodas, padedantis pagreitinti inžinerinės pramonės gamybos procesus. Aprašytas metodas išsiskiria savo originalumu iš kitų mums žinomų būdų mechanikos inžinerijos srityje. Rezultatas pasiektas dėka glaudaus bendradarbiavimo tarp visų gamybinės korporacijos specialistų ir padalinių bei geros valios bendradarbiavimo tarp gamintojų ir užsakovų. Mokslinė svarba išreikšta tarpdisciplininio bendravimu, padedančiu siekti ir kurti naujas žinias bei patirtį, kvalifikaciją ir pan. Praktinė reikšmė – pagerinti techniniai ryšiai tarp gamintojų ir greičiau generuojamos alternatyvios idėjos. Sukurti ir įdiegti sferiniai elementai pagerino gaminio technologiją ir sumažino gamybos proceso laiką.

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APPLICATIONS OF VIRTUAL REALITY  
 TECHNOLOGIES IN DESIGN AND DEVELOPMENT  
 OF ENGINEERING PRODUCTS AND PROCESSES

S u m m a r y

The paper deals with application of virtual reality (VR) technologies for accelerating new product and process design. Significant benefits on efficiency and flexibility of processes as well as functionality of new products are available to get applying such technologies. The article describes the method, which allows speeding up the industrial production. This method originated from multiple attempts to use VR technologies in the area of mechanical engineering products and processes design and develop. The result was achieved due to tight collaboration of corporate specialists and divisions, and good-willed cooperation between the manufacturer and the client. Scientific value is expressed as cross-disciplinary communication that enables developing new information, transferring and accepting knowledge and experience, acquiring and improving skills, accumulating experience and so on. The practical value is improved the technical communication and more rapid generation of alternative ideas. Designing spherical elements and implementing them into the existing 2D drawings decreased the time consuming process.

**Keywords:** 3D virtual prototype, spherical element, tight collaboration, specialists, producers, clients.

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