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Automation of Designing Car Safety Belts

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Abstract. Designing seat belts for modern cars is largely a routine process. Supporting the design process by conventional CAD techniques despite many benefits does not shorten time-consuming design tasks as significantly as we would expect. Only the use of Generative Modeling method can considerably automate routine part of the design process of safety belts. The key to the development of Generative Model is to develop a basis for a seat belt retractor, which determines the whole structure of seat belt assembly. The paper describes in details the design of the Generative Model of the base of a seat belt retractor and the impact of its individual parts on the final form of the belt assembly. In addition, the base is equipped with a Poka-Yoke system, integrated into the Generative Model which ensures the elimination of assembly errors. To build the Generative Model, CATIA system and Knowledgeware tools were used. The paper also shows examples of CAD models of belts assemblies developed using elaborated Generative Models.

Keywords. Knowledge-based Engineering, safety belt, retractor base, poka-yoke, generative model

1. Introduction

Subassemblies used in modern cars have to meet new technical and economical requirements. Safety belt designed and produced by a specialized company can be a top example of such subassembly. Both a designer and a producer of a belt have to have means to design and manufacture it, where assured and safe technical solutions are used which can be easily adopted to the requirements of a customer. Therefore, the belt should comply with functionality list and technical limitations defined by an ordering party. Usually a designer is aware of maximum number of functionalities of a belt and its technical limitations and the chosen solution is an inteligent combination of selected functionalites and respective technological solutions integrated in the whole assembly of a seat belt.

Seat belt assembly must be adapted to specific requirements and limitations of casing in a car. The designing process, which relies on inteligent matching final solution with a long list of partial solutions and on adapting them to limitations of casing, is particulararily suitable for aiding it with Generative Modeling (GM) techniques [1], [2], [3]. This method goes far beyond the simple parametrization although it uses it intensively. Such factors as routine designing process, matching parts of ready made

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technical solutions, adaptation to size and shape of elements and subassemblies according to given criteria and limitations, multiplicity of relations, especially geometrical ones, between collaborating elements predestine this aiding designing method to be used [4], [5]. Designer can do it without many tedious tasks and be sure that many errors can be avioded which result from temporary lack of focus.

The Generative Model (GM) is based on well identified methodology [2][6-9] which includes identification, record and processing of designing knowledge, integration of that knowledge to geometric model in CAD tool, testing and increasing functionality of GM. GM is an associative CAD model which adapts to input parameters, defined in various ways, beginning with common user editable parameters and up to environmantal features which are detected by the model e.g. identification of geometrical features of other parts of the structure. The ability to adapt to these parameters by change of form or size of elements of GM is a distinctive feature of such models [10-13].

One of the most important elements which reflect selected functionalities and limitations is safety belt retractor base. In this base functionalities and limitations are represented as integrated geometrical features. These identified and implemented parts in the base enable placing particular subassemblies which decide on these functionalities and limitations. It is crucial for making GM design in a proper way and use it as a base for choosing the form of the rest of parts. Such GM approch enables not only advanteges concerning design proces but has the important influence on final car parameters and also reduces mass and in consequence energy effciency of transportation operation [14], [15].

In the further part, two key tasks will be presented, connected with GM creation of safety belt and in particular safety belt retrector base. The key tasks are knowledge acquistion and GM creation in Knowledgeware environment of CATIA system.

2. Knowledge modeling

2.1. Ontology introduction

Ontology is a specific backbone for the knowledge gathering process. It contains the detailed structure by which knowledge will be introduced and which will allow it to be prioritized and ordered. It is also characterized by a series of implemented tools in the form of templates, which are the basic element to allow later work on the acquired knowledge. Ontology modeling implies both conceptualization and formalization of the applied domain.

These diagrams can also be divided into two categories in terms of the nature of knowledge that will be written in them:

- Declarative knowledge (also called descriptive) - can take the form of formal and informal knowledge. It mainly refers to the description of the state / situation of objects / activities and the concepts and relationships between them, and indicates what the problem is and what it is intended to solve, rather than what steps to take to achieve this. Examples of this form of knowledge are models and theories.
- Procedural knowledge (also referred to as operational) - indicates how to achieve the intended objectives, that is, the pledge of the procedures, functions or activities to achieve the intended results.

