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FLEXIBLE METHODS OF SURFACE DESIGN WITH FASTSURF[1]

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For the occasion of the 70th birthday of my former teacher
and present colleague István Reiman

Abstract

This paper illustrates the powerful design methods of FastSURF, the surface modelling system of CADKEY. It contains several surface definitions and offers a number of highly developed methods of constructions and manipulations on surfaces. Solutions for fitting and trimming problems arising at the construction of composed surfaces are shown on three practical models.

Keywords: CAD, surface modelling, surface fitting, trimming of surfaces.

1. Introduction

While studying a professional CAD system our aim is to find the answer to two questions particularly interesting from the geometrical viewpoint. First, how the implementations follow the theory of geometric algorithms developed in surface modelling, what helps our research work. Second, which geometric knowledges are necessary for working by the system, what is a useful information in the education of geometry. Namely, teaching the theory necessary for geometric constructions and teaching the technique and tools of constructions are equally important tasks of a geometry course. Consequently, the appearance of the CAD systems as new tools for generating, storing and transferring geometric informations requires the renewing of the geometry courses in the engineering education [1, 2]. In this respect we have achieved good results by integrating constructions with CADKEY in the first year geometry practice classes [3, 4, 5]. The presented modelling examples require basic knowledges of the theory of curves and surfaces included in differential geometry and also the fundamental phenomena of spline technique. These problems are planned for higher-level and Ph.D. courses, and they show that all chapters of the classical geometry

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courses are necessary for understanding the geometric content of the commands offered by the system and for visualizing the models appearing on the screen in different projections.

2. Tangent Fillet and Surface Editing

In the model of a hair-dryer (*Fig. 1*) the following surfaces are constructed: the body consists of rotational surfaces, the blowing part is constructed as ruled surface. The closing end of the body is defined by a circle as surface boundary in a plane. The handle consists of three surfaces and it is fitted to the body by a ring of tangent fillet surfaces. The upper part of the handle is trimmed to this tangential ring.

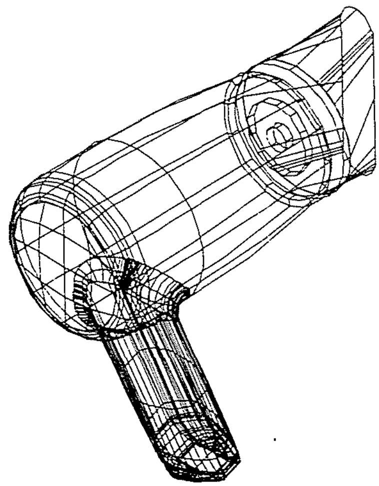

Fig. 1. Composite model of a hair-dryer

We are focusing on the construction of the handle and its tangential fitting to the body. These parts are shown in *Fig. 2* in a side view. We have to remark to the figures that the surfaces are drawn by their parameter lines, which are not necessarily the bordering lines of the projection. This is the case also in *Fig. 2*, where the lower border of the body is not shown. This fact makes the impression as if the joining ring would not touch the body.

The outer parts of the handle are defined in the same way but with different data (*Fig. 3*). Each of these surfaces is defined by a curve mesh, where a set of spline segments are to be given in the longitudinal and in the cross direction. In this example the curve mesh is a very special one, because there are given three longitudinal curves but only one cross-

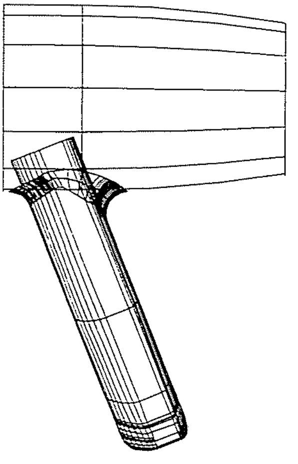

Fig. 2. The body, the handle and the fitting ring

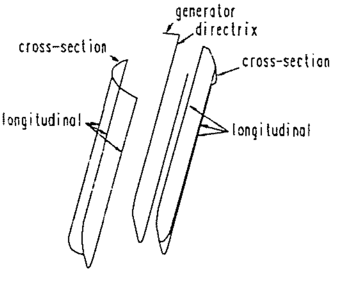

Fig. 3. Defining curves of the three surfaces forming the handle

section curve. The lower end points of the longitudinal leading curves are coinciding.

The single curve in the cross direction fits with its endpoints and midpoint to the upper endpoints of the longitudinal curves. This single curve determines the shape of the cross-sections of the surface as it is moving along the primary curves while shrinking into a point. The middle part of the handle is a translational surface generated by a straight line segment moving along an U-shaped directrix.

