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Automated Package and Design of Fuse Boxes and Cable Channels for Electric Vehicles

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Summary

In this work, it is shown how automated procedures can be used to improve the design of electrical components in vehicles such as electric fuse boxes and cable channels.

First, it is shown how the elements e.g. fuses and relays of a fuse box are automatically arranged in a given installation space. Secondly, an automation was applied to analyze the minimal cross section of cable channels, which is just as well a recurring problem during the design of the vehicle electrical system. Both procedures shown can save time as well as help to get fast and reproducible results during the development process.

Keywords: automated design, car, electronic, optimization, battery, cable harness

1. Introduction

Today, vehicles and especially electric vehicles (EV) are fully digitally designed using computer aided design (CAD) such as CATIA V5 or Siemens NX. During the development process, the shape of the vehicle, the available space for components, the position of the components and thus the electrical system change, especially in the early phase (concept phase) of the development. This change causes many recurring and time consuming investigations of the package.

However, recurring problems, if they are well defined, can be solved with automated procedures [1]. In this work, the procedure of solving recurring problems is shown by means of two examples using CATIA V5 and its coupled programming language Visual Basic for Application (VBA).

First, it is shown how fuses and relays can be fit in a given space automatically. Secondly, it is shown how the measuring task of finding and estimating the minimal cross section of a cable channel can be automatically performed. Finally, the time saving potential is discussed and further ideas are presented.

2. Automated Construction of Fuse and Relay Boxes

To design fuse and relay boxes, it is necessary to check the given space in the vehicle in advance. As for the example of fuse boxes, this implies a proper examination, including the positioning of geometrical elements with simplified dimensions, within the given space. It is thus possible to decide if there is enough space for the fuse box or not. The positioning of the geometrical elements is implemented with the CAD-Tool CATIA V5. This approach is required to check if all needed components of a fuse and relay box fit into the given space, especially since a bigger space can be demanded in time [2].

One of the disadvantages of this manual method is the amount of time needed to place the geometrical elements. Furthermore, it is uncertain whether the final positioning truly represents the best and most convenient spatial arrangement. At this point, automation sets in: with the help of an automated positioning procedure, it is possible to save time and create reproducible arrangements that can be compared in order to determine the best solution.

The aim is to set up an automated process, where the free selectable geometry of the available space is the main parameter. For this purpose, the mentioned process is at first thoroughly examined and then put into practice through different concepts. In order to determine if all the elements of a fuse and relay box fit into the available space, they need to be positioned in a virtual space beforehand as shown in Figure 1. The developed program allows the user either to directly activate the elements for positioning or to run through a full automation process that positions the elements with the help of a programmed logic.

With the former, the geometrically simplified elements are arranged inside a box. An elaborated collision recognition prevents the penetration of the installation space or other elements. The fully automated positioning on the other hand, demonstrated how such a design problem can be automated and which challenges can be expected or anticipated. Well-elaborated automation solutions like the one described above, are not only ideal for time-consuming and repetitive activities but do also provide extremely precise results thanks to the looping of certain operations.

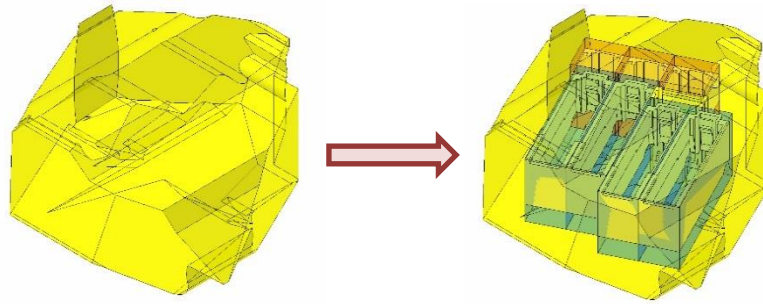


Figure 1: Given space (left) without and positioned elements in the given space (right)

Implementation

At first, a suitable programming language for the implementation of automations in CATIA V5 has to be determined. In this example, the programming language VBA is used and the parameters can be entered through a graphical user interface as shown in Figure 2.

