Research on heat dissipation of car seat optimizing based on ARIZ analysis

Chunmeng Liu¹, Juan Dong², Xin Yang³, Bingyang Xue⁴, Fei Wu¹ and Fu Shi⁴

¹Changchun Lear FAWSN Automotive Seat Systems. Co., Ltd., Changchun 130013, China;
²Jilin University, School of Material Science and Engineering, Changchun 130025, China;
³Changchun FAWSN Automotive Parts Co., Ltd., Changchun 130013, China;
⁴E-mail: dongjuan007@163.com

Abstract. The heat dissipation of car seat back is poor if there is no extra ventilation system. This paper applied ARIZ (Algorithm of Inventive Problem Solving) to get 6 proposals to optimize the heat dissipation of car seat back. Various TRIZ (Theory of Inventive Problem Solving) methods were used, such as Function Model, Cause and Effect Chain, Contradiction Analysis, Substance Field and SLP (smart little people) and so on. All these methods were used by a logical structured process (ARIZ) which incrementally evolves the complex problem to a point where it was simple to solve.

1. Introduction

As a people seats in a car, a car seat back is supporting his/her back. Currently safety requirements are most important for a car seat back. A car seat back is supposed to provide enough support when car is crashed, so that people in car won’t be hurt. However, automobile comfortability is becoming more and more important, so improving car seat comfortability is also necessary. Then both safety and comfortability should be considered when a car seat back is designed.

It was found that the interior temperature of the vehicle is one of the key factors that determines the level of comfort within the car’s environment. Human bodies are highly sensitive to the surrounding temperature especially car seats as their closeness and large contact area with the occupants [1].

Generally, car seat back is constructed with back frame, back foam, back trim cover and so on. Back frame is fixed to cushion frame by 4 bolts, and back foam is outside of back frame, and then back trim covers on the surface of back foam. Some components in back trim cover are fixed to back frame. Both foam and trim cover are elastic to protect and relax occupants. These components are shown in Figure 1 and Figure 2.

As the occupant’s back sinks into the back foam, the heat coming from human body is dissipated through the foam and the trim cover. When ambient temperature is high (≥25°C), with long contact time between the occupant’s back and the seat back, the heat gathering from human back can’t be dissipated soon. It causes higher temperature (≥ 33°C) of contact area, and then the occupant may experience sweating and feel uncomfortable during long-term driving.
Current common solution is setting a ventilation system [1-5] in seat back. A typical ventilation system is shown in Figure 3. However, ventilation system is complicated, expensive, and consumptive. Also, it needs more space to lay out. Above all, ventilation system is limitedly adopted in some premium cars.

Additionally, a kind of extra external lumbar is found to solve the problem as shown in Figure 4. But the strength and durability are historically being a concern. When it is compressed by human body, it distorts so much that the ventilation effect is not good. Also, it seems not to be consistent with seats’ original style, and looks like a cheap choice.

So, it is difficult to improve the heat dissipation of seat back when all the requirements (strength, durability, damping, cost etc.) must be approached at the same time. ARIZ (Algorithm of Inventive Problem Solving), which is one of the TRIZ (theory of Inventive Problem Solving) methods [6-8], can guide to an effective solution.

TRIZ is a structured methodology for problem identification, root cause and breakthrough idea generation. It is an approach in new product development, pointing to multiple paths of solutions and a useful tool for various groups [6-11].

ARIZ is a step-by-step program for the analysis and solution of inventive problems [9, 10, 12]. It is an iterative use of all TRIZ problem solving tools. As a logical structured process, it incrementally evolves a complex problem to a point where it is simple to solve. Then applying various TRIZ
methods (Technical Contradiction and 40 Inventive Principles, Physical Contradiction, Substance Field Model and so on) to solve the problem.

2. Problem solving process
There are three phases (Analysis, operation, Verification and improvement) to solve a problem according to ARIZ-85C [9, 10, 12], and various TRIZ tools are recommended as shown in Figure 5. But it is free to choose different TRIZ tools in distinct phases, and it is unnecessary to go through all steps in the procedure.

Several TRIZ tools have been used in the paper, such as Function Model, Cause & Effect Chain, Technical Contradiction, Substance Field Model, 76 Standard Solutions, Physical Contradiction, 40 Inventive Principles [5-15] etc.

3. Application of ARIZ for Optimizing Heat Dissipation of Car Seat

3.1. Problem Description
The system is “Car seat”. The function of the system is “Dissipate the heat from an occupant’s back”. The restriction to achieve the function is “meet requirements on strength, durability, electricity and cost”.

3.1.1. Function Model. Construct Function Model to analyze the system. The Function Model is shown in Figure 6.

Two factors are found to effect heat dissipation when the system has been analyzed: thermal conduction of car seat is insufficient, and thermal convection of car seat is insufficient.

Considering the limit of current seat material and resource, improving thermal conduction of car seat is given up temporarily. So, the target problem is confirmed to be “thermal convection of car seat is insufficient”.

