Development of CAD models from sketches: a case study for automotive applications

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Abstract: Today products are designed not only for their functional requirements but also for aesthetics. In the automotive industries, styling has become a major part of the design process with class-A surfaces. Class-A surfaces are freeform surfaces with a continuous curvature. The process of engineering any component or system begins by generating a concept that actually describes the product in terms of its form, function, and fit. Concept sketches help the designers to arrive quickly and easily at a stage where a satisfactory design can be specified for detailed design. These concept sketches can be used for development of the digital concept design and analysis of the curves and surfaces. Software such as Alias exists and thus can be used with suitable hardware for sketching the concept of the car body on a computer screen. In this paper a systematic procedure is discussed for generating class-A surfaces from the images of concept sketches which are manually prepared on paper. These images are imported into the sketch tracer module of CATIA V5. A designer can use the image as the reference and produce a digital sketch by tracing the image using CATIA V5 software without adding any special hardware. Later, interrogation of these surfaces for improved aesthetics can be attempted. This method will be useful for the users of CATIA V5 to improve their design practices and skills.

Keywords: concept sketches, clay modelling, class-A surface, reflection lines, isophotes

1 INTRODUCTION

Product styling is carried out to create visual attractiveness in products. Styling is widely accepted as an important way to add value to a product without changing its technical performance.

As new product quality rankings converge, styling is emerging as a key differentiator for consumers. The role of styling is to create fresh and exciting design concepts that are not just contemporary but trend setting as well. Styling enhances the visual appeal of the vehicles and at the same time develops innovative designs and components for customers. Today, not only are products designed considering the functionality but also special considerations are given to their aesthetics which can produce a desire in a person's mind to own that product. This is the reason for the evolution of class-A surfaces and their importance. Class-A surfaces are those aesthetic free-form surfaces that are visible to us and that have an optimal aesthetic shape and high surface quality.

Restyling of existing products is frequently performed in the automotive industries, since engineers usually prefer the evolution of a product to a complete redesign. Customer feedback, client assistance suggestions, and market directives usually influence the decision on redesign or restyling of a product. However, quite often product modifications are less expensive than the development of a new product.

A traditional car development process involves the development of many handmade rendering sketches in order to offer a vision of the model's look. From these sketches, a few are selected and, by pasting the four views of a constrained drawing on the wall, which are made on a 1 : 10 scale, the scaled-down clay model is developed. One scaled-down clay model is finalized and the model is scanned using three-dimensional scanners. Then a 1 : 1 clay model

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of the finalized sketch is developed. In this phase all the changes require much time. A comparison between concept development and styling by the conventional method and the approach based on computer aided design (CAD) is provided in Fig. 1.

The objective of this work is to present a case in which the images of manually prepared conceptual sketches are used in CATIA V5 software to trace the curves for developing CAD models and surface interrogation. An attempt is also made to compare a surface that is not checked for curvature continuity and a surface checked for curvature continuity for their aesthetics and appearance. The approach used here can reveal the discontinuity in the surface which is difficult to notice otherwise although both are created in the same software. The procedure adopted here can be practised by the users of CATIA V5 to improve their innovations. A sketch on paper by an artist is made use of in this procedure. This appears