The generated surfaces are shown in *Fig. 4*.

The ring-shaped surface between the handle and the body consists of four parts. The tangent fillet surfaces to the outer parts of the handle and to the body are generated by the system with a user given radius automatically. However the automatic generation of a fillet surface between

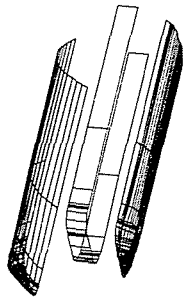

Fig. 4. The parts of the handle

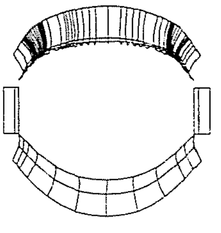

Fig. 5. Automatically generated parts of the fitting ring

the middle part of the handle and the body leads to the unsatisfying result shown in *Fig. 5* in top view.

As the parts of the handle join with zero order continuity, the two symmetric fillet surfaces joining tangentially to the middle part of the handle at both ends and to the body do not join to the other two fillets (on the top and bottom of *Fig. 5*). Consequently, they have to be constructed separately. Proper surface patches instead of them can be generated from four boundary curves. The boundary curves of the patch on the front side are shown by heavy lines in *Fig. 6*.

Two opposite boundaries are those of the neighbouring fillets, the other two are constructed as spline segments, then projected onto the body and the middle part of the handle, respectively (*Fig. 7*).

The surface generated automatically from the boundary curves can be modified according to given geometric constraints. Additional geometric data, e.g. tangent vectors at the node points of a boundary curve (see the four vectors pointing downstairs in *Fig. 7*) can be given in order to ensure the tangential continuity of this surface and the middle part of the handle along their connection line. Then the surface will be regenerated according to the given boundary conditions. The middle parts constructed in this

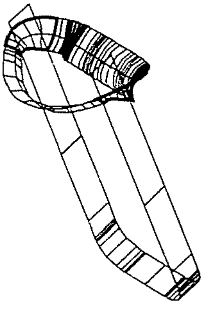

Fig. 6. Surface patches generated by four boundary curves

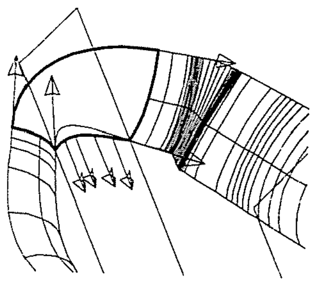

Fig. 7. Geometric data of the constructed patch: boundary curves and tangent vectors

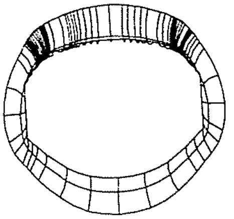

Fig. 8. The fitting ring

way and the two automatically generated parts of the fitting ring are joinig to each other, to the body and to the handle smoothly (*Fig. 8*).

In *Fig. 8* the ring is shown in top view. The symmetric patches on the left- and right-hand sides appear in this projection with straight inner borders, that are lying on the middle translational surface of the handle. The outer border lines of the patches are lying on the body. Finally, the upper parts of the handle are trimmed off to the lower boundary of the fitting ring (*Fig. 9*). The trimming of surfaces has been carried out along the composite connection curve lying on the three parts of the handle.

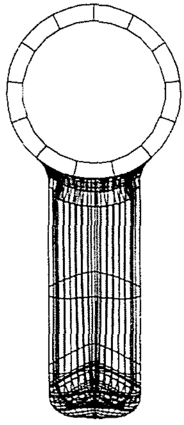

Fig. 9. The trimmed handle, the fitting ring and the body in front view

3. Trimmed and Blending Surfaces

On the model of a water tap different trimmed, fillet and blending surfaces are presented (*Fig. 10*).

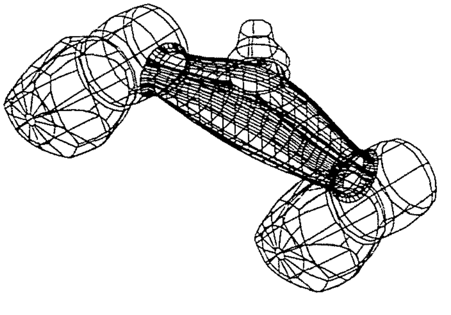

Fig. 10. Model of a water tap

The first trimmed surface is the front half of the tap body. It is cut at both ends to the fillets joining to the tubes and on the top along a surface

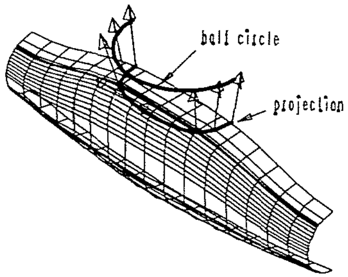

Fig. 11. Normal projection of a curve onto a surface

curve. This surface curve is generated by projecting a half circle onto the surface in the direction of the surface normals (*Fig. 11*).

