Integrated Product Modeling of Special Forms in Vessel and Pipeline Construction

By *Peter Köhler** and *Oliver Strohmeier*

1 Introduction

The launch of efficient parametric CAx systems and a constant engineering data management are the current objectives of many enterprises. However, it first has to be stated that particular problem areas with special constructions often cannot be handled despite these modern tools.

Investigations of a number of commercial CAD systems and their sheet metal tools showed that two weak points need to be eliminated and compensated for in the field of sheet metal design. On the one hand it is not possible to generate part surfaces bend-shaping fairly in all cases with the present modeling options. On the other hand the integrated software tools for sheet metal bending are also only conditionally suitable for developing special forms.

With some industry solutions for sheet metal handling it is only possible to create a certain number of special forms; it is not possible to react flexibly to changing requirements.

In general it is the case that the input of "expert knowledge" to design production and functional oriented geometry into CAD systems is not sufficient, only obvious difficulties transparent to the user can be dealt with.

In the "Computer Integrated Design" group the prototype of an application system for design in the vessel and pipeline construction was developed. The objective was not to create a new isolated solution for sheet metal development, but the bi-directional integration of application solutions into commercial CAD systems.

In the context of the project guidelines, methods, algorithms and software tools for the bend-shaping-fair design of complicated sheet metal parts and assemblies were developed. They are capable of complete integration into CAD systems based on the ACIS geometry-kernel. By means of function and production-oriented problem structuring and differential geometrical bases produced for special forms, integration into other CAD systems is possible, provided that there are comparable possibilities to integrate the application orientated geometry features and interaction components or to create them fairly in terms of requirements.

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In view of the application, three major tasks had to be solved:

- layout of suitable construction and geometry features,
- balancing of weaknesses of the CAD systems for the attention of differential geometrical boundary conditions with the generation of rule surfaces,
- development of special forms of the sheet metal tools in the CAD systems.

2 Differential-Geometrical Bases

In differential geometry it is well known that all accurately developable surfaces (Torsen) belong to the ruled surfaces, which can be created by the movement of a straight line along a guidance curve according to a rule (constant or variable direction vectors). However, not every ruled surface is developable. Torsen are exclusively arbitrary cylinders, cones and tangent surfaces.

If an engineer wants to create an accurately developable surface between two curves, s/he has to observe further differential geometrical criteria.

Finally, the lateral surface of a body is also developable, if it can be created by the movement of a straight line along two curves with the restriction that the straight line always lies in a tangential plane (Fig. 1). Therefore, for each point on the curve, it is necessary to find one or more points on the other curve in such a manner that the tangents of both points are in the same plane. [1]

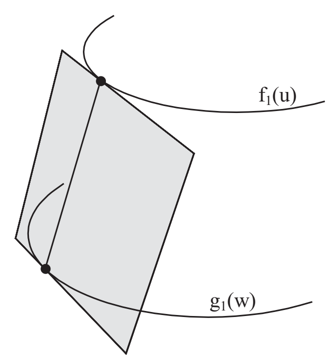

Figure 1. Tangential plane.

If the tangents of two space curves given in parameter form lie accurately in one plane, the following applies:

$$\begin{vmatrix} g_1(w) - f_1(u) & g_2(w) - f_2(u) & g_3(w) - f_3(u) \\ f_1'(u) & f_2'(u) & f_3'(u) \\ g_1'(w) & g_2'(w) & g_3'(w) \end{vmatrix} = 0$$

For each value of the parameter u on one curve, there must be a parameter value $w = w(u)$ on the other curve, so that the equation is fulfilled.

In CAD systems, blend and lofted surfaces are usually created with the help of a symmetrical division of the composite sections so that a Torse only results in special cases. Some systems permit it to manipulate the internal

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defined points of division. This method presupposes maximum experience and offers no guarantee for the generation of a development-fair surface.

Fig. 2 shows a blend from a circle to an ellipse. The faceting of the lateral surface of the left part was generated on the basis of a symmetrical division of the connection outlines. This surface approximation can be developed, but it is not quality assuring, since positive and negative bending angles result, which are unacceptable both technically and visually.