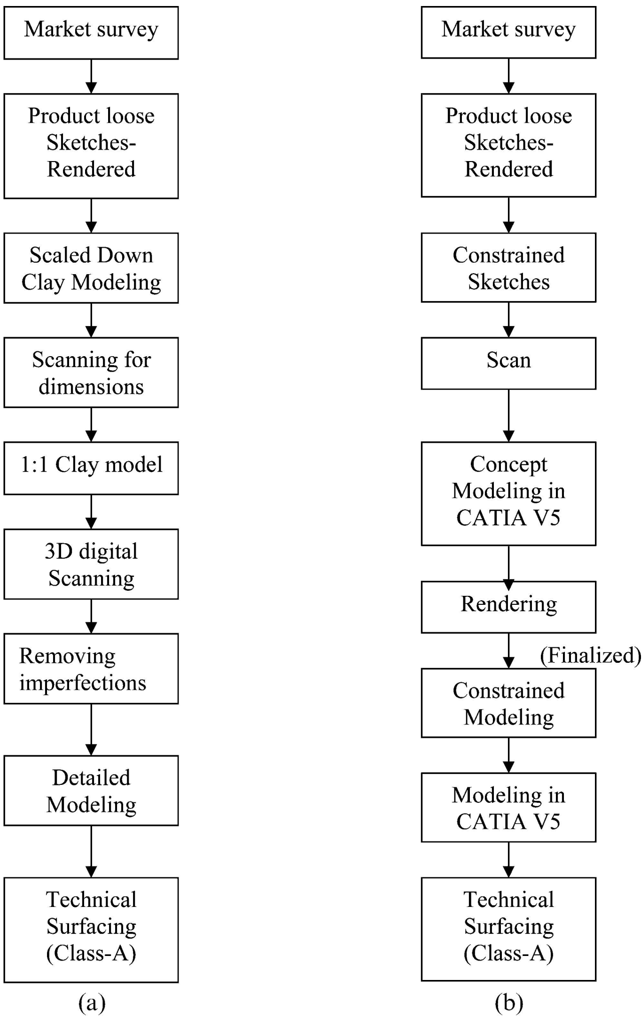

Fig. 1 Concept development and styling: (a) conventional method and (b) CAD-based approach

to be a novel approach. From the experience of the present authors it was found that awareness of the capability of CATIA V5 for surface interrogation is limited among users.

2 LITERATURE REVIEW

To determine the industry practices and surface interrogation techniques for styling, a literature review was carried out and the relevant observations are presented here.

Tovey [**1**] discussed sketching and its role in the concept design of automotives. Automotive designers use sketches to support the styling activity through its two phases of concept design and design development before handing over to the downstream development processes. The importance of 'computer aided styling' over CAD is highlighted.

Tovey [**2**] described the work on sketch mapping as a usable tool and contrasted it with the more conventional direct modelling approach which is seen to have limitations. He also gave a brief description of work in progress on deriving forms directly from sketches. The concept design methodology was also discussed.

Sußner *et al.* [**3**] discussed the use of reflection lines and specular highlights for the quality control of car body surfaces. A prototype with a highly reflective surface was built and viewed in a cubing room, which has many parallel arranged lights. The reflections of the lights are a good measure for surface quality, i.e. for detecting surface curvature discontinuities and for discussing the character of the shape.

Hagen *et al.* [**4**] presented a detailed survey of surface interrogation methods. Orthotomics are used for convexity tests. Focal surfaces, a new tool for analysing freeform curves and surfaces, are special line congruences that are used to analyse the quality of the surface before sending the data to CNC machines.

Hahmann [**5**] gave a general method for surface interrogation which includes reflection lines, isophotes, curvature plots, highlight lines, and isolines. These tools are mainly used in computer graphics and found application in analysing freeform surfaces in CAD.

Theisel [**6**] showed that isophotes and reflection lines are different tools for surface interrogation. Isophotes were used to identify curvature discontinuities between surfaces, and reflection lines were used to measure the quality of the surface.

Monacelli [7] discussed the virtual reality (VR) applications for reducing the time and cost involved in the vehicle development process. VR can help to change the initial concept sketching from a manual method to a digital environment. VR has applications in styling and the designer can visualize the digital model in a better way.

Barone [8] explained the need for renovating the traditional styling process to a CAD-based styling process and addressed the difficulties faced during the traditional styling process.

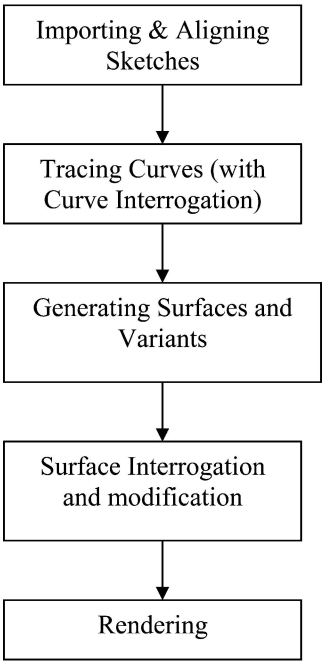

Fig. 2 Methodology for CAD-based concept development and styling

3 STYLING OF A CAR BODY

A study was carried out on the styling of automotive exteriors because the first impression that a customer has of a car is the design of the car body. To be competitive in the market, not only is it necessary to have a good design but also it is crucial that the stylists' guidelines will be accurately implemented when building the car.

The disadvantages with the traditional car development process are the time taken to make changes and the inability of the clay model to create variants of the new product. As the concept model can be seen only at the final stage of the design process, making changes to the concept model in the final stages is difficult.

The methodology adopted and the step-by-step procedure of the CAD-based development process for the car body using CATIA V5 are explained in Fig. 2.