The delimitation of the nature of the knowledge stored in the database on declarative and procedural basis brings disproportionate benefits to the further stages of the use of the implemented knowledge. It allows you to preserve the order of management of the knowledge which is entered, its hierarchy, and also allows you to maintain an appropriate structure in the created database. It should be borne in mind, however, that such division is not intended to permanently separate the two types of knowledge. Although knowledge about instances and relationships between these elements is written in a separate part, and all the procedures and steps necessary to achieve the intended individual, the whole is not able to exist without each other. This form significantly improves the functionality of the knowledge base [10], [11]. It is a modern and practical solution that is an indispensable part of the design and construction process.

Table 1. Ontology basic structure.

	Methodology build	Methodology use
Acquisition of knowledge	Analysis of the field of application Design or adapt the ontology of the field Improving and developing ontology	Application of knowledge acquisition tools to acquire knowledge in the field of design, product and design process of CAD modeling
Formalization of knowledge	Develop rules for creating a formal model Construction of a formal model	Construction of a set of Generative Models in the given design and design class Storage of Generative Models
Implementation of knowledge	Develop alternative ways to create a Genarative Model Developing methods for transforming a formal model into a Genarative Model	Construction of a set of Generative Models in the given design and design class Storage of Generative Models

2.2. Ontology used to implement knowledge of seat belt retractor housing

Using the classic knowledge base is quite a hassle. The necessity to study the complementarity of the knowledge contained in the books, the constant return to the same information and their verification is not a convenient step for the user. In addition, when you encounter a problem, you need to find additional information to solve it. The next inconvenience arises when you want to re-run the process or need to use another user's knowledge base. Another problem is the lack of ability to overlap and emphasize certain information. This prevents the user from accessing the required data quickly. All these problems are eliminated using an ontology based knowledge base:

- No problem with the structure,
- No need to search for missing information,
- Anyone can use this database,
- The workload and time required to build the base entail unruly benefits, facilitating the designer / builder's work.

The graphical form of elements is predetermined, but it is possible for the user to interfere and adjust the appearance of the elements for his own needs, preferences or standards imposed on them for the realization of the process of acquiring knowledge. The KADM (Knowledge Aided Design Methodology) [2][5][10][11] ontology used in the natural knowledge construction work also had some necessary elements to build a correct knowledge base structure. These are the following diagrams for the informal model:

- activity diagram,
- activity diagram of the constraint entity,
- unit structure diagram and constraints
- and the structure view"

Structure and constraints diagram is designed to impose constraints on structural elements using the structure view diagram. This allows the user to impose certain constraints on a particular element of the structure, in detail in the form intended for that purpose, e.g. strength limitations resulting from certain construction calculations or dependency of certain related elements.

Activity diagram is intended to enable the structural diagram to be supplemented by detailed steps from forming and shaping a part to finished product. It allows user to save the technology used, the following steps during the manufacturing process, and the control rules. The knowledge stored here is a procedural knowledge that fully reflects the path of transition from idea to finished product using specific procedures. For building ontology and Knowledge Base constraction PCPAK environment was used [16].

3. Development of aiding tools for safety belt design

3.1. Standard solution

With a classic approach to modeling, in order to create a whole range of different types of enclosure construction, user needs to create around 70 different models. By using CATIA v5, you can do this in a single file with built-in knowledge base using the Knowledgeware module in the form of parameters, relationships and rules that control the display of the desired housing. Despite this, the model becomes "heavy" with so much data and is not working properly with it. Such a form can serve to build the base of existing constructs, but does not introduce the automation of this process.

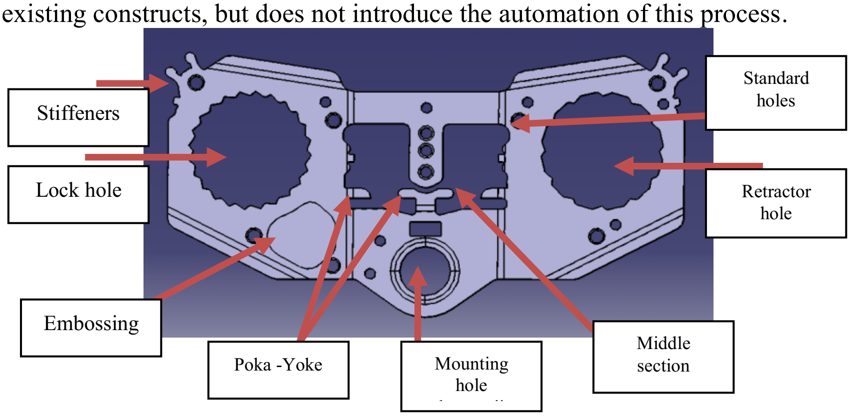

Figure 1. Structural design of the seat belt retractor housing.

