Free form surface modeling and analysis

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ABSTRACT

Creating 2D and 3D models in CAD and following creation of drawings are standard procedures for constructing in the current industrial practice. Most models of industrially produced machine parts can be made by basic processes of modeling using construction or hybrid methods. Listed procedures are based on input of a basic – primitive body and its shaping using predefined design elements, combined with the use of construction methods from the default 2D geometry and using methods of extraction, rotation, or dragging a profile along the curve. Requirements of industrial practice and current production technological possibilities often require the implementation part of a more general form, which cannot be created by mentioned methods. In advanced stages of 3D models it is possible to use the methods of free surface shaping, based on creating of parametric, semi parametric or non-parametric network of 3D curves representing the basis for generating surface that defines the boundary of solid body.

Keywords

Computer Aided Design, Curves, Shape Analysis, Rapid Prototyping, Surface, Virtual Prototype.

1. INTRODUCTION

Computer Aided Design is a standard of the current industry practices in the field of mechanical engineering, electrical engineering, civil engineering, as well as medicine and other relevant fields. 2D and 3D models of components and assemblies are used for the subsequent formation of the manufacturing technical documentation, preparation of production technology, and also for performing simulations and analyzes in these fields. Virtual environments of computer tools enables to perform a wide range of simulations and analysis, without the need for physical prototypes [Sam08]. 3D digital models represent a virtual prototype that contains a large amount of information about the component or assembly for the entire course of the product life cycle. The 3D and 2D drawings are currently still basic information medium for preparation of production and assembly technology [Shi10]. The digital model is also the basis for the generation of data for processing programs that control the machining process for numerically controlled machine tools [Zei10] [Lee99]. Advanced methods of 3D modeling in CAD, based on the free form surfaces modeling generate often components or preparations for the manufacturing of these parts that are difficult to manufacture by "conventional" machining methods [Bro98]. 3D printing methods widen the potential of implementing complex shaped 3D models and simplify their production at reasonable cost. Specific is also the area of industrial design, where combination of procedures of free forming surfaces modeling and visualization methods allows the implementation of proposals combining functional and aesthetic aspect [Sta11].

2. BASIC MODELING METHODS

Body components with unusual shapes can be usually created by the basic methods of design, based on the insertion of the base - primitive body and subsequently predefined standard design elements. It is possible to create a wide range of rather simple components, which are unlikely to stronger later editing and with a relatively small number of objects forming. This is known as a so called Features-method [For07].

If allowed by the used application, Features and design method can be combined using hybrid methods. The result is a 3D surface or solid body, which can be edited by changing the parameters forming elements, features or of sketches [Dvo13]. Sketch is geometry composed of points, lines, circular arcs and certain approach to free shapes is enabled by spline here. An important factor in basic and advanced modeling is associativity and parametrics of objects. Associativity represents the relationship of objects, usually based on a common attribute, which is usually the position, size and orientation of the object, or coherence of parameters directly, or through a mathematical relationship [Cam16]. On the indexed parameters can

be referenced not only within individual objects within the model, but also from other models, which are part of the assembly [Chen04].

Associative parametric models have a transparent history and subsequently created objects linked to the previous cannot be shifted within a list before the one you created earlier. Nonparametric model does not have a detailed history, objects do not have a mutual bond and subsequently created object can be used to edit the previous one. This process is used for example when smoothing freely shaped surfaces when curve, the resulting intersection of a plane and the surface is subsequently used as the parental forming area and when modifying it is adjusted [Ata13].

3. ADVANCED FREE FORM MODELING METHODS

Surface and solid objects created by methods of free shaping are obtained by one or a combination of the following procedures:

- Creating curves by modeling methods.
- Import points from an external file.
- Utilization edges and surfaces of existing surface and solid geometry.
- Defining transitions between multiple body or surface faces.

Primary or basic surface geometry also represent surfaces arising from forming geometry tools for creating surfaces. Geometry arising from previous surface geometry can be considered for secondary surfaces as transitive, related, or editing surfaces, imported in a universal format for third-party for data conversion among different systems.