Figure 5. Problem Solving Process in ARIZ-85C.
3.1.2. Cause & Effect Chain. The Cause & Effect Chain of the problem is made as Figure 7. As a result, “insufficient thermal convection of car seat back” is a key point to cause the target problem.

Figure 6. Function Model of the system.

Figure 7. The Cause & Effect Chain of the problem.
3.2. Technical Contradiction

3.2.1. Define Technical Contradiction TC1 & TC2. According to the Cause & Effect Chain, increasing the density of seat back foam is good for the strength of seat back system, while it is bad for thermal convection of seat back system. So, there are Technical Contradictions, TC1 & TC2 which is shown in Figure 8. Figuring out TC1 will enhance thermal convection of air, so TC1 is chosen. 

![Figure 8. Technical Contradictions.](image)

3.2.2. Solve the Technical contradiction. Description of the contradiction: to enhance the strength of seat back system, it is necessary to increase the density of seat back foam, but it will reduce thermal convection of seat back system.

Turn it to be standard contradiction in TRIZ. Improving parameter: No.14 Strength; worsening parameter: No.17 Temperature.

Search Inventive Principles in Contradiction Matrix, and these principles can be found: Principle 10. Preliminary action; Principle 30. Flexible shells and thin films; Principle 40. Composite materials.

According to the principle 40, Proposal 1 is got which is shown in Figure 9.

![Figure 9. Diagram of Proposal 1.](image)
Proposal 1: A layer of 3D mesh material is bonded to solve the problem, without changing back foam density. The 3D mesh material goes from upper area to lower area of the seat back, so that heat air can go through the clearance. Thermal convection will be improved.

3.2.3. Enhance Contradiction. Enhance the Technical Contradiction from two directions, then choose one direction to intensify the contradiction. Add a factor X1 to solve the contradiction. The key points are shown in Figure 10.

| Path 1 | Increase back foam density |
|--------|---------------------------|
| Path 2 | Reduce back foam density  |
| Intensify the contradiction | If back foam density is high enough, foam strength will be enhanced, but heat couldn’t dissipate at all. |
| Problem description | It is necessary to find a factor X1 to solve the contradiction |

Figure 10. Enhance the Technical Contradiction.

3.2.4. Substance Field Model. Construct a Function Model (see Figure 11) from another perspective, and then build a Substance Field model (see Figure 12). Add a X1 so that a new Substance Field model (see Figure 13) is built. Proposal 2 is proposed according to S2.2.3 in 76 Standard Solutions.

Figure 11. Function Model.

Figure 12. Original S-F model.

Figure 13. Improved S-F model.
Proposal 2: According to S2.2.3, X1 can be cavities. Increasing foam density is good for strength, but it will result in poor ventilation capacity of foam material. So X1 means some through-holes in the back foam, then a thin layer of soft and low-density foam is bonded to improve the touching comfortability. Proposal 2 is shown in Figure 14.

Figure 14. Diagram of Proposal 2.

3.3. Physical Contradiction & 40 Inventive Principles.
Analyze the different requirements of seat back system from both macroscopic direction and microscopic direction, then add a X2 to solve the problem. Apply Substance Field Model and 76 Standard Solutions to approach to the X2. No new proposal is proposed, so go to next step.

A physical contradiction is got according to the definition of X2.
Physical Contradiction: to “improve thermal convection of car seat”, density of back foam should be very low; to “Maintain enough strength of seat back to protect occupant”, density of back foam should to be very high.

Analyze the Physical Contradiction “density of back foam should be both low and high”. Low density is required on the contact zone between human body and seat back, high density is not limited on the contact zone. Therefore, apply “Separation in space” to get proper Inventive Principles. Principle 1, Principle 2, Principle 3, Principle 4, Principle 7, Principle 13, Principle 17, Principle 24, Principle 25, Principle 30 are recommended. As a result, Proposal 3 is proposed.

Proposal 3: Proposal 3 is shown in Figure 15, based on Principle 17 “Another dimension” and Principle 24 “Intermediary”.
Add two layers on the insert area of trim cover. The surface is a layer of flexible mesh fiber, then a layer of multiporous material (3D mesh) is added under the surface. When ventilation function is needed, roll the second multiporous layer so that a big ventilation space is formed between the first layer and original trim.

Figure 15. Diagram of Proposal 3.
3.4. “Little Smart People”

Build a LSP (Little Smart People) Model based on the operation zone which has been shown in Figure 6. Little people with different shapes and colors meant different components, and these little people are smart and active. The LSP Model for current state is shown in Figure 16.

In current state, Heat People are carried by Air People to go through clearances of trim cover surface, soft foam in trim cover, lining cloth, seat back foam and so on. Clearances are so small and crossed that so many Heat People are accumulated between trim cover surface and human body.

Then build the first Target State LSP Model which is shown in Figure 17.

Imagine these Little People working like this: Heat People are carried by Air People to go through the clearances of trim cover surface, soft foam in trim cover, lining cloth, seat back foam and so on. All other Little People are in lines, so that clearances are some through-holes. Because these through-holes work well, Heat People are not accumulated between trim cover surface and human body.