3.2. Generetive Model (GM).

According to this concept, the created model was supposed to contain elements allowing to automate some of the activities contained in it. To do this, you must include the entire construction in the necessary parameters and then use the previously mentioned Knowledgeware toolbox.

3.3. System for the design of the seat belt retractor housing.

The general approach to building a system to assist the construction of the seat belt retractor was to use the appropriate Power Copy, User Defined Feature, and Document Template. It was necessary to identify similar housing features for all models and save them in the right form.

The idea behind this model was to make a few simple steps to achieve the ultimate form of the seat belt retractor. In addition, the intention of the constructor was to insert individual design features in the form of the User Defined Feature knowledge template with the block access to the construction of the individual features for the third party, ie, the use of the Black Box Protected option.

3.3.1. Start building the system - Document Template.

Two Geometrical Set elements were inserted into the tree structure to preserve order and functionality, enabling them to incorporate the elements underlying the structure, that is, a group called Input Elements and Structural Elements containing the structure for the housing base.

Figure 2. Different geometric shapes of the outer edge for the seat belt retractors.

Based on the sketches. a user is able to go on to create a three-dimensional structure. The essential feature of creating these components was to provide a common solid for all types of enclosures.

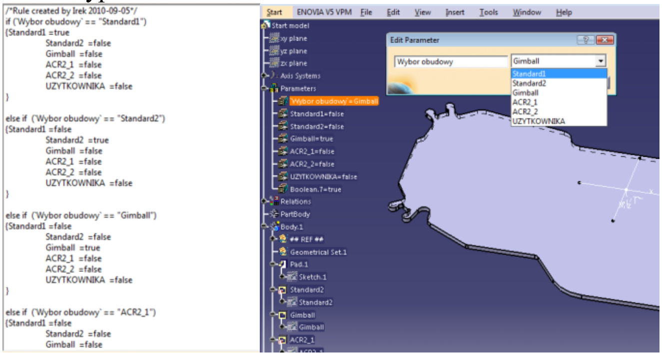

Figure 3. Rules used in the system [left]. Form of choosing a variant of the retractor housing [right].

The last step is to save the file as a knowledge Document Template. After this operation, when inserting this template into a new document, the user will automatically receive the correctly created base shell file structure.

3.3.2. Design features saved as User Defined Feature.

As for the process of constructing the base shape of the outer edge of the casing, it was necessary to prepare the work space by adding and renaming the two Geometrical Set sections. After this operation, a base element was required based on which the planned cutout was to be made and the earlier designation of the base elements of the structure.

A cuboid of 2mm thickness was drawn out of the rectangular sketch. To make sure that the later construction will not have any undesirable constraints, there is a need to extract the input elements from the resulting solid. This capability is provided by the Extract utility located in the Generative Shape Design module. In addition, the use of the Create Datum tool allows you to deprive the "parent" elements extracted.

The next steps are actions analogous to the outer edge, that is, drawing and positioning the sketches of the individual sections of the middle section placed in the Structural Elements group and their subsequent cutting using the Pocket tool. Ultimately, it is important to specify parameters and write rules that controls the display of the selected structure.

For other structural features saved as a User Defined Feature template, the creation process looks virtually identical, except that other spatial operations are used to obtain the desired feature (Hole tool). This is illustrated below (Figure 4).

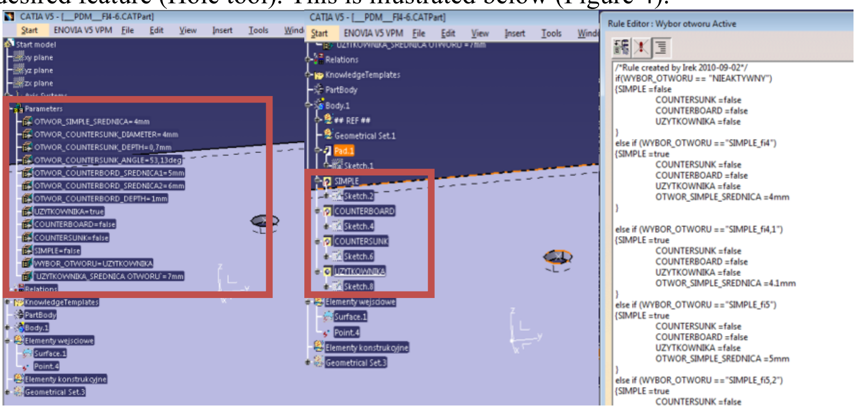

Figure 4. Tree with parameters implemented in the file [right]. Geometric operations [left].