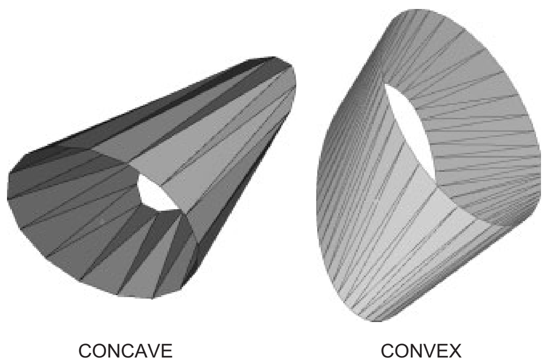

Figure 2. Approximation of faces.

The target must be to create convex lateral surfaces between convex connection outlines. Therefore the tangential condition specified above has to be realized internally in the system. The right hand component in Fig. 2 illustrates a corresponding geometry generation. In efficient CAD systems the Gaussian curvature can be used to analyze surfaces. It is defined by the product of the two main curvatures of a surface and must be zero in all points for accurately developable surfaces.

3 Creation of Special Geometry Feature

The sphere tangent technique (Fig. 3) is generally recognized as a basic principle for the linkage of circular cylinders and cones, in order to create piecewise planar penetration curves [2].

However, without computer application there are limitations to its use, since the ability of the respective engineers spatial imagination is limited. In summary, the necessary work procedures in function and geometry-oriented features can be used for arbitrary oriented connections and manifolds. The integrated features in the modeling steps, which require the generation of datum planes and datum axes represent the position and orientation of the cross sections for connection. Reference components, which map the auxiliary spheres are added. In an ideal case the CAD system permits the direct generation of the reference spheres. Otherwise suitable circles are used as reference. It must be realized that because these multiple problem definitions accompany intersection problems, further feature components were required, in order to cut and trim the patches according to the task.

The sphere tangent technique is transferable with modifications to oblique circular cylinders and cones and elliptical

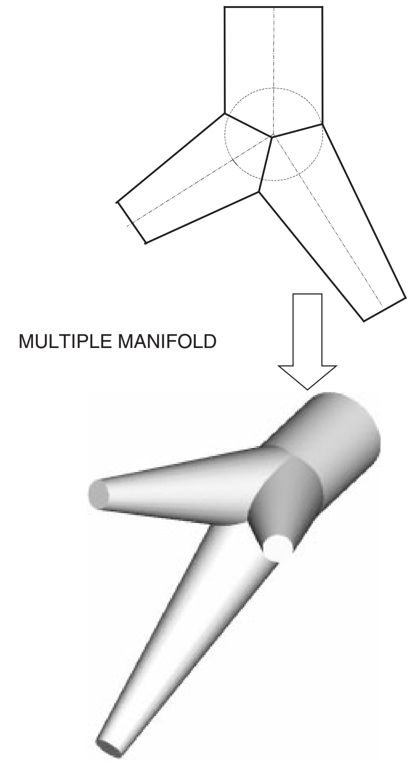

Figure 3. Modeling by auxiliary spheres.

Torsen, if suitable ellipses or ellipsoids can be indentified as reference components.

With the sphere section technique, which also has some integrated features, connections and manifolds between non-parallel circles can be generated in such a way that the lateral surface is part of an elliptical cylinder or cone. Thus the Gaussian curvature is automatically equal to zero.

This technique uses the characteristic, that an elliptical cylinder or a cone can always be generated between two arbitrary cut planes of a sphere (Fig. 4).

Moreover, planar intersection curves also result between two circular Torsen whenever they have at least one circle in common. Thus, with this technique, it is easy to create multiple manifolds, special forms of connecting pieces and similar forms from piecewise planar curves in a 3D-CAD system (Fig. 5).

The geometry feature created for manifolds, sockets, and other connections takes these geometrical regularities into

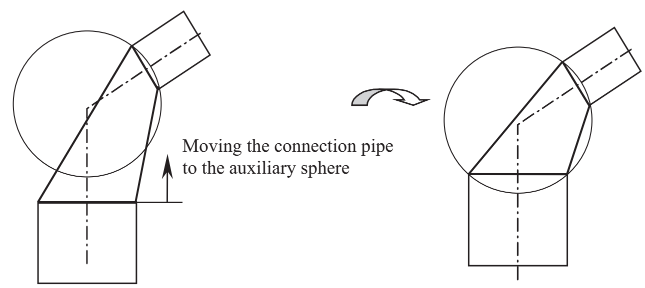

Figure 4. Sphere section technique.

