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MODELLING OF MANUFACTURING SYSTEMS BY RAPID PROTOTYPING TECHNOLOGY APPLICATION

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Abstract: *Technologies of Rapid Prototyping (RP) represents the rapid production of 3D physical parts using by additive manufacturing technology. The start these techniques became available in the late 1980s and were used to produce 3D models and prototype parts. Today they are used for a much wider range of applications and are even used to manufacture production-quality parts in relatively small numbers. Rapid Prototyping is widely used in the automotive, aerospace, medical, and consumer products industries. In paper is presented application of Fused Deposition Modelling rapid prototyping technology for realization of models of manufacturing systems components represent by industrial robot.*
Keywords: *modelling, manufacturing systems, rapid prototyping*

INTRODUCTION

Technology of Rapid Prototyping (RP) represents new type of manufacturing technology that is used for production of the rapid building of physical objects using additive principle. Beginnings of Rapid Prototyping technology are dated in the late 1980's when Stereolithography technology was defined as a method and device was built for making solid objects by successive "printing" of thin layers of the ultraviolet curable material one on top of the other, what led to production of models and prototype parts. In 1986 the first company was founded which generalized and commercialized such procedure, 3D Systems Inc. Today, there is much wider range of Rapid Prototyping methods that are used to manufacture the models, parts or final products. Before application of Rapid Prototyping technology operator must to handle the models of future parts while using Computer Aided Design (CAD) systems, then to transform them into STL format that is further used in Rapid Prototyping devices for parts production [1].

There are a multitude of experimental Rapid Prototyping methods either in development or used by small groups of individuals. This paper is focused on application of Rapid Prototyping technique that is currently commercially available, Fused Deposition Modelling (FDM) technique.

DESCRIPTION OF FUSED DEPOSITION MODELLING METHOD

Fused Deposition Modelling (FDM) was developed by Stratasys in Eden Prairie, Minnesota. In this process, a plastic or wax material is extruded through a nozzle that traces the part's cross sectional geometry layer by layer. The build material is usually supplied in filament form, but some setups utilize plastic pellets fed from a hopper instead. The nozzle contains resistive heaters that keep the plastic at a temperature just above its melting point so that it flows easily through the nozzle and forms the layer. The plastic hardens immediately after flowing from the nozzle and bonds to the layer below. Once a layer is built, the platform lowers, and the extrusion nozzle deposits another layer. The layer thickness and vertical dimensional accuracy is determined by the extruder die diameter, which ranges from 0.013 to 0.005 inches. In the X-Y plane, 0.001 inch resolution is achievable. A range of materials are available including ABS, polyamide, polycarbonate, polyethylene, polypropylene, and investment casting wax [1].

For better orientation of user in process of setting of suitable parameters during the preparation of printing there was algorithm elaborated which accumulates all factors and steps that lead to selection of most suitable variant. All the attempts were realized as a part of preparation stage for *printing on UPrint machine that utilize FDM technology to build the prototype. This technology, developed by Stratasys, uses the software program to orient the model and generate building slices. Printer dispenses with basic building material and support material. Each material has its own nozzle. Creation of particular prototype layers with use FDM method is shown in Figure 1.*

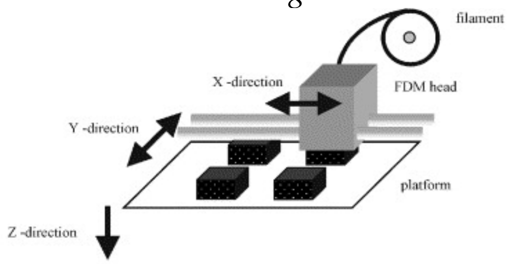

Figure 1. Principle of Fused Deposition modelling method

INDUSTRIAL ROBOT IRB 140 FOR APPLICATION IN MANUFACTURING SYSTEMS

Industrial robot IRB 140 from ABB Company (Figure 2) is compact and powerful device. It disposes with six motion axis and belongs to the class of small robots. Producer makes only one smaller 6-axial model than IRB 140 which is IRB 120. It can handle relatively high weight and considering it dimensions it has also a good reach (up to 810 mm). IRB 140 was introduced to the market in 1999 as a robot with high average period of failure-free operation (MTBF), low demands for maintenance and short reparation times. The speed which can be reached makes it the fastest in its category. When using IRB 140T, the cycles periods are significantly shorter thanks to the maximum approach speed and acceleration option together with the motion control - Quick Move from ABB. Movements according to trajectories are executed with high accuracy. Repeated returns to the given positions can be realized also accurate (± 0.03 mm). Robot can manipulate with objects up to 6 kg of weight.

Final part of robotic arm can turn around six axis of rotation and the controller allows the connection with other additive devices with possibility to control another 6 axis. Turning around the axis is realized thanks to the servomotors, which can execute also other types of motions. In combination of servomotor with gearing and gear track it is possible to create the control of linear motion. Such a connection can be used for track motion systems, while having this device programmed and controlled with use of single controller [2].