Proposal 4 is got based on Target State 1 which is shown in Figure 18.

Proposal 4: Design some through-holes in seat back system, so that heat can be convective easily.

Build the second Target State LSP Model which is shown in Figure 19.

Imagine these Little People working like this: Heat People are carried by Air People to go through the clearances of trim cover surface, soft foam in trim cover, lining cloth, seat back foam and so on. Clearances are so small and crossed that Heat People can’t go fast. But if a lot of Air People push Heat People, Heat People must go fast and they will not be accumulated between trim cover surface and human body.
Proposal 5 is got based on Target State 2 which is shown in Figure 20.

Proposal 5: Blow wind from bottom of seat back system to quicken air convection. Chilly air from air conditioner in car is guided to bottom of seat back system directly, without adding an electric fan system.

Build the third Target State LSP Model which is shown in Figure 21.

Imagine these Little People working like this: Heat People are carried by Air People to go through the clearances of trim cover surface, soft foam in trim cover, lining cloth, seat back foam and so on.
Clearances are so small and crossed that Heat People can’t go fast. Then a lot of Soft Foam People grasp Heat People, and pass them out of the seat back system quickly. Therefore, Heat People are not accumulated between trim cover surface and human body.

![Figure 21. Target State 3.](image)

Proposal 6 is got based on Target State 3 which is shown in Figure 22.
Proposal 6: Replace current soft foam with soft silicon sheet. Heat can be conducted to non-contact-zone easily through silicon sheet, then convert to the air in car.

![Figure 22. Diagram of Proposal 6.](image)

3.5. Rank Alternatives
Considering all impacts about improvement, comfortability, feasibility, tooling cost, and product cost and so on, all the proposals have been analyzed and ranked. As a result, Proposal 3 is the most suitable one.

![Figure 23. Diagram of Optimized Proposal 3.](image)
4. Application
Proposal 3 has been optimized, and the result is shown in Figure 23. After an occupant with a cotton T-shirt had leaned seat back for 20 minutes at 25°C, the temperature of trim cover surface was less than 33°C.

5. Conclusions
By applying ARIZ on the optimization of car seat heat dissipation, those conclusions are conducted:
1) The analysis tools provided in ARIZ such as function Model, Cause and Effect Chain are efficient to analyze the whole seat system, which provides better understanding about the principle of the original dissipation system on seat back and how the components influence the dissipation results.
2) The problem-solving tools provided in ARIZ such as Contradiction Analysis, Substance Field and SLP are extremely helpful on leading out the dissipation solutions. Six proposals which are very potential are provided in this research, and after the engineering evaluation and application, one of them has been adopted successfully.
3) The process of ARIZ provides a practical method on solving the engineering problems. With the application of ARIZ, it is very effective to solve the structure issues during the product developing process.

References
[1] Abdulmunaem Elarusi, Alaa Attar and HoSung Lee 2017 Journal of Electronic Materials 46 (4)
[2] L E Alkire and W H Carter 1992 U.S. Patent 1 pp. 439-681
[3] L H Johnson 1964 U.S. Patent no. US3127931
[4] C Malvicino, S Mola, A Zussino and J Wolowicz 2001 SAE Technical Paper
[5] D. F. Gallup and a. et. 2007 Thermally Conditioned Vehicle Seat Delphi Technologies, Inc, Troy, MI. US7238101
[6] Innovation Method Society 2012 The Administrative Center for China's Agenda 21. Innovative Method Tutorials Beijing: Higher Education Press (in Chinese)
[7] G S Altshuller 1996 And suddenly the inventor appeared Technical Innovation Center, INC., Worcester
[8] G S Altshuller 1999 The innovation algorithm, TRIZ, systematic innovation and technical creativity Technical Innovation Center, INC., Worcester
[9] Tan Runhua, Wang Qingyu, Yuan Caiyun and Duan Guolin 2001 Theory of Inventive Problem Solving: TRIZ-The Process, Tools and Development Trend of TRIZ Journal of Machine Design (in Chinese)
[10] Wei Zihui, Yan Huiqiang and Tan Runhua 2008 Research and Application of ARIZ based on TRIZ Journal of Machine Design (in Chinese)
[11] Tan Runhua 2000 The conceptual design of a fast clasping mechanism based on function means tree and TRIZ TRIZ Journal http://www.triz-journal.com
[12] Vladimir Petrov 2005 Logic of ARIZ TRIZ Journal https://triz-journal.com
[13] Boris Zlotin and Alla Zusman 2009 Producing TRIZ Solutions TRIZ Journal http://www.triz-journal.com
[14] Jamali K, Hashmi S 2010 Managing Projects through the Theory of Inventive Problem Solving (TRIZ) International Research Journal of Finance and Economic 44: 169-185
[15] Domb E 2011 How to Help TRIZ Beginners Succeed. [Online] Available: http://www.trizjournal.com/archives/1997/04/a/index.html, 1997; retrieved on 10, Feb. 2011