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Surface continuity aspect in context of a car body modelling

Zagadnienie ciągłości powierzchni w kontekście modelowania karoserii pojazdów

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Surface modelling is one of the most difficult modelling discipline. A properly developed model must meet functional and technological requirements and additional design look. Because of that, the surface continuity aspect is so important in surface modelling. The paper presents basic information on the issues related to the surface continuity criterion and presents the influence of continuity on the aerodynamic properties of the object.
KEYWORDS: surface modelling, surface continuity, aerodynamic

Modeling of car body elements is a challenge for constructors. Due to the need to provide the appropriate visual qualities and to guarantee the possibility of creating a modeled element, designers from this industry constitute an extremely narrow group of specialists. An additional element that hinders the task is the need to use sophisticated surface-modeling techniques using CAx systems.

Problems related to surface modeling result mainly from a specific approach based on the knowledge of mathematical foundations regarding the curves and surfaces on which such models are based. Knowledge of the continuity and production technologies of modeled elements is also required. An exemplary surface model is shown in fig. 1.

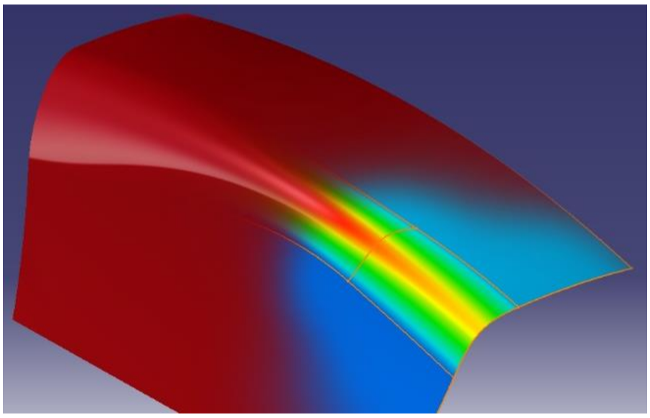

Fig. 1. Example of a car body part – the effect of using surface modeling techniques

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Continuity criterion

From the point of view of the constructor of surface models, geometric continuity is the basic criterion for quality evaluation of curves. The quality of the curves is essential in the case of defining surfaces (the resulting surface patch will be as good as the curves on which it has been defined). In CAD systems, algorithms defining individual curves guarantee that their geometric continuity will be maintained, but a combination of several different curves can already be realized with different degrees of continuity [1, 2]. The curve defining the surface patch is very often the result of combining several elementary curves – therefore, it is necessary to analyze the continuity of the curves at the stage of defining the basic elements.

It can be said that the criterion of continuity includes a set of conditions that can be verified at the common point of two curves or along a line connecting two patches of surface. In computer-aided design support systems, four basic degrees of continuity are distinguished, denoted as: G0, G1, G2 and G3 [1, 3, 4].

A graphical interpretation of individual continuity criteria is shown in fig. 2.

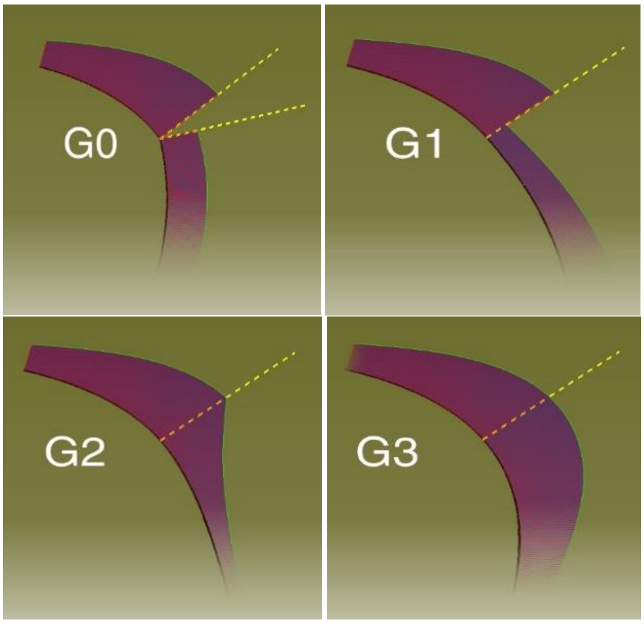

Fig. 2. Graphic interpretation of successive degrees of continuity

You can talk about continuity G0 when two crosses have a common point. In other words: the lack of continuity G0 means that the curves are not in contact with each other. In the case of a surface, continuity G0 means that two surfaces of the surface share a common edge [1, 2].