Compact dimensions of robotic arm IRB 140 can present its main advantage in some applications. On the other hand, rather low load capacity and small range can limit the possibilities of its use in some cases. Most typical application areas of this robotic device are: welding and linking, assembly, cutting and finishing, die casting, bonding and batching, injection of plastics, manipulation tasks, removing and packaging.

Figure 2. Industrial robot ABB IRB 140

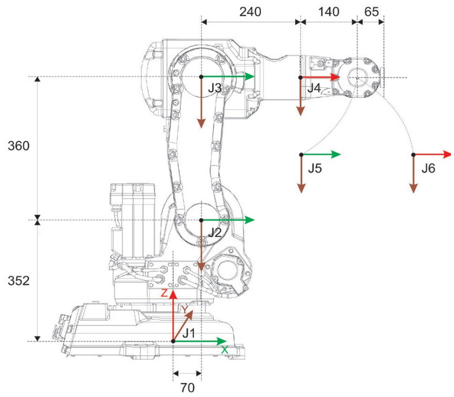

Figure 3. IRB140 - dimensions and degrees of freedom

PRODUCTION OF INDUSTRIAL ROBOT MODEL BY FUSED DEPOSITION MODELLING APPLICATION

Rapid Prototyping methods are one of methods that uses special computer format STL (also called STereoLitography). From historical point of view it is the work of developers who establish this format as output data form obtained after digitalization with 3D scanner. Polygon surfaces also known as facets represents areas for volume description. Model in STL format created in some three dimensional CAD software has surface constituted from number of triangles. Number and size of triangles defines the preciseness of curvature of particular model surfaces. STL format can be used in two different forms: ASCII and binary form.

Size and number of triangles defines the preciseness of curvature of surfaces [3].

Currently in industrial practice there is huge number of CAD software that allows constructors and designers to design the product models according to their ideas that are used with addition of third dimension. Nowadays all CAD software products provide functions and tools necessary for export of created models in STL format that is further used in Rapid Prototyping process. User of 3D technology can change spatial orientation according to his requirements. They should be based on functionality and corresponding quality of complicated surfaces (complex surfaces, planar surfaces under angle, cavities, holes) and also on expected proportion of used basic and support material with focus on economical matters. In most cases automatic mode can be chosen for definition of model position but in that case it is barely justified or explained on the base of functionality of some part surfaces. Next parameter that is important from the viewpoint of final quality and price is definition of thickness of single printed layer. With this parameter there is also related style of model and support material addition as two basic building substances used for prototype production. Material can be build as one unit or particular layers can be printed in grid with lower density what reduces the printing price. Factor of input data quality, factor of suitable software and physical part orientation and factor of relevant density and building layers style are most problematic aspects in process of realization of rapid prototyping technology [3].

For better orientation of user in process of setting of suitable parameters during the preparation of printing there was algorithm elaborated which accumulates all factors and steps that lead to selection of most suitable variant. All the attempts were realized as a part of preparation stage for printing on UPrint machine that utilize FDM technology to build the prototype. This technology, developed by Stratasys, uses the software program to orient the model and generate building slices. Printer dispenses with basic building material and support material which is used if necessary for creation of holes, cavities, drafts, etc. Each material has its own nozzle.

Fused Deposition Modelling is very often in practice used RP process that provides parts mainly from ABS plastic. FDM produces the quality parts in Acrylonitrile Butadiene Styrene (ABS) which is a common end-use industrial material allowed to perform operational tests on produced parts. Real production thermoplastics are stable and have no appreciable warpage, shrinkage, or moisture absorption, like the resins in competitive processes.

To prototype successfully, first select an appropriate rapid prototyping tool. There are hundreds of rapid prototyping tools available. They range from simple graphics packages that allow you to draw screens to complex systems that allow you to create animation. Each tool is better for some functions than for others. Although several rapid prototyping techniques exist, all employ the same basic five-step process. The steps are [4]:

1. Creation of CAD models of the product parts.
2. Conversion of CAD models into STL formats.
3. Use of STL files in Rapid Prototyping devices.
4. Production of the parts by one layer atop another.
5. Cleaning of parts and assembly of the product.

Model of industrial robot IRB 140 was created and subsequently modified in CAD/CAM/CAE system Pro/Engineer. Transfer of models between Pro/Engineer and another CA systems was implemented using the exchange format IGES where they were treated. On Figure 4 is example of CAD model of industrial robot in Pro/Engineer. On the start of the production process are generated STL data in the Pro/Engineer system and these STL data are next loaded to the Catalyst program for layered rendering of the model (Figure 5).