3.3.3. Design features saved as a Power Copy template.

The last part of the system are sets of components used already after the transformation process into a sheet metal element in the Generate Sheetmetal Design module. They will be used to generate Stamp elements, position the insertion points, and define the fold lines for the final form of the casing.

The ready-made templates inserted into the file will copy the items written directly into the structure of the tree.

3.3.4. Templates insert.

This is the stage, which includes placing all previously described templates in the base file.

Consequently, the user automatically receives the external shape of the retractor housing. Now we can proceed to inserting the remaining templates. Finally, the design assumes the form shown in the figure below (Figure 5). When inserting each item, a dialog box appears asking to indicate the characteristic input elements for insertion of these structural features.

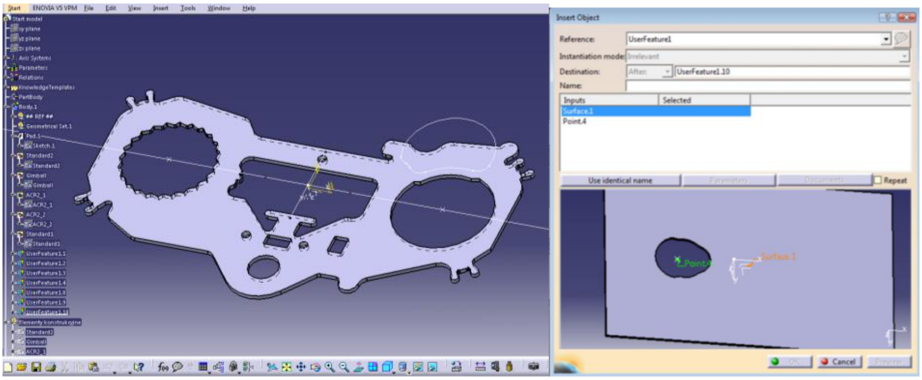

Figure 5. Final retractor model shape.

3.4. Overal system shape

The built-in system based on the implementation of knowledge base construction and advanced CAD system brings the user great benefits. The database can be extended with new product references and using it becomes fast and transparent (Figure 6).

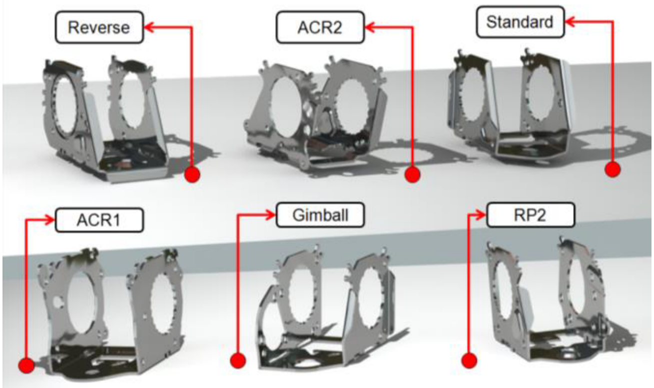

Figure 6. Alternative retractors housings as result models from Generative Model.

4. Conclusions

Safety belt is a typical example of specialized car subassembly. GM aids designing of such subassemblies greatly but these methods are not sufficiently popularized. Detailed description of the usage can be helpful in spreading the method in automotive industry. The main difficulty in planned and systematic use of the GM method is the lack of organized, deliberate and systematic actions connected with acqusition and recording of designing knowledge and systematic approach to GM creation. At the early stage it is important ot determine if models are to be made ad hoc or they are to become systematic base for majority of designign process. In the latter case it is necessary to plan the whole structure and conseqently create part of the final product as GMs.

The assumption that for the whole product GM will be made only once is difficult to meet and instead of expected results it can cause frustration and dissatisfaction of the applied method. The solution is to create GMs of smaller product fragments, preplanned sets which usually works better.

The use of GMs gives very good results as it not only reduces time devoted to routine tasks but first of all decreases the number of mistakes and thus improves CAD models quality which are realized in these routine tasks. It enables for analysing greater number of possible configurations and potential solutions, offering more comfort for a designer and allowing him/her to focus on conceptual and innovative tasks.

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