Primary surfaces are formed of a curved geometry by modeling methods. Areas are considered as primary. Conversely, surfaces that are generated from already existing surfaces, e.g. as transitions or extractions of solids are secondary surfaces. The submitted text is focused on creating and editing primary areas.

Ruled

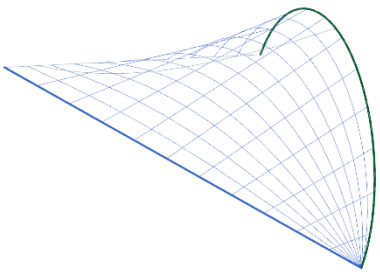

Figure 1. Isolines of ruler's surface.

Forming geometry is represented by any two curves, or a curve and a point. Segments of a surface represent line segments connecting bordering points on forming geometry of curves. This is the simplest type of primary surface. An example of ruler's surfaces - Ruled is shown in Fig. 1. The example shows the area formed by basic units of forming geometry, where curves segments of a surface are formed by a line and a circular arc, not lying in one plane [Bay10]. One of the forming geometry segments can be also a point. Basic procedures of the ruler's surfaces can still be modified by using specifying methods, modifying the segments of used geometry [Kos15].

Through Curve

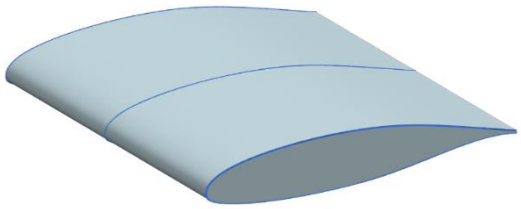

Figure 2. Through Curve on forming curves.

Advanced method of creating curves represents the primary Through Curve Mesh, Fig. 2. It uses a network of curves, which are not interconnected. It consists of slice surface, over which a surface within the modeling tolerance lies.

Editing of a surface is done by editing of each of the segments forming the surface separately. The number of cuts may be arbitrary, min. 2. If the area is related to one of the already developed surface, we can define tangency and curvature. The accuracy and variability of surface is greater than in the case Ruled, but we cannot determine the properties in other directions than along a geometry. E.g. the wing of the plane with a rectangular floor plan is thus created model accurate enough.

Through Curve Mesh

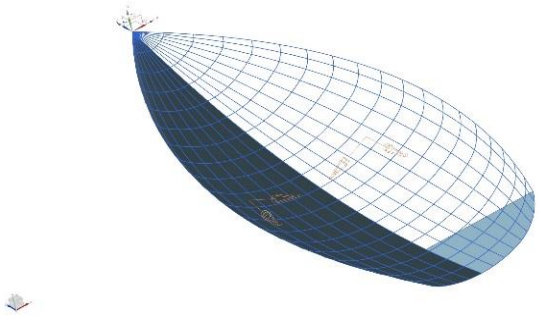

Figure 3. Through Curve Mesh on a net of forming curves.

The method is based on the use of the network of curves, the individual constituting elements are divided into two categories - Primary and Section. Primary Curves can be considered longitudinal and

transverse section curves are used for the ribs. Crosscurves between slices refine the formation of surface and lead to a more exact and more editable result than the previous method Through Curves. Simultaneously, in editing arises more restrictive conditions that may cause difficulty in editing a specific shape, and optionally following selection of Through Curves. Example of surface formed by Curves Through Mesh is in Fig. 3. The number of longitudinal and transverse curves can be arbitrary, min. two in both cases. Just like Through Curve connections to adjacent areas can be defined. Primary surface created by various methods can be combined in one model and determine the accuracy and editability of a geometry as a whole.

Swept

Swept surface is advisable when required pulling cut geometry by one to three curves of the guide with the possibility of specifying the vector of cut surfaces orientation.

Possibility to define the orientation vector surface while creating is obvious in example of the model of a helical coil spring with a square cross-section. Fig. 4 is an example of pulling a square cross-section of the helix using the method Sweep Along Guide without specifying vector of surface creation.

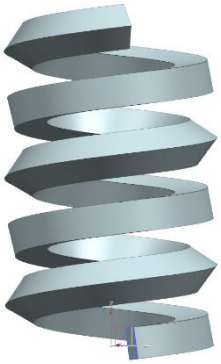

Figure 4. Sweep along guide, without defining section orientation.

