ENGINEERING DESIGN OF HEADREST FOR PASSENGER MOTOR CAR

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Keywords: Headrest, Engineering design (ED), Requirement, Alternative, Evaluation

Abstract
This work presents a complete solution of engineering design of a headrest for passenger motor car using systematic engineering design. This work is based on the design theory represented by worldwide known Professors W. Ernst Eder, V. Hudka, G. Pahl and W. Beitz and shows how it can help designers or design teams searching for solutions of their tasks. It is necessary to say, that in comparison with methodologies (e.g. German VDA) which strictly tells you step-by-step how to proceed, these methods improve the creativity and the effectiveness of engineering designers.

Headrest in modern luxury passenger motor car has to perform many very important functions. From the main thing which is safety to others such as comfort, high level of industrial design, etc. So the engineering design of headrest involves many questions and problems and our team without any former experiences in this branch attempted to develop a new engineering design of headrest using mentioned systematic methods.

1. Introduction
This work has been carried out as the second part of semestral project at the Department of Machine Design. At first we have developed an engineering design of headrest using our own intuition only and current design knowledge and this developed engineering design have become a starting point of this work.

The assignment task was to make an analysis of this current product and to improve it using systematic engineering design. The result should be a new competitive engineering design of headrest for luxury cars of 3rd millennium.

2. Current product analysis
Because we focused on high class cars, the most important points for us have been:

- SAFETY
- COMFORT
- HIGH LEVEL OF INDUSTRIAL DESIGN

Current engineering design analysis shows that headrest’s values of required properties are deficient and therefore it's necessary to improve this current product.

3. Design specification
The aim of this step was to work out a complete quantified list of requirements (a design specification) with set priorities (fixed requirement or desire feature).

We thought the classes of properties in relation to all phases of life cycle of technical systems (planning, designing, technological & organizational preparation for manufacture, manufacture and assembly, distribution, working process, liquidation) and new properties are the achieved result of it. These new properties are indicated by red colour in the table below (Figure 1).
4. Industrial design – preliminary studies
At the beginning of searching for a final solution, we made preliminary seat studies, where our headrest should be implemented.

5. Principal alternatives
We were thinking about two solution alternatives
- ALTERNATIVE 1  - economic alternative
  - alternative with manual position adjustment, mechanical drive and without airbag for rear passenger
- ALTERNATIVE 2  
  - alternative with automatic position adjustment with possibility of manual readjustment, electric drive and airbag for rear passenger

Our preferred alternative is alternative 2. The economic alternative has been developed only for option of our customers and its dimensional layout will not be fully detailed.
6. Working transformation process

Figure 3. Working transformation process - headrest

7. Function structure

This structure contains sub-functions (especially inside working transformation process) that the technical system must fulfill to the transformation of technical system inputs into the desired effects. The main function of headrest is to save passengers, it means to prevent head or neck injury in case of an accident.

There are two features of safety in modern cars. Feature of passive safety, which prevents not to occur an accident (ABS, ESP, ASR, clear outward visibility, etc.) and feature of active safety, that reduce consequences of an accident, when the accident is already occurred (active belts, airbags, headrests, etc.).

Our engineering design of headrest should fulfill the strictest requirements of active and also passive safety together with high comfort for passengers.

Figure 4. Function structure – alternative 2
8. Organ structure

8.1 Morphological matrix
The next step was the morphological matrix construction, which shows Fig.5. Sub-functions are situated in the first column (related to the function structure) and in the next columns are action principles. For execution a sub-function a more individual action principles can be used. So, if we make two attempts to link the action principles for each sub-function, we probably get two variants of one alternative. The same method has been used for both alternatives.

![Figure 5. Morphological matrix – alternative 2](image)

8.2 Concept sketches
We have achieved two variants for each alternative. We considered 2 alternatives, so now we have altogether 4 solution variants.