3.1 Importing concept sketches

The input for concept development is sketches. Concept sketches help the designers to arrive quickly and easily at a stage where a satisfactory design can be specified for development of detailed design. The sketches are imported into the sketch tracer module of CATIA V5. They are aligned such that the front view of the car will lie on the front plane. Similarly all the views of the car are aligned to lie on the corresponding plane. The sketches will form a bounding box and the model will lie within the bounding box. Figure 3 shows the aligned concept sketches imported into CATIA V5 using the images (scanned) of manually prepared concept sketches.

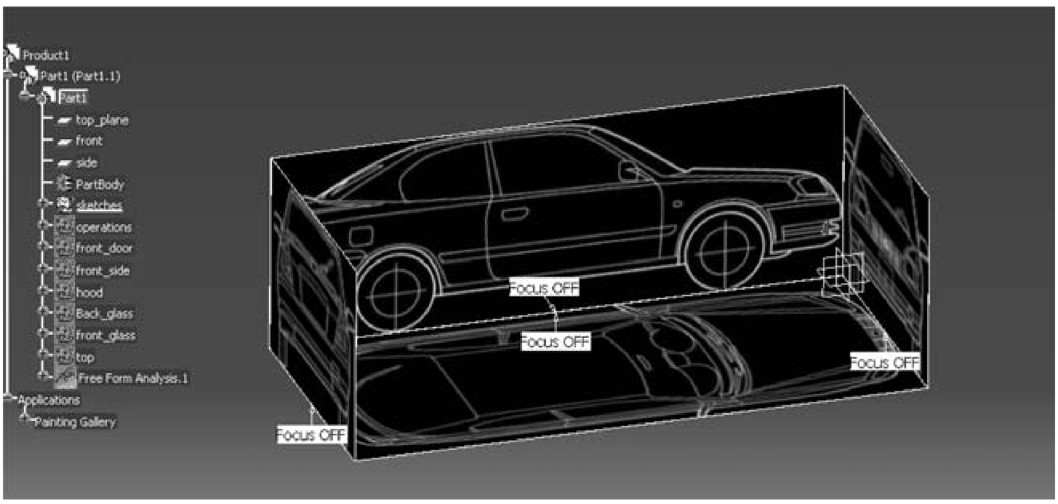

Fig. 3 Concept sketches imported into CATIA V5

3.2 Tracing and translating curves

Two sketches that will best represent the curve to be generated are selected and curves are traced above the sketch. Both curves will lie on the corresponding plane of sketch. To generate a single curve from the curves traced, an intersection technique is used; the curves traced are extruded and intersected so that the resulting curve will be the required curve for surface generation.

If all three sketches represent a curve, then points are plotted in one view and with the other two sketches as references the points are translated such that the points will appear to lie on all three sketches.

The generated sketches are mirrored to generate a group of curves as shown in Fig. 4, which are suitable for generating patches.

3.3 Curve interrogation

Good curves will result in good surfaces. Therefore, before generating surfaces the curves are analysed for their quality. Porcupine curvature analysis in CATIA V5 checks for a smooth variation in curvature (plots) throughout the curve. If the curvature variation is smooth, then the curves will result in smooth surfaces. If it is not smooth, then the control points representing the curves are translated so that a smooth variation in curvature is obtained. Figure 5