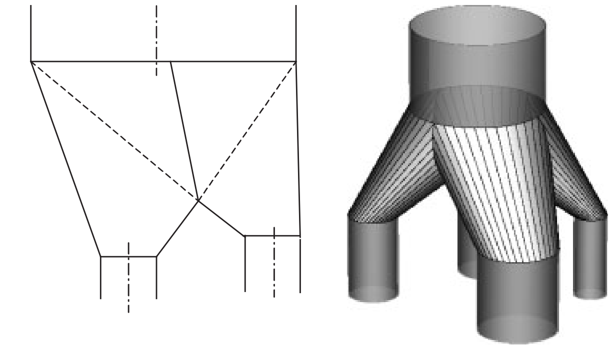

Figure 5. Lead-out cones at a vessel.

consideration. Beyond that, special geometry features were developed, for example reducers and special forms that are the basis for breeches pipes and connecting pieces. Also connection cross-sections, which lie in a buckled plane, are properly treated.

4 Surface Approximation

Over the range of sheet metal design, within which the development-fair construction can no longer be handled on the basis of standard forms, approximate solutions are used. Conventionally, the vessel and pipeline construction engineer uses the so-called triangle technique. Here the cross sections are interconnected by triangles in equal partition. The development takes place by stringing the triangles together in one plane. This technique does not always supply useful results, in particular, if the cross sections for connection are not parallel to each other. Relevant to the most possible exact approximation of a developable lateral surface are the positions of the lateral lines, because these can be transformed, maintaining length, into plane. In the range of this research project algorithms were developed, which calculate the points and direction vectors of the lateral lines based on the necessary differential geometrical laws.

Since amassments from triangle areas (determined by the development) can lead to problems within the sheet tools of commercial CAD systems, alternative square techniques for the description of the lateral surface were expanded. Here the area approximation takes place from "outside", i.e. the tangential planes (Fig. 1) become even patches of the faceting.

techniques were continually modified to approximate even connection outlines with strong curvatures more exactly.

5 System Integration

The results obtained were realized on the basis of the geometry kernel ACIS and the MicrosoftFoundationClasses in an application system, which can be integrated into different CAD systems. Thus the technical designer can work continuously within the CAD system. Here it is possible to call the dialog components of the application system. The construction and geometry features were already explained, so that the following describes how the application for special forms was integrated into the user interface.

With the aid of Fig. 6 two applications are described.

One of the tasks to be solved, consists of designing a multiple bypass at a vessel discharge. In this case a more generally accepted procedure rather than a pre-defined construction feature was used. After the user advised the system of his or her construction intention ("generate a bypass"), the relevant connection sections are picked interactively on screen. In this example the lower cross section at the lateral surface of the vessel and the cross sections of the bypasses are already defined by the connection pipes. The system differentiates internally between starting and secondary cross sections. In the first case only one cross section choice is possible. The number of bypasses (secondary cross sections) against it is unlimited. The selection is checked by the system for input errors, like a double selection of a cross section or an empty selection. If the input is error free the user has to define the desired accuracy (number of lateral lines to be created) before the system starts the internal determination of geometry. Likewise it is possible to control the manner of lateral surface faceting. There are two options, the preset triangle technique and the square technique. The particular