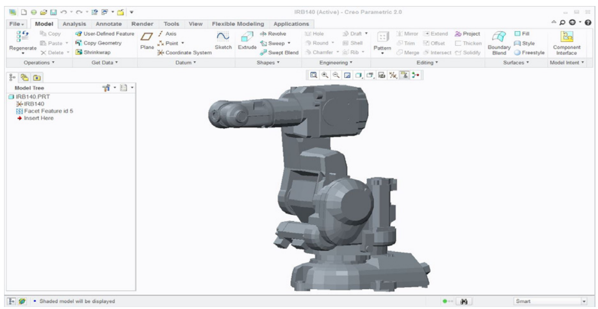

Figure 4. Model of the robot in CAD system

For RP methods there are specific production devices (3D printers) that use their own software based on principle of reading and processing of *input STL data. In spite of different manufacturers, such programs have the same characteristic features: settings for single layer resolution, settings for density of model material, settings for density of support material, STL processing to layer mode.*

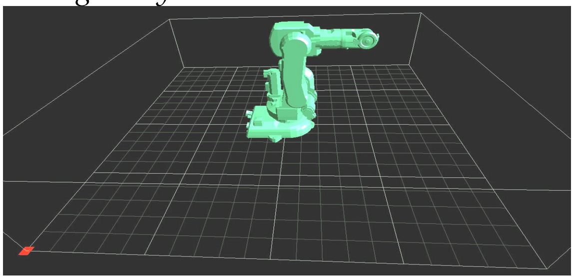

Figure 5. Model in Catalyst software

All these software solutions allow their user to change large number of different settings. Changes are made by user himself. Programs for preparation of FDM production make many actions easier and more automatic, but deciding process about particular parameters is still up to user. In case of using the automatic mode these decisions are made by program without explanation, so there is space for optimization of setting contrary to user criteria. Solution could be realized in implementation of deciding steps or automatic decision with actual information about reasons running on background, eventually together with information about parts already produced. Higher parameters of quality mean longer printing times and higher energy consumption, but utilization possibility of such models is much higher as they can be used instead of real functional parts. On Figure 6 is view of workplace of 3D FDM printer UPrint with printed part [5].

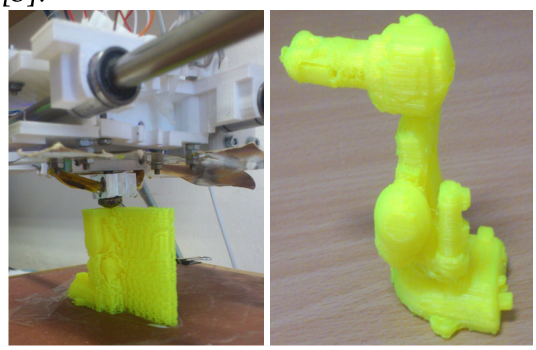

Figure 4. Printed model of industrial robot IRB 140 by FDM method

CONCLUSION

In industrial practice there are currently more than 20 vendors for RP systems, the method employed by each vendor can be generally classified into the following categories: photo-curing, cutting and glueing/joining, melting and solidifying/fusing and joining/binding. Photo-curing can be further divided into categories of single laser beam, double laser beams and masked lamp. The initial state of material in Rapid Prototyping technologies can come in either solid, liquid or powder state. In solid state, it can come in various forms such as pellets, wire or laminates. The current range materials include paper, nylon, wax, resins, metals and ceramics. Most of the RP parts are finished or touched up before they are used for their intended applications. Applications can be grouped into design engineering, analysis and planning and tooling and manufacturing. A wide range of industries can benefit from RP and these include automotive, aerospace, biomedical, consumer, electrical and electronic products.

References

[1.] C. K. Chua, K. F Leong, C. S. Lim, Rapid Prototyping: Principles and Applications. World Scientific Publishing, Singapore, 2004.
[2.] ABB IRBT X004, Data sheet. Available on: http://www.abb.sk/product/seitp327/569910ed39487cb6c12574360040afa9.aspx?productLanguage=sk&country=SK.
[3.] J. Novak-Marcincin, J. Barna, L. Novakova-Marcincinova, V. Fecova, Analyses and Solutions on Technical and Economical Aspects of Rapid Prototyping Technology. Tehnicki vjesnik, Vol. 18, No. 4, 2011, pp. 657-661, ISSN 1330-3651.
[4.] J. Novak-Marcincin, L. Novakova-Marcincinova, J. Barna and M. Janak: Application of FDM rapid prototyping technology in experimental gearbox development process. Tehnicki Vjesnik, Vol. 19, No. 3, 2012, p. 689-694, ISSN 1330-3651.
[5.] J. Novak-Marcincin, M. Janak and L. Novakova-Marcincinova: Increasing of product quality produced by rapid prototyping technology. Manufacturing Technology, Vol. 12, No. 12, 2012, p. 71-75, ISSN 1213-2489.

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