The next step in process of searching for the solution is to create concept sketches for each variant. These sketches show main components that are used in individual variants, and show their functions.
8.2.1 Concept sketch – alternative 1 (variant A)

We know that during the front crash, the passenger flies forward, the belts catch him and then passenger goes back into the seat. However, passenger goes back from 30 to 50 mm above the level of the seat. So, if position of the headrest weren’t adjusted properly, neck of the passenger could be injured. Just therefore it is very important to adjust position properly.

The sketch shows how this alternative ensures the proper position adjustment and which components provide the active safety.

When a passenger sits down on the seat, the optical sensor focuses the passenger’s head position. The information about the position goes into the CPU and there it is compared and evaluated with information about headrest position (there is equipment to monitor the headrest position in the seat backrest). Then the indicator situated on the dashboard shows to passenger the result – if the headrest adjustment is ideal or not. Passenger then adjusts the position manually.

Used components:
- Pyroshells – intended to bring the headrest nearer passenger’s head in a flash, if the crash occurs, and thus free head movement of passengers is caught better
- MATE – components intended to recognize the direction of crash (situated under seats)
- Interposer bars – intended to ensure the vertical movement and to carry headrest shell
- Mechanical pawls – intended to fix the vertical headrest position

8.2.2 Concept sketch – alternative 2 (variant A)

Focus and information evaluation is the same as in alternative above. But there are differences in position adjustment.

When a passenger sits down on the seat, the optical sensor focuses the passenger’s head position. The information about the position goes into the CPU and there it is compared and evaluated with information about headrest position (there is equipment to monitor the headrest position in the seat backrest). Then the CPU automatically adjusts the headrest to the proper position. If the passenger wants to readjust the position, it is possible manually using the control panel on the seat. In the case of bad adjustment, indicator situated on the dashboard shows to the passenger that the headrest position is not ideal.
Used components:

- **Pyroshells** – intended to bring the headrest nearer passenger’s head in a flash, if the crash occurs, and thus free head movement of passengers is caught better
- **MATE** – components intended to recognize the direction of crash (situated under seats)
- **Airbag for rear passengers**
- **Circular bars** – intended to carry headrest shell
- **Ball screw** – intended to ensure the vertical movement
- **Stepping motor** – intended to drive the headrest mechanism
- **Pinion** – intended to turn the headrest

Note:
The function of further 2 variants is the same. However, there are used different components to ensure this function. The similar concept sketches have been also created for these variants.

9. Variant evaluation

If organ structures are established, it is necessary to evaluate variants and choose the best one for a detail dimensional layout.

I mentioned that our team was focused on headrests for high-class cars. This fact count on rich customers and it means that for us the high quality is more important than low cost.
Note: We have performed variant evaluation of both alternatives. However below, we only concern with engineering design of optimal variant (variant A) of the alternative 2

10. Preliminary layout
This layout shows possibilities of position adjustment and how our headrest works during a crash.

Figure 9. Preliminary layout

11. Dimensional layout

Figure 10. Dimensional layout – assembly drawing
12. Evaluation

At the end of our searching for the solution, we have evaluated our new engineering design of headrest with current ED and with the engineering design of competitors. The evaluation gives us the answers regarding the requirement fulfilment, competitiveness, etc. The chart below shows that we were successful and our new engineering design fulfils the requirements of headrests for luxury cars of 3rd millennium and it is fully competitive.

13. Conclusion

Although our team hadn’t had any former experiences in the designing of headrests before we started to design it, we were able to create a new competitive engineering design of the headrest using systematic engineering design approach. It shows that a systematic method is one way how to improve the effectiveness and creativity of engineering designers or design teams.

Acknowledgement

This semestral project has been already presented to the management of GRAMMER Company, Tachov, Czech Republic, and GRAMMER Company, Amberg, Germany. Special thanks are expressed to Professor Stanislav Hosnedl, who was continuously helping our team to improve the structure and content during the work development.
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