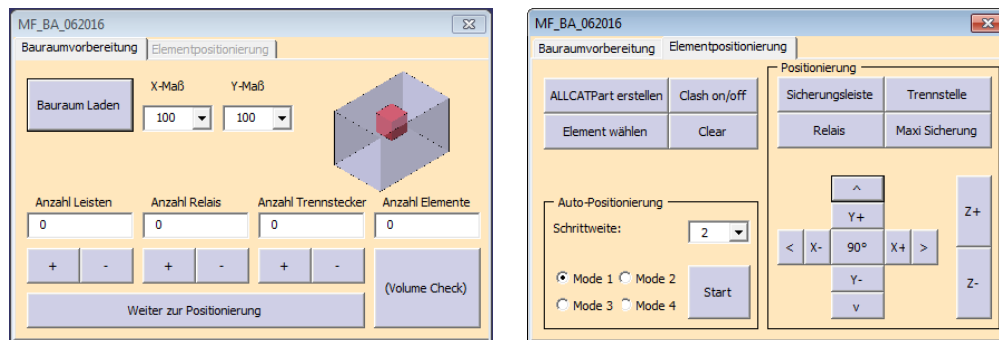


Figure 2: Developed graphical user interface

In order to implement the automation, a typical examination of the installation space is analyzed and broken down into several smaller work steps. Hence, every work step could be automated separately and then be re-assembled to a complete system. By doing so, the overall complexity of the entire automation process is reduced drastically.

Further, the individual work steps and the respective functions are tested after they are joined to the complete system in order to guarantee that they would not have adverse effects on each other. These test runs are made by design engineers in order to identify potential problems in advance and thus proper functioning of the automation is ensured. Finally, an appropriate user interface was created: the individual work steps can be controlled separately but are embedded in a uniform function system. With the implemented automation, the single geometrical objects can be moved in the hollow space. The possible moving directions are shown in

Figure 3. The program is able to recognize a collision of the moved object with the boundaries of the given space or the other elements and interrupts then the movement of the current object. An example of the positioning for a fuse bar and a relay socket is shown in Figure 4. In Figure 4A a simplified hollow space in which the elements should be positioned is shown. The moving directions of the fuse bar and the relay-socket are shown in Figure 4B and Figure 4C. Figure 4C demonstrates also how the elements are positioned relative to each other and the final positioning of the elements is shown in Figure 4D. In this way, all elements can be positioned in the given space in order to find the best arrangement. In addition to the moving function,

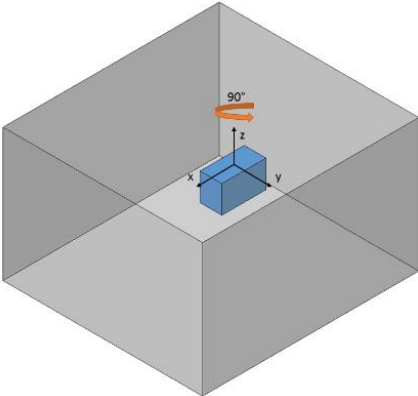


Figure 3: Possible moving directions of an element

there are several options integrated in the user interface to extend the function of the automation. Examples for further options are choosing different starting positions of the elements or editing the position of a single element if errors in the automated positioning are detected.

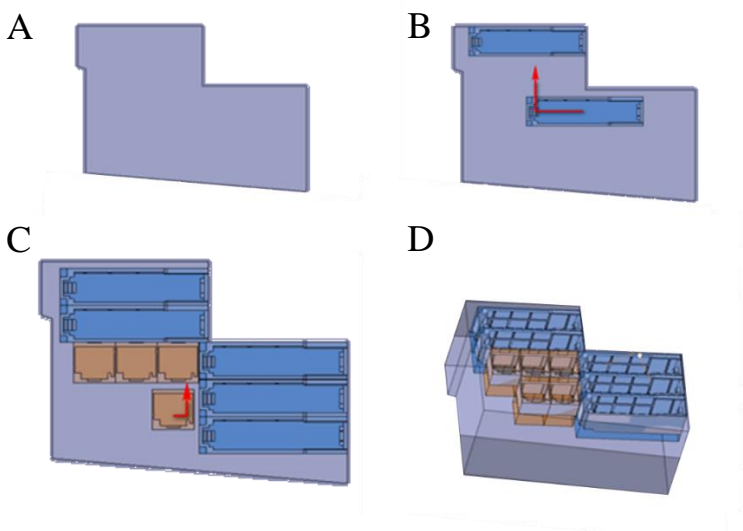


Figure 4: Example of an simplified hollow space (A), positioning of a fuse bar next to another one (B), positioning of a relay-socket next to other elements (C), complete positioning of the elements in the hollow space (D)

The 3D elements are shifted during every step in the program causing the automation to slow down if a large number of elements must be positioned. Since CATIA V5 visualizes every single iteration, the time saving of the automation algorithm depends on the number of the geometrical elements and the complexity of the given space. Therefore, a simplified positioning algorithm is used (only 2D positioning is considered) due to performance issues in the current implementation.