The projected curve defines the lower boundary of the neck constructed between the half body and a half cylinder. This cylinder defines the geometric constraints on the upper end of the neck, but it is no part of the model (*Fig. 12*). The neck is generated as a blending surface between two non-intersecting surfaces, where the input data are the surfaces to be joined, furthermore a curve on each surface forming the opposite boundaries of the blending surface. In our case the given curves are the surface curve on the top of the body and the lower boundary of the cylinder, respectively (*Fig. 12*). The generated blending surface is joining with tangential continuity along its given boundary curves to the corresponding surface.

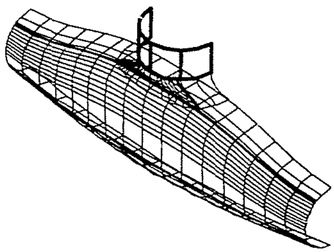

Fig. 12. Blending surface

After constructing the blending neck, the body is trimmed to the surface curve building the lower boundary of the neck (*Fig. 13*). The body of the water tap is trimmed off also at both ends to the fitting rings constructed as fillet surfaces between it and the tubes automatically (in *Fig. 13* the left-handed fitting ring is shown).

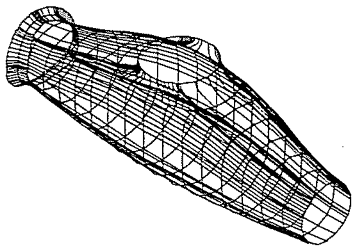

Fig. 13. Trimming to the fillet surface

Such a fillet surface is defined by two intersecting surfaces and the radius of a rolling ball moving along the line of intersection of the surfaces while touching them. Both of the surfaces are trimmed automatically by the system to the generated fillet surface along the connection lines. In *Fig. 13* the body is shown after trimming to the fillet ring at one end. In *Fig. 14* the tube is shown trimmed to the fillet ring.

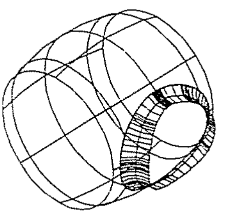

Fig. 14. The hole on the tube after trimming to the fillet surface

The cock of the tap is constructed as a rotational surface then by cutting it with three planes, and covering the holes by planar surface patches defined by the boundary curves of the holes. In *Fig. 15* the constructed cock is shown on the left side, the rotational surface, the cutting planes and the lines of intersection are shown on the right side.

The planar surface patches covering the holes are shown in *Fig. 16.*

The right-handed parts of the water tap (tube, fitting ring and cock) are generated by mirroring the left-handed parts about the symmetry plane. A connection part to the omitted spout on the top of the neck is a rotational surface (*Fig. 10*).

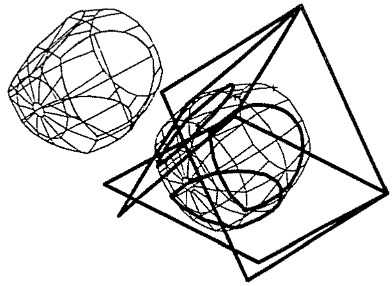

Fig. 15. Cutting a rotational surface with planes

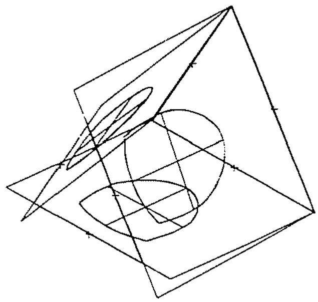

Fig. 16. Planar surface patches defined by their boundary curves

4. More Surface Constructions

The model of an electric shaver is also composed from differently generated surfaces (*Fig. 17*).

The handle is generated by a curve mesh consisting of four longitudinal leading curves and two cross-section curves given at the starting and ending positions (*Fig. 18*).

A rotated offset of the closed cross-section curve at the upper end of the handle and three other closed spline curves form the generating curve set of the cock part (*Fig. 19*).

The head is covered by a planar surface constructed from a rectangle trimmed away to the upper boundary of the head (*Fig. 20*).

Finally, three circular blades are placed on this planar covering surface (*Fig. 21*).