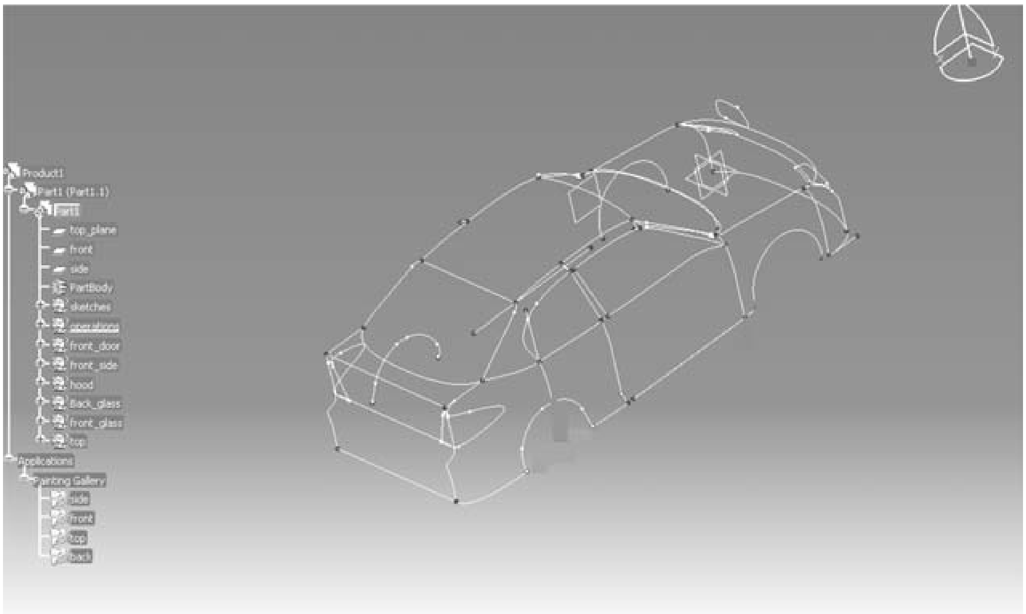

Fig. 4 Curves for patch generation

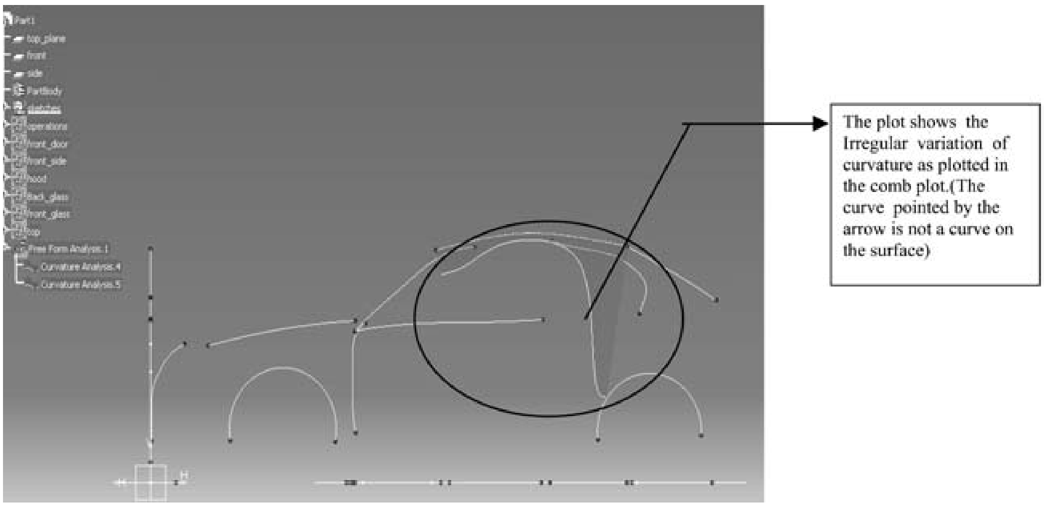

Fig. 5 Irregular variations in curvature

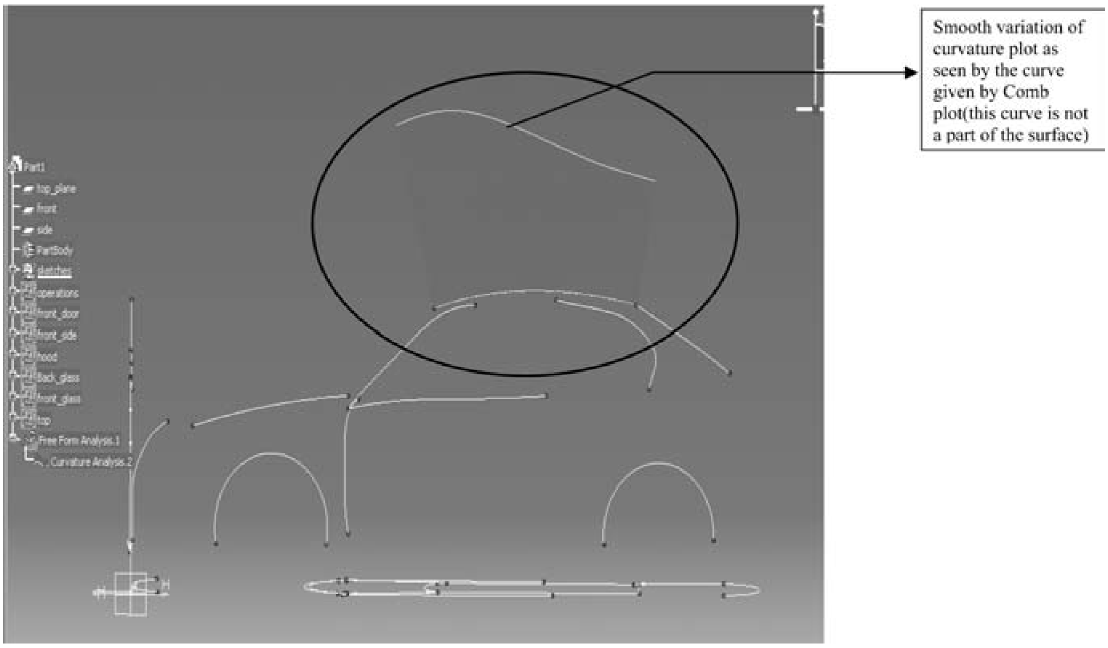

Fig. 6 Smooth variations in curvature

represents an irregular variation in curvature and Fig. 6 shows a smooth variation in curvature. The curvature comb plot will show variation in the magnitude of the radius of curvature. When the magnitude of the spikes is small, this indicates a flat region on the curve. The magnitude must vary smoothly, or the curve will have sudden peaks and valleys. This is also useful in analysing the continuity between the curves. For curvature continuity it is necessary that there is no step in the curvature comb.

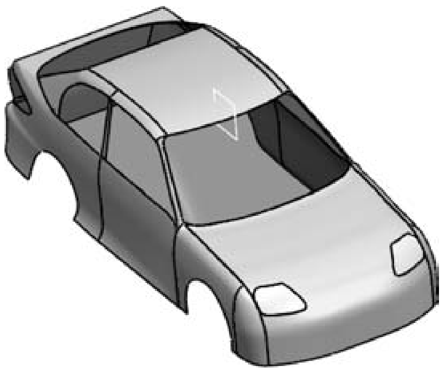

Fig. 7 Concept model

3.4 Generating surfaces and variants

Surfaces are generated from the curves as patches. Figure 7 shows the concept model generated in CATIA V5. The surfaces representing a particular component in a car (e.g. the hood and the top are separate components) are placed in separate open bodies because of the ease in restyling. Figures 8 and 9 show some of the variants generated during the present study.