Further developments could concentrate on improving the positioning algorithms, especially with focus on positioning the elements in 3D space (more powerful programming languages could help here). However, the optimized positioning of elements in 3D and 2D space is not well-defined because it is a so-called “bin packing problem” and could be part of further research too [4].

3. Automated cross section determination of cable channels for harness systems

In modern vehicles, electrical wires and cables are typically led through cable channels due to structure and safety reasons. An example of a typical cable channel is shown in Figure 5. For cables in cable channels, the minimum cross section area of the channel as well as its minimal bending radius is crucial. Changes in the cable channel geometry (e.g. due to changes of the package or the position of surrounding components) can lead to changes of the minimum cross section area or its location within the cable channel.

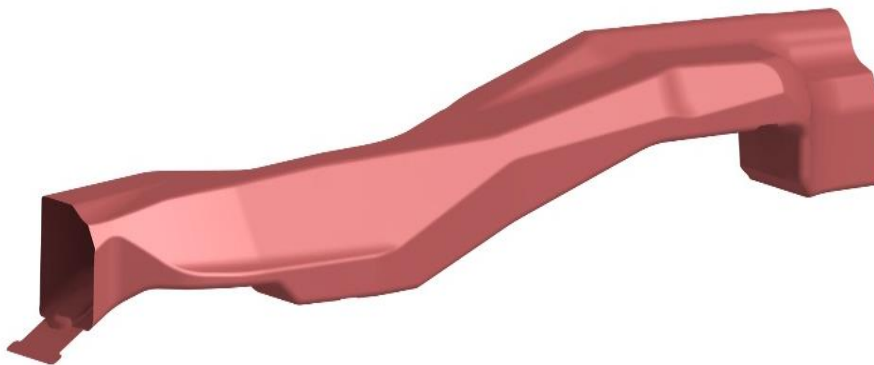


Figure 5: Typical cable channel in a modern vehicle

Currently, every cable channel inside the vehicle must run through a separated cross section analysis in CATIA V5 manually. Every change of the package or cable harness requires an entirely new and time-consuming analysis. However, not every modification of the package can be fully implemented in the given development time.

In complex cable channels or package situations, the location of the minimal cross section area can be only roughly estimated beforehand, and therefore the entire channel must be examined in detail in order to find its

minimum cross section area. Moreover, the orientation of the minimal cross section plane can only approximately be determined as well.

All these factors suggest an automation concept of the analysis to find the minimal cross section area. With the use of macro programming, the analysis can be fully automated and the development time can be reduced [5]. The cross section analysis can also provide a useful basis for an argumentation and visualization of the problem (e.g. in package development meetings).

Implementation

The automation concept is based on a sphere, consisting out of s circular areas, which is lead along a spline through the cable channel. The generated sphere from $s=1$ to $s=200$ circular areas is shown in Figure 6.