The handle and the head of the shaver are joined by a blending surface generated by the system automatically from the upper boundary curve of the handle and the lower boundary curve of the head. It joins the two

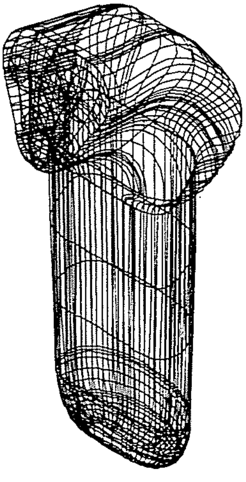

Fig. 17. The model of a shaver

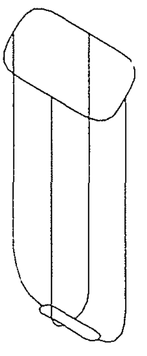

Fig. 18. Generating curves of the handle

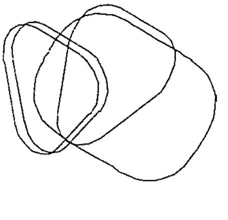

Fig. 19. Curve set defining the head

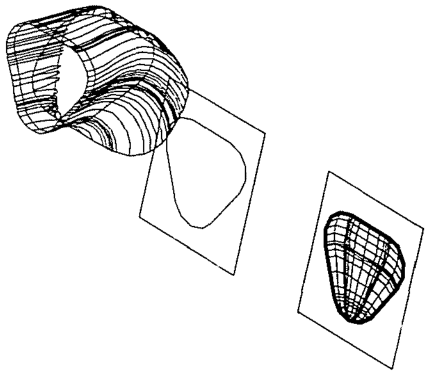

Fig. 20. Generating a planar surface

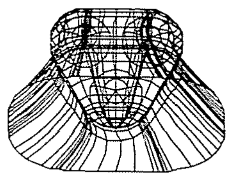

Fig. 21. Top view of the head

surfaces tangentially. In *Fig. 22* the head, the blending surface and the handle are shown in front view. The covering face and the blades are omitted.

The construction of the protecting cap starts by the generation of a curved surface defined by a set of circles. The upper curved face of the cap is cut off from this surface by a cylindrical surface generated by the upper boundary curve of the head (*Fig. 23*). This construction is implemented in FastSURF as trimming a surface to another surface, while the line of intersection is computed. On the left side of *Fig. 23* the surface defined by three circles and the cylindrical surface are shown. On the right side the first surface is trimmed to the second one.

In order to construct the side of the cap a new cylindrical surface is generated by the line of intersection constructed in the last step, and it is cut off by a plane on the other end. This construction is shown in a side view in *Fig. 24*.

Finally, the cap consists of the curved upper face, the cylindrical side surface around it and a circular patch covering the hole left by the last circle on the first generated curved surface (*Fig. 25*).

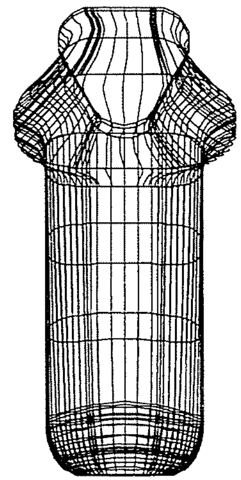

Fig. 22. Blending surface between the head and the handle

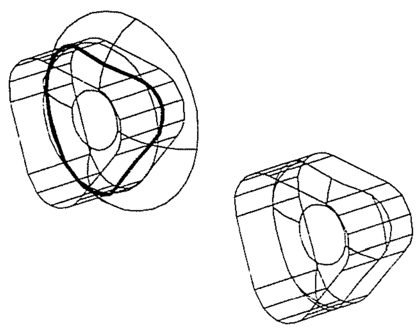

Fig. 23. Trimming a surface to a cylindrical one

The circular patch is constructed as a planar surface patch determined by its plane and the closed boundary curve (in this case circle) in the plane.

5. Conclusions

The three composite models generated by FastSURF show a number of methods of surface definitions and constructions implemented in the system. Several other surface manipulations are provided too, for example, the editing of node points of a surface, which are not used in the presented constructions. The models have been made by the 7.04 version of Fast-

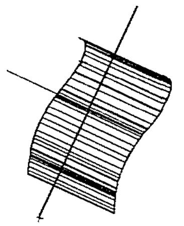

Fig. 24. Cylindrical surface and the cutting plane

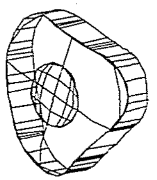

Fig. 25. The cap consists of three surfaces.

SURF on a PC486 of 16MB RAM. Practically each step of the constructions has been carried out in few seconds. The numerical problems at some computations led to a wrong solution, or ended without a solution, but the huge variety of the implemented surface manipulations always provided an other way of construction resulting in a pleasing solution.

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