G1 continuity is ensured when there is a combination of two curves that meet the criterion G0, and additionally these curves are tangent. This means that the directions of contact between the two curves at the contact point are consistent, i.e. the angle between them is 0° or 180° [1, 2].

The condition of continuity G2 satisfies the system of two curves, which at the common point have the same radius of curvature. Two patches of the surface with G2 continuity have the same radius of curvature along the common edge [1, 2].

In the case of G3, the continuity of changes in the curvature (gradient) must be maintained in the area of the common point of the two curves. If the system of two curves has continuity G3, it means that at no point there is a radical (step) change in curvature [1, 2].

Among the standards of surface quality modeled in CAD programs, there is the concept of a class A surface. It is a surface that in its geometry keeps contact and continuity of curvature everywhere. In other words, it is a continuous surface patch G2 or higher. The shape of the A-class surface has exceptional aesthetic features, which is often used in surface modeling for the needs of industrial design. Characteristic for such a surface is a gentle, continuous distribution of reflections of light and reflections, giving an attractive visual effect [1–4].

The effect of surface continuity on aerodynamic properties

In the case of car body elements modeling, it is crucial to ensure the lowest possible coefficient of air resistance that the modeled object puts in motion. In order to illustrate the effect of surface continuity on aerodynamic properties, several examples of models meeting the condition of continuity G0 and G1 have been developed. In simulations, it was limited only to the case of G1, because this criterion is relatively easy to meet with small model changes, and there is no problem with creating elements that meet this criterion.

Fig. 3 shows the developed examples of models: a bullet test element, a wheel arch piece, a fairing and a simplified car profile. All of these models were simulated by CFD (computational fluid dynamics), mapping the object's movement at a speed of 100 km/h (about 28 m/s) in the air [5].

The obtained simulation results are presented in figs. 4–11. There are shown the speed distributions of the medium (air) along with the plotted streamlines.

As can be seen, the type of surface continuity retained in individual models did not have a particularly large impact on the course of the streamline. It is probably due to the fact that the authors' intention was to obtain almost identical models, differing only by appropriate rounding, introduced in order to limit the influence of significant changes in the results. The main purpose of the analyses was to determine the coefficient of resistance c_x for individual cases and to check how the change in the degree of continuity affected the value of this coefficient. The obtained results are compiled in the table.

TABLE. Values of the drag coefficient for the simulations carried out

Model	c_x for G0	c_x for G1	Difference
Missile	0.46	0,24	47,82%
Mudguard	0.26	0,24	7,69%
Deflector	0.77	0,49	36,36%
Vehicle profile	0.21	0,11	47,62%
		Average	34.87%

As it can be seen, in each of the considered cases, the G1 continuity model obtained a lower value of the coefficient c_x, which confirms earlier assumptions.

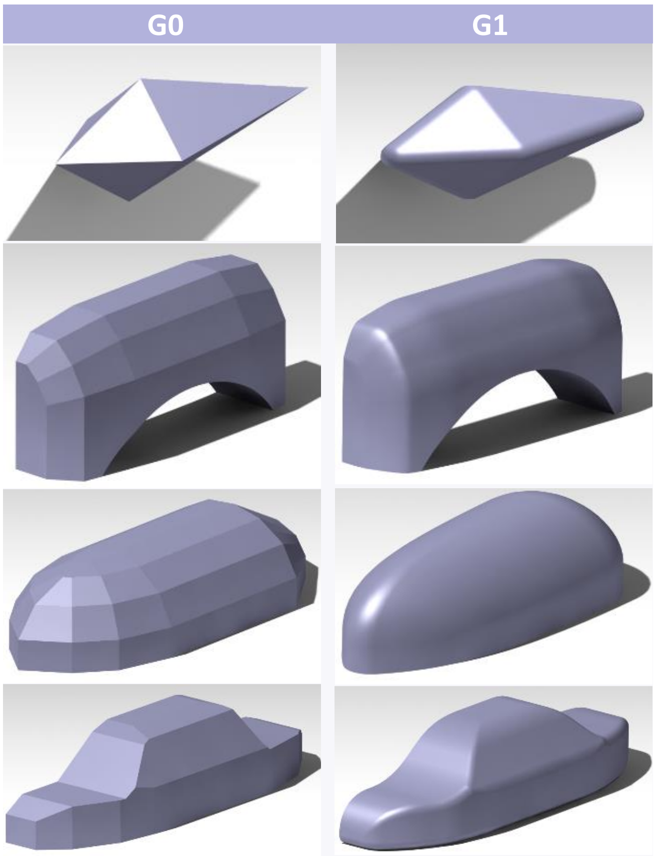

Fig. 3. Models developed for stimulation purposes (meeting the G0 continuity criterion – on the left, G1 – on the right)

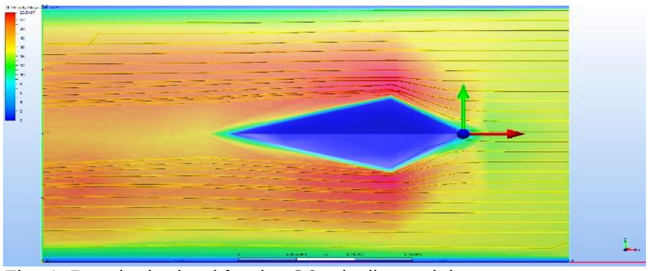

Fig. 4. Result obtained for the G0 missile model

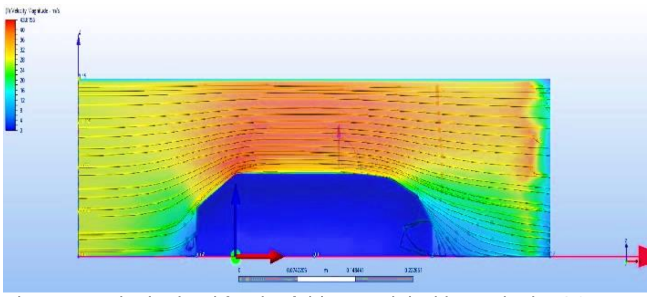

Fig. 5. Result obtained for the fairing model with continuity G0

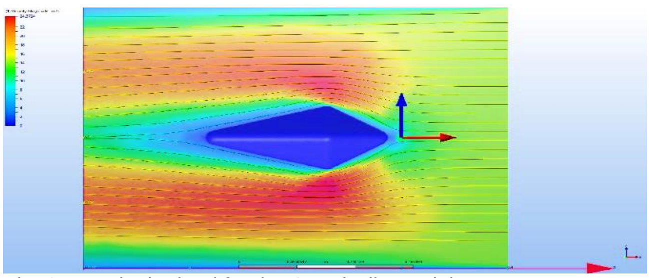

Fig. 6. Result obtained for the G1 missile model

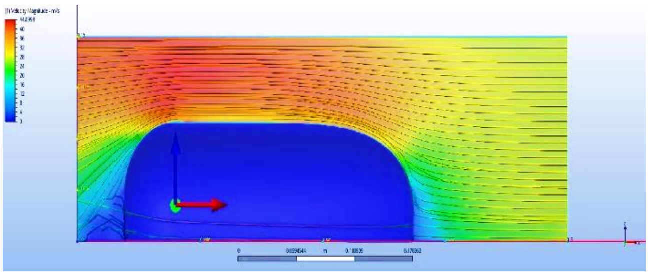

Fig. 7. Result obtained for the fairing model with continuity G1

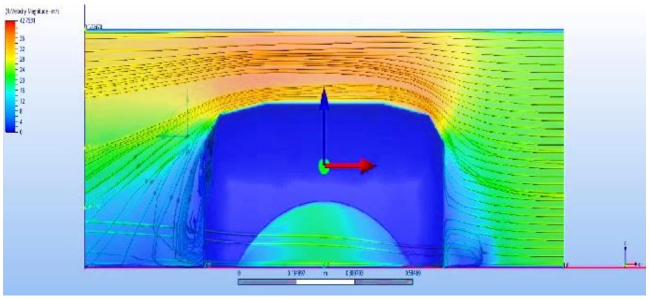

Fig. 8. Result obtained for the wheel arch superstructure with G0 continuity

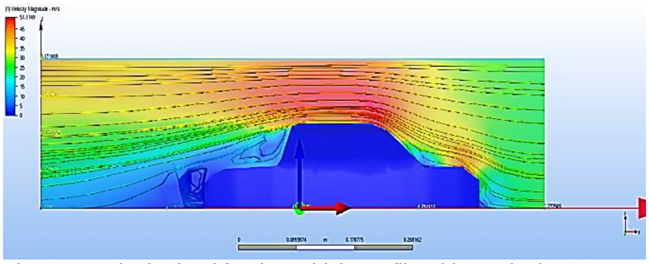

Fig. 9. Result obtained for the vehicle profile with continuity G0

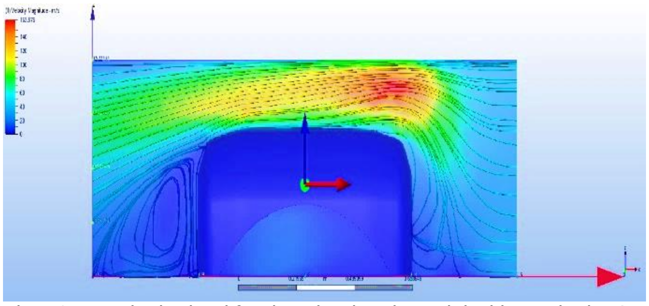

Fig. 10. Result obtained for the wheel arch model with continuity G1

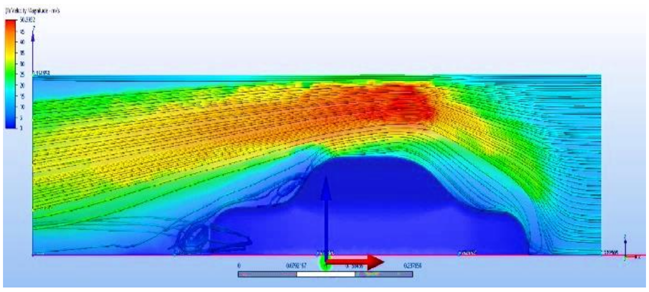

Fig. 11. Result obtained for the vehicle profile with continuity G1

Conclusions

Designing elements using surface modeling techniques requires the ability to control the degree of continuity between individual surface panels. The application of the G2 or G3 continuity criteria allows obtaining surface elements with smooth transitions that guarantee that the requirements regarding the appearance of a given element are met, and also affect other relevant issues. For example, the continuity of the surface affects the aerodynamic properties of the object. According to what has been presented, the introduction of appropriate radii of rounding between the individual panels of the element allows to reduce the resistance coefficient. In the cases considered, an average decrease in the value of this coefficient was obtained by approx. 35%. As part of the analysis, the G0 and G1 continuity criteria were limited because an attempt to meet further, higher degrees of continuity could lead to even greater differences in the obtained results. This would involve significant remodeling of elements, which the authors wanted to avoid, however, to show the evident impact of continuity rather than the form of the element.

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