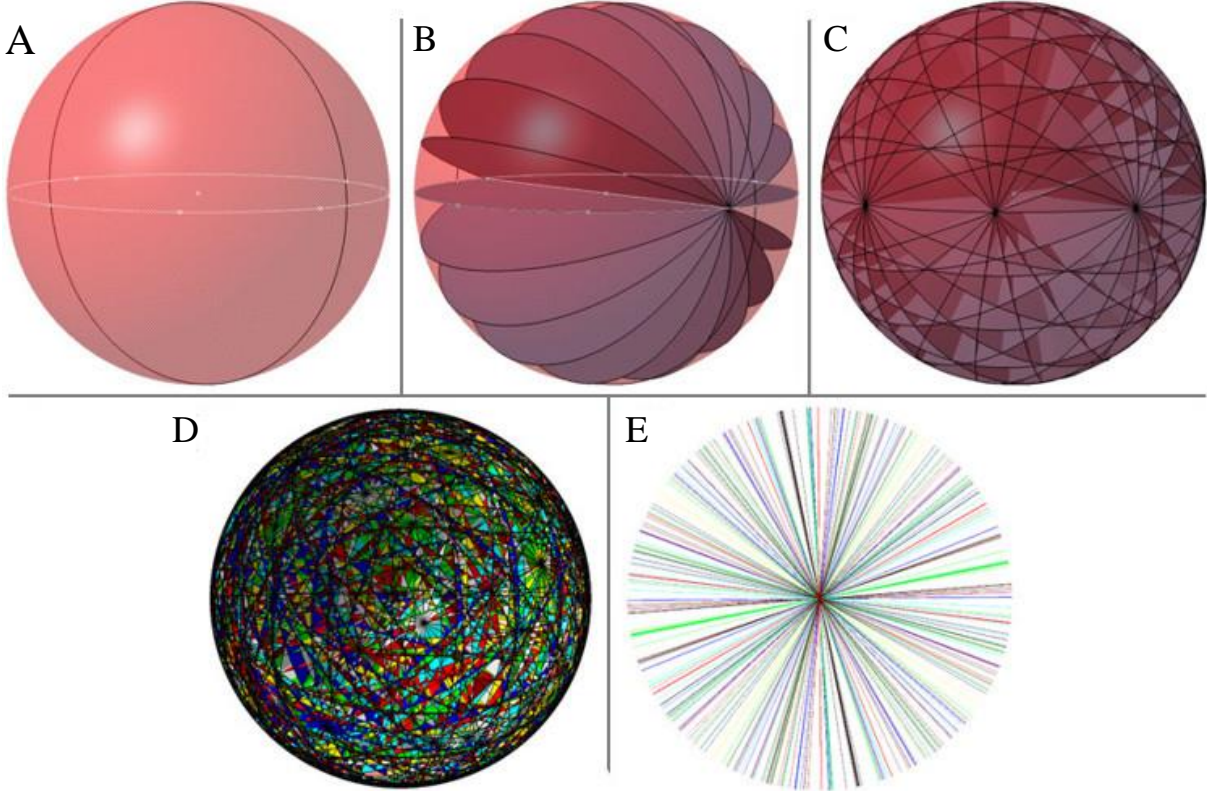


Figure 6: Generation of the sphere with $s = 1$ (A), $s = 9$ (B), $s = 36$ (C), $s = 200$ (D) and sphere cut through the center with $s = 200$ (E)

The circular areas are needed to cover as many orientations of the cross section area as possible. The circular areas are cut with the boundary of the cable channel and the resulting surfaces are used to determine the minimum cross section area. The cable channel is limited by two planes parallel to each other. Thereafter, n

intermediate planes are generated equally spaced between the input and output planes. The number of planes n determines the accuracy of the measurement.

Subsequently, the generated planes are cut with the cable channel boundary and the center of gravity of the resulting surfaces is used to generate a spline through the cable channel. The generated planes between the the input and output planes are shown in Figure 7A. The centers of gravity and the generated spline is shown in Figure 7B [3]. The main criteria for generating the circular areas (and in thus subsequently the sphere) is that their diameter is larger than the largest width of the cable channel, to cover the whole cable channel as shown in Figure 8A.

Afterwards, the pre-designed sphere is placed on the centers of gravity as shown in Figure 8A and trimmed with the cable channel as shown in Figure 8B. All unusable, open intersections are deleted in an intermediate step because they do not provide meaningful statements as shown in Figure 8C.

Finally, the area of the remaining sections is analyzed. The minimum cross section area of all remaining sections is the minimum local cross section area in the current center of gravity as shown in Figure 8C. The minimum of all local minimum cross section areas is the minimum cross section area for the whole cable channel as shown in Figure 8D.

In a similar procedure, the minimal radius of the cable channel can be analyzed. Further research could be focused on improving the user interaction as well as presenting the result in CATIA V5. The performance issues are similar to the former example and skipping the visualization (if possible) after each iteration could help here as well. Another research topic could be the optimized design of cable channels starting from the harness system.

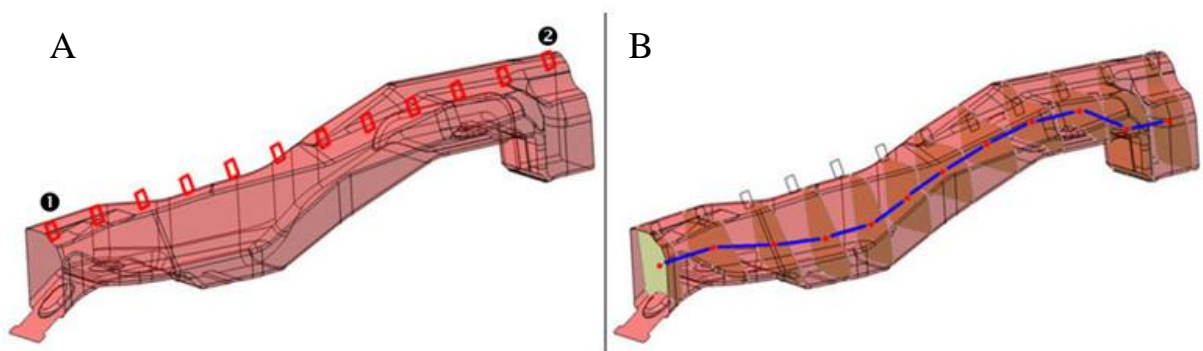


Figure 7: Cable channel with parallel planes between the input plane ① and output plane ② (A), cable channel with intersected planes, the centers of gravity of the resulting intersections and a spline through the centers of gravity (B)