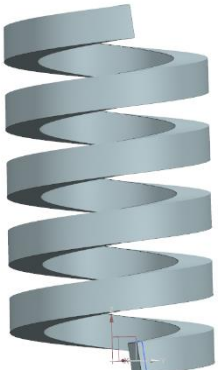

Figure 5. Swept with defining section orientation.

Cut is twisted in proportion to shooting tangent and normal vector to the helix. The following Fig. 5 shows the use of identical forming geometry for formation of the spring with orientation of the vector on the axis of the helix. Using Sweep surfaces is useful when demand constant trailed or variable cut after one to three defining curves.

Effective Methods of free Surfaces editing.

Procedures of the primary surface of the curves are highly efficient and accurate methods of free surfaces, which are editable by changing the geometry forming. The procedures described above can be used in case of direct assignment and the possibility to create, or modify the model fundamentally [Kim16]. In the case of freely deformable surfaces can be used for direct editing groups of tools, allowing a change of control surfaces on the poles of isolines to change the shape. Typical tool is e.g. X-form. Selecting the density of points on field lines, representing surface poles can determine the accuracy of the edits and depth of surface changes. Demonstration of modification and editing of the planar surfaces by the X-form is in Fig. 6.

Managing poles of edited surface can be mounted on points that may be created as the default auxiliary geometry or can be imported as a point cloud from an external file. Such points for editing are often the results of measurements of spatial data, or the results of calculations using external tools.

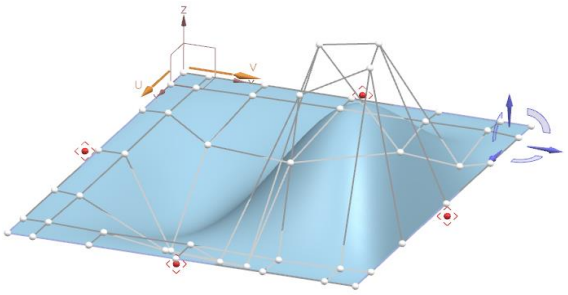

Figure 6. Creating and editing free surface using poles on isolines.

Other editing options are based on the extraction of non-parametric geometry - curves on surface, caused by a section on the plane, or offset curves on a surface. Non-parametric geometry is then modified and used as forming in their place of origin to modify parental surface. Mentioned method is often used especially when smoothing surfaces. Editing surface by methods of free shaping is related to the analysis of forming curves and continuous analysis of the area during editing.

4. SURFACE ANALYSIS

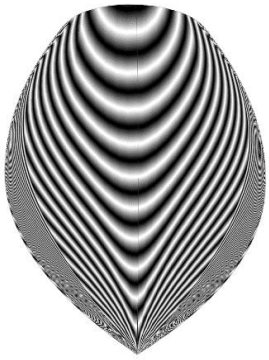

Figure 7. Analysis of the reflectivity of the symmetrical surface.

Another case of surface analyzes is assessment of consistent shaped body while smoothing surface where we perform an analysis of reflectance, involving virtual projection spectrum rays on flat body and the deformation of the image. Example of reflectance analysis is in Fig. 7. Surface analyzes are of great importance especially when constructing cavities molds for casting, or injection molding of complex products.

5. CONCLUSION

Creating a model including free forms offers a wide range of approaches and methods. Specific attributes of complicated freeform surfaces is a difficult identification of negative chamfers, which is a key parameter in the creation of tools, especially molds for plastic injection, which currently represents a significant share of industrial methods. Progressive, currently significantly incoming technology, is the 3D printing - Rapid Prototyping. Free forms, modeled in the virtual environment of a computer application can be easily implemented using a 3D printer at acceptable manufacturing tolerances. Postprocessing of data for 3D printing from digital models is much easier than preparing a program for numerically controlled machine tools, and even complex free form shapes are due to the possibilities of available machine tools difficult to implement. Research and development of methods of free shaping and subsequent analysis of surfaces is based on a systematization of procedures and identifying a key for the best choice when deciding in case of the possible using of multiple approaches.

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