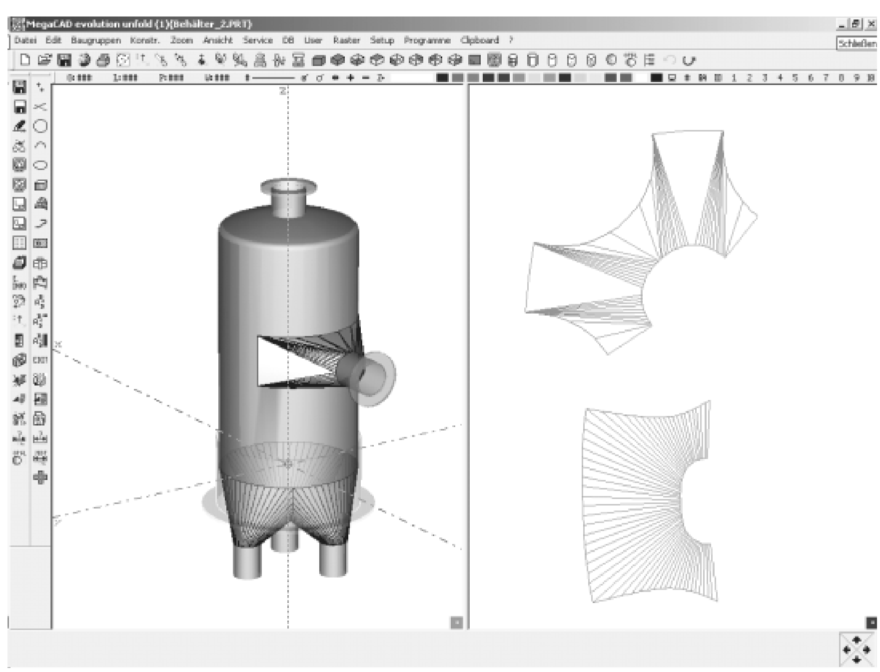

Figure 6. Practical example.

selection has an effect on later development, which should be handled by the sheet metal tool of the CAD system.

In the following internal analysis the construction intentions are seized by feature recognition algorithms and their conversion is prepared. The selection of several secondary cross sections is recognized as feature "breeches pipe" or "bypass" and treated accordingly. After all connection geometry and construction intentions are clarified, the facetted lateral surfaces are created considering the differential geometrical boundary conditions. These were already described. With circular or elliptical outline components the system examines, whether or not some faces can be generated as circular cylinder or conical surfaces, to avoid unnecessary surface approximations.

After all necessary blending is accomplished, the finished models of the lead-out cones are available for the technical designer for further processing. In the right hand window of the screen, one of the developments determined is represented. The second sheet metal cut belongs to the transition-connecting piece. The characteristic of this special form is that the secondary cross section consists of several segments, which lie in different planes. Suitable techniques for these "buckled" connection outlines were also developed, in order to generate developable lateral surfaces and face approximations as exactly as possible.

Acknowledgements

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Investigations of Catalytic Activity of Nonnoble Metal Catalysts for the Electrochemical Reduction of Oxygen*

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Nonnoble catalyst are discussed as an appropriate alternative for noble metal compounds in fuel cell systems. Two different kinds of catalysts based on ironphthalocyanine and ironsulfate are prepared and characterised for the electrochemical oxygen reduction. Both types show catalytic activity depending on the conditions of preparation.

1 Introduction

For the cathodic oxygen reduction in the direct methanol fuel cell non noble metal catalysts are an interesting alternative to the usually used noble metal based catalysts. Beside lower costs a high selectivity towards the oxygen reduction is desirable for the application in direct-methanol fuel cells. Due to the problem of methanol crossover (methanol permeation through the membrane to the cathode) performance losses by formation of mixed potential can be prevented or reduced.

At the ICVT carbon black supported iron and nitrogen based catalysts are prepared and studied since 1996 [1 – 3]. Precursors are metals together with carbon-nitrogen-fragments which are seen as catalytic constituents [4]. Two different syntheses are considered. On the one hand the preparation of thermally treated N_4-chelates on metal base (for example ironphthalocyanine FePc) and on the other hand the thermal treatment of iron (for example of ironsulphate $FeSO_4$) with an external nitrogen source. The focus of this work is set to the temperature of the thermal treatment.

2 Experimental Work

2.1 Catalyst Synthesis

The synthesis of the FePc based catalyst starts with the deposition of FePc onto the carrier carbon black (Vulcan XC72-R) [3]. The phtalocyanine is dissolved in concentrated sulphuric acid and mixed with the corresponding amount of carbon black to a homogeneous suspension. This is given into ice water. Due to the decrease of solubility the FePc is

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