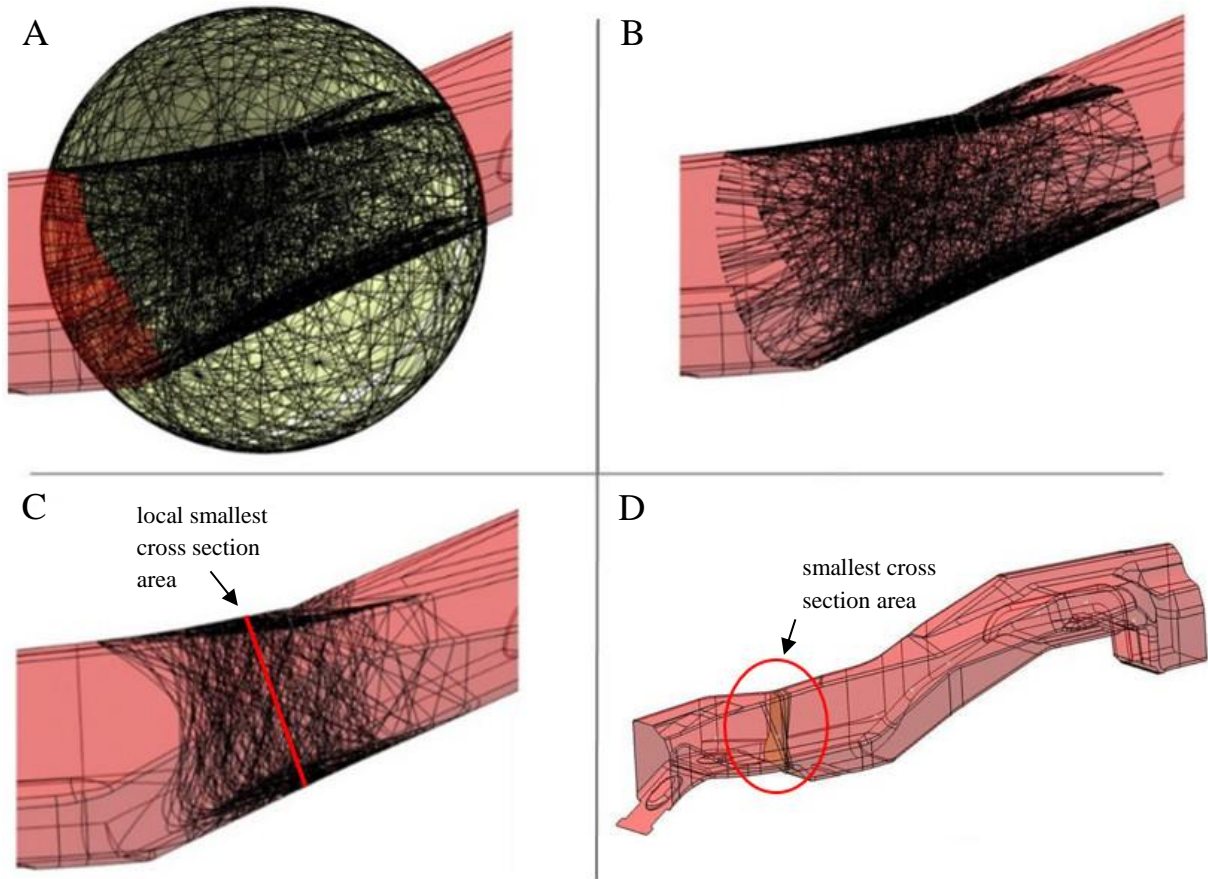


Figure 8: Sphere on center of gravity (A), sphere trimmed with the cable channel (B), sphere with closed intersections only and the smallest local cross section area (C) and the cable channel with the smallest cross section areas (D)

4. Summary and Outlook

This work shows that automations are in fact possible and feasible. The time saving potential is present and the work-input can be minimized, too. Automations are particularly suitable for recurring and complex engineering problems.

Two different tools for CATIA V5, which allows partial automation of the examination of the installation space for the design of fuse and relay boxes as well as finding the minimum cross section area, were successfully developed. These tools offer an insight into problems and challenges when implementing automations in CATIA V5. However, in many cases, the performance of the automation could be challenging and limits the usability of automation tools.

To address this performance drawback in order to optimize the tool's applicability in daily automotive development processes, further research could investigate more powerful programming languages as well as their deeper interaction with the CATIA V5 calculation algorithm e.g. without visualization of every single iteration.

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