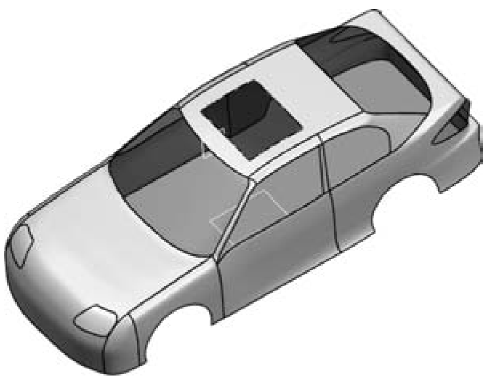

Fig. 8 Variant: glass top

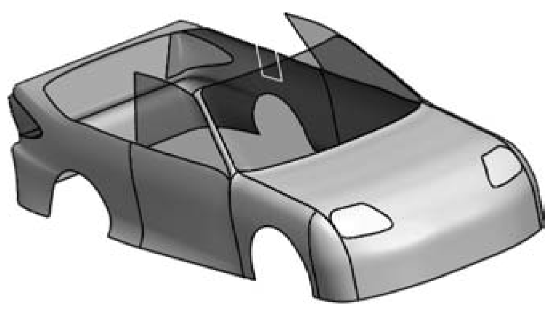

Fig. 9 Variant: convertible top

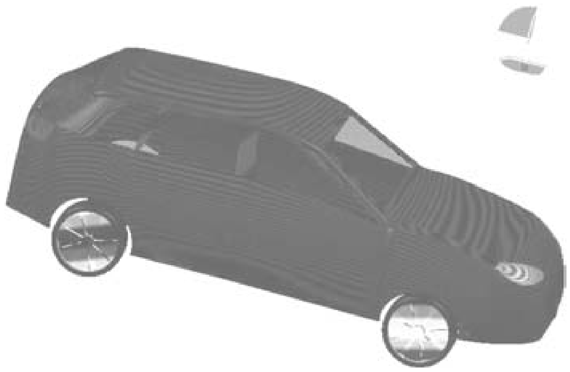

Fig. 10 Isophote plot

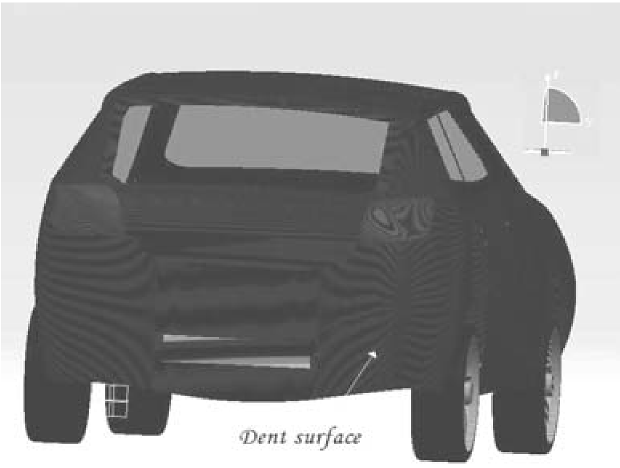

Fig. 11 Isophote plot on a dent surface

3.5 Surface interrogation

Surfaces are interrogated for class-A quality. Isophotes and reflection lines are the most commonly used tools for surface interrogation. Isophotes are used to identify the discontinuity between surfaces. They highlight the behaviour of the form or shape of a surface when light reflects from the surface. This reflection of light gives the user an understanding about the curvature discontinuity. This reflection should be natural and streamlined and should have uniformity. It is used to identify curvature discontinuities and to locate the dents in surfaces. Curvature discontinuities are represented by discontinuous highlight plots. Figure 10 shows the isophote plot of one of the models. Dents are represented by convergence of the highlight plot at the point of dent. Figure 11 shows the isophote plot on a dent on the surface. Reflection lines are used to measure the quality of surfaces. It is the reflection of a family of parallel lines on the light plane on the surface. Figure 12 shows the reflection line plot on the car surface.

3.6 Rendering

Rendering of the models is carred out to improve the visualization aspects of the model. Real-life rendering is mainly performed to make the customers appreciate the look of the final models. A VR environment is used for visualization and real-life rendering. Figure 13 shows the rendered model generated in CATIA V5.

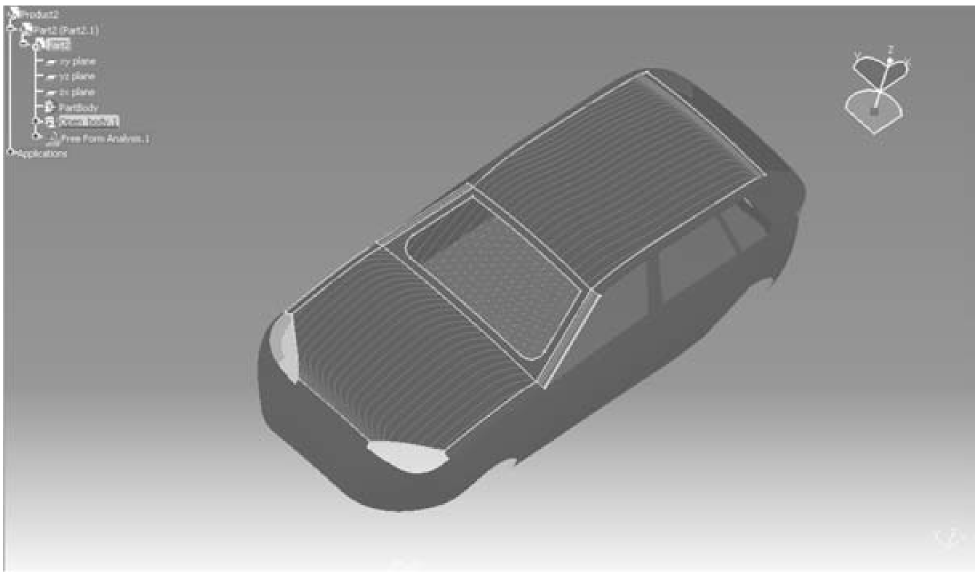

Fig. 12 Reflection line plot on the surface

Fig. 13 Rendered model

4 CONCLUSIONS

This paper tries to provide a systematic approach in developing styles from the images of the manually prepared concept sketches made by an artist with the aid of CATIA V5 software. It also interrogated two surfaces specifically to reveal the discontinuities that are present on a surface. If curvature continuity is not satisfied while designing a surface conventionally, the surface may have discontinuities and aesthetics will have to be improved. This approach is useful for any product development that needs class-A surfacing. The users of CATIA V5 can implement the same technique in their practice without adding any costly hardware.

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