Sakarya University Journal of Science

ISSN : 2147-835X
Publisher : Sakarya University

Vol. 28, No. 6, 1296-1306, 2024
DOI: https://doi.org/10.16984/saufenbilder.1514093

Research Article

An Implementation of TRIZ in Innovative Product Development: An Oil Cap for Propeller Shaft

Onur Şen

Tirsan Kardan A.Ş., R&D Center, Manisa, Türkiye, o.sen@tirsankardan.com.tr
*Corresponding Author

ARTICLE INFO

Keywords:
TRIZ
Product design
Development
Innovative product
Propeller shaft

Article History:
Received: 10.07.2024
Accepted: 16.12.2024
Online Available: 22.12.2024

ABSTRACT

In today's competitive and rapidly developing market, the importance of innovative products is increasing. Innovative products are needed to maintain growth and competitiveness. For this purpose, companies study on innovative applications and try new methods in product development processes. In this context, this study focuses on integrating the TRIZ tool into the product development process and producing creative solutions to the problems encountered during the design and development phase. And the benefit of TRIZ is discussed by conducting a case study involving the development of an innovative product. In the case study, the development process of the oil cap, which is located on the propeller shaft used to transmit torque and rotation in motor vehicles and whose main function is to provide sealing between the external environment and the internal volume of the propeller shaft, is discussed. The reason why the oil cap was chosen as a case study was the difficulty encountered in the design process, as the oil cap was expected to both provide sealing and allow air flow in the area where it was positioned. TRIZ methodology was successfully implemented to development of the oil cap. As a result of the study, an innovative product was developed, and validated by implementing tests. Thus, TRIZ's contribution to innovative product development was objectively demonstrated with a case study in which a commercialized product was developed. Besides, a practical guide based on real study, which designers could apply in innovative product development, was presented by this study.

1. Introduction

The product development is a process that is multidisciplinary and implemented by systematic approaches. Product development (PD) involves subsequent processes supported by several tools such as in Figure 1. All tools have specific benefits and functions in PD process. For example, Ishikawa diagram, also known as the fishbone diagram, is utilized to identify the root causes in overcoming the problems while quality function deployment (QFD) is used to define customers' needs and use the needs in PD process by determining specification of the product and prior parameters.

Most PD models start from the idea generation stage, eliminate the ideas, continue with the ideal idea, and end with a final product (part or service) or process [1]. Analyzing and prioritizing ideas and choosing the ideal one, as well as generating the idea, confront the designer as a critical and challenging step [2].

Majority of manufacturing companies are in a search of developing competitive products with all aspects such as efficiency and cost. The most effective way to reach competitive products is to create innovative products. That's why innovative PD is so vital, and it plays a significant role in developing competitive products by considering customer needs, in many

Cite as: O. Şen (2024). An Implementation of TRIZ in Innovative Product Development: An Oil Cap for Propeller Shaft, *Sakarya University Journal of Science*, 28(6), 1296-1306. https://doi.org/10.16984/saufenbilder.1514093

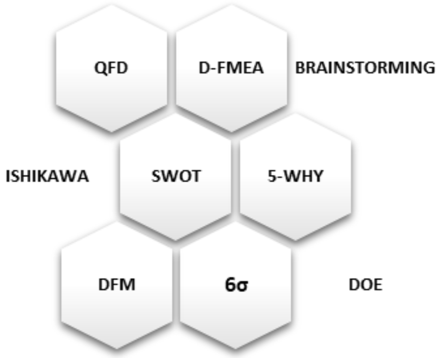

Figure 1. The basic tools for PD process

sectors. The key reasons, which show why innovation in PD is important, are given in Figure 2.

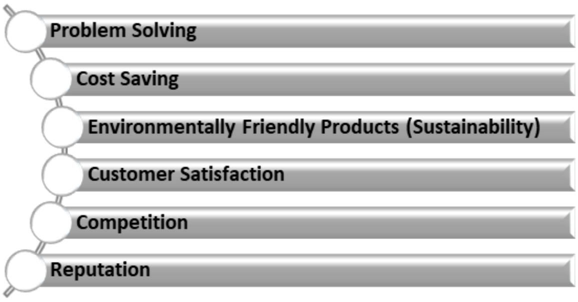

Figure 2. The reasons for why innovative product development is needed

Development of an innovative product is achieved by creating a product with novel features that offer new solutions compared to the state of the art. The biggest constraint here are the existing products and solutions offered in the industry or similar industries. To overcome this limitation, there is a need to use a method or approach beyond the basic PD tools mentioned in Figure 2. At this point, one of the most effective tools that can be used is TRIZ. TRIZ, an acronym of “Theoria Resheneyva Isobretatelskehuh Zadach” in Russian, which is translated as “Theory of Inventive Problem Solving”, was presented by Altshuller, who is Russian engineer and inventor, in 1940s [3, 4]. The unique feature of TRIZ compared to other methods is that it offers solution suggestions for a worsening feature caused by an improved feature in PD process [5].

TRIZ holds a significant importance in product design due to its systematic approach to innovation and problem-solving. By utilizing principles which have been obtained from the numerous analyses of patents and inventive solutions, TRIZ provides a unique methodology for defining and overcoming design challenges. It offers a toolbox of inventive principles, contradiction resolution methods, and ideation techniques that empower designers to break through conventional thinking barriers and arrive at creative solutions. By integrating TRIZ into the PD process, designers can ease innovation, minimize trial and error, and ultimately enhance the quality and efficiency in their designs.

TRIZ methodology involves many tools, which can be selected depending to the type of problem, such as the substance field analysis, the contradiction matrix, the 39 parameters, the 40 principles of innovation, the 76 standard solutions, etc. [6]. Figure 3 shows some TRIZ tools in terms of their usage degree collected with a survey by [7]. According to the survey results, Contradiction Matrix, which is relatively easy to implement, is in the middle ranks, while ARIZ has the lowest usage. Here, the Contradiction Matrix is used to solve fundamental problems that arise as technical contradictions, while ARIZ represents a step-by-step algorithm for solving specifically designed and defined engineering problems [8, 9].

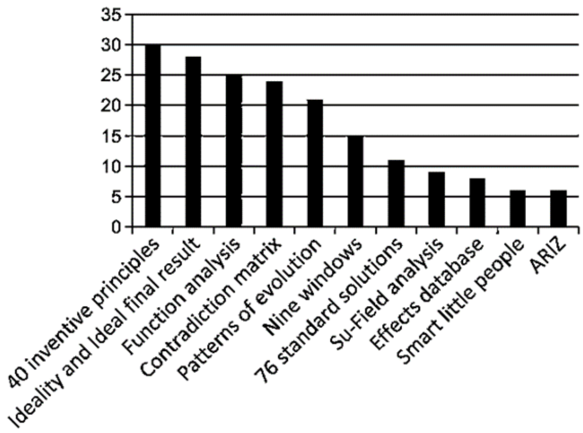

Figure 3. The usage degree of TRIZ tools [7]

When the studies in literature were examined, it was seen that TRIZ was mentioned as making a significant contribution to creating innovative products. Besides, it has been observed that most of the studies do not go beyond the level of theoretical knowledge in terms of content. In a study which was one step ahead of the others, L. S. Chen, S. H. Chen [6] conducted an application on smartphones by using Su field analysis and revealed that it was not easy to find a solution among many standard solutions as a disadvantage.

C. L. Yang, R. H. Huang, W. L. Wei [10] applied the TRIZ methodology in the new PD process in their studies. However, the study does not serve as a guide, and also the benefit of TRIZ is not clearly seen.

Abramov [11] introduced TRIZ-assisted stage-gate process in which he integrated TRIZ tools into stage-gate process, which was used to develop new product, from idea to product. It was reported that this approach accelerated new PD and reduced the costs.

In this study, the adaptation and utility of TRIZ were discussed by carrying out a case study involving the development of an innovative product. The study focused on generating creative solutions against the problems, which were encountered during design and development phase, by integrating the TRIZ tool into the PD process. And the study ultimately demonstrated the utility of TRIZ in a real design work, where the product was eventually commercialized, by creating a competitive and innovative product, unlike the studies in literature.

Another important aspect of the study was that the innovative product developed through TRIZ was subjected to a verification process. And so, the efficiency of TRIZ on the innovative PD was demonstrated more objectively. Moreover, Kotler and Keller [12] state that the failure rate for new products is half that, while Castellion and Markham [13] point out that this rate is around 80%. And considering these all situations, it becomes even more meaningful to include the product validation process in the study to observe the impact of TRIZ.

2. General Methods

The oil cap developed by means of TRIZ is located on the yoke shaft, which is one of the components composing propeller shaft, as given in Figure 4. When having a look at the current oil cap, it's seen that it consists of a plug and a body. As shown in the Figure 4, while there are holes on the body for air circulation, the plug is located on the body to cover the holes.

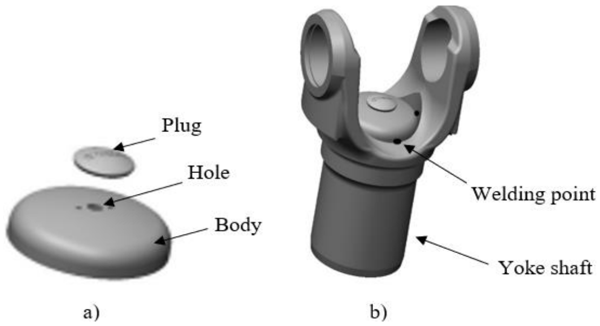

Figure 4. Current oil cap and its usage: a) exploded view of current oil cap, b) high pressure washing resistance

The main function of the oil cap is to provide sealing between the external environment and the internal volume of the propeller shaft. The difficulty in the improvement of the oil cap is that bidirectional air flow is desired between the external environment and the internal volume of the propeller shaft, while the entry of foreign matter from the outside is not desired. To overcome this difficulty, the TRIZ method was implemented in the PD process.

In overview, the study was carried out in six phases as illustrated in Figure 5. The first phase is called "problem identification" where the problem causing the need for design development is defined. The next phase is "idea generation", where TRIZ begins to be integrated. While Phase-3 involves choosing among the alternative ideas generated through TRIZ tool, Phase-4 is a step where the selected ideas are applied on the design. The last two phases are Phase-5 in which prototypes, a physical sample of the design, are presented, and Phase-6, in which the prototypes are tested and validated.

Phase-2 and Phase-4 are the key points, as the TRIZ methodology has been implemented in the PD process by utilizing TRIZ tools in these phases. In Phase-2, contradiction matrix, one of the TRIZ tools, was utilized, because it is easily applicable and gives results in a short time.

2.1.Problem identification

To solve a problem permanently, it is highly vital to describe the problem well. In this context, this

Figure 5. The six phases of TRIZ integrated product development approach based on problem solving

is the first step where the challenges and issues are defined and revealed. It provides the well understanding of the main factors under a specific problem, such as impacts, importance, and constraints. That's why, problem identification is crucial for the processes which require problem-solving in various fields such as engineering, science, and business. There are several methods that can be used for this purpose, such as Ishikawa, the 5 Whys, Fault-Tree Analysis (FTA), Failure Mode & Effects Analysis (FMEA).

In this phase, first, the features that were desired to be improved, were called as "desired feature", clearly identified and given in the Table 1. Subsequently, functional losses in other features due to the improvement of the desired features were called as problems and given in the Table 1 as well. Here, the relationship between the desired feature and correspondingly the worsening feature is defined as a contradiction. As the number of contradictions in the design increases, the difficulty level of the design increases.

Table 1. Desired features and problems in design of the oil cap

Desired features	Identified problems (against the desired feature)
bidirectional air flow	weakening of sealing quality (no or low filtering impurities)
filtering impurities	blocking bidirectional air flow
advanced sealing	blocking bidirectional air flow
ease of assembly	weakening of sealing quality

2.2. Idea generation

This phase is the key, and it reveals the difference from traditional PD processes. Because, in this phase, TRIZ tools were used to generate possible solutions to overcome the problems defined in Phase-1. For this purpose, one of the TRIZ tools, the contradiction matrix, was used. Features, which had contradictions with each other were selected on the contradiction matrix, and inventive principles, which are potential solutions to the problems, were identified. This flow was shortly summarized through Figure 6.

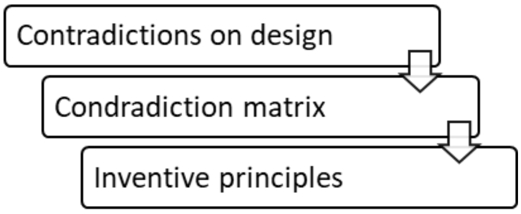

Figure 6. The function of contradiction matrix

The contradictions matrix, which involves 39 rows and columns, is partially given as Table 2 to describe its structure and usage. The horizontal axis represents worsening feature considered as problem, while the vertical axis represents the improving feature. And the box, where the intersection of the selected worsening and improving features is, presents the potential solution suggestions called as inventive principles. Inventive principles are represented with numbers 1 to 40, and every number represents a principle as given in Table 3.

The features on the contradiction matrix are just generalized terms to cover different application areas and sectors. Therefore, specific to the problem we have, we need to determine the features corresponding to the feature we want to add to our product (improving feature) and the feature that will worsen (worsening features) depending on the improved features. That's why corresponding terms on the matrix was determined for 4 desired features and 4 identified problems of the oil cap and given in Table 4.

Finally, the inventive principles for the oil cap were determined by considering the improving and worsening features. To make it easier to understand, contradiction matrix was customized as given in Table 5 for the oil cap. The matrix gave totally 11 inventive principles.

Table 2. Contradiction matrix partially [14]

Improving Feature ↓ / Worsening Feature →		1 Weight of moving object	2 Weight of stationary object	3 Length of moving object	4 Length of stationary object	5 Area of moving object	6 Area of stationary object	7 Volume of moving object	8 Volume of stationary object	9 Speed	10 Force (Intensity)	11 Stress or pressure	12 Shape	13 Stability of t c	14
1	Weight of moving object	+		15, 8, 29,34		29, 17, 38, 34		29, 2, 40, 28		2, 8, 15, 38	8, 10, 18, 37	10, 36, 37, 40	10, 14, 35, 40	1, 35, 19, 39	28, 27, 18, 40
2	Weight of stationary object		+		10, 1, 29, 35		35, 30, 13, 2		5, 35, 14, 2		8, 10, 19, 35	13, 29, 10, 18	13, 10, 29, 14	26, 39, 1, 40	28, 2, 10, 27
3	Length of moving object	8, 15, 29, 34		+		15, 17, 4		7, 17, 4, 35		13, 4, 8	17, 10, 4	1, 8, 35	1, 8, 10, 29	1, 8, 15, 34	8, 35, 29, 34
4	Length of stationary object		35, 28, 40, 29		+		17, 7, 10, 40		35, 8, 2,14		28, 10	1, 14, 35	13, 14, 15, 7	39, 37, 35	15, 14, 28, 26
5	Area of moving object	2, 17, 29, 4		14, 15, 18, 4		+		7, 14, 17, 4		29, 30, 4, 34	19, 30, 35, 2	10, 15, 36, 28	5, 34, 29, 4	11, 2, 13, 39	3, 15, 40, 14
6	Area of stationary object		30, 2, 14, 18		26, 7, 9, 39		+				1, 18, 35, 36	10, 15, 36, 37		2, 38	40
7	Volume of moving object	2, 26, 29, 40		1, 7, 4, 35		1, 7, 4, 17		+		29, 4, 38, 34	15, 35, 36, 37	6, 35, 36, 37	1, 15, 29, 4	28, 10, 1, 39	9, 14, 15, 7
8	Volume of stationary object		35, 10, 19, 14	19, 14	35, 8, 2, 14				+		2, 18, 37	24, 35	7, 2, 35	34, 28, 35, 40	9, 14, 17, 15
9	Speed	2, 28, 13, 38		13, 14, 8		29, 30, 34		7, 29, 34		+	13, 28, 15, 19	6, 18, 38, 40	35, 15, 18, 34	28, 33, 1, 18	8, 3, 26, 14
10	Force (Intensity)	8, 1, 37, 18	18, 13, 1, 28	17, 19, 9, 36	28, 10	19, 10, 15	1, 18, 36, 37	15, 9, 12, 37	2, 36, 18, 37	13, 28, 15, 12	+	18, 21, 11	10, 35, 40, 34	35, 10, 21	35, 10, 14, 27

Table 3. 40 inventive principles: Numbers and definitions [15]

1	Segmentation	11	Beforehand Cushioning	21	Skipping	31	Porous Materials
2	Taking out	12	Equipotentiality	22	Blessing in Disguise	32	Color Changes
3	Local quality	13	The Other Way Round	23	Feedback	33	Homogeneity
4	Asymmetry	14	Spheroidality - Curvature	24	Intermediary	34	Discarding and Recovering
5	Merging	15	Dynamics	25	Self-service	35	Parameter Changes
6	Universality	16	Partial or Excessive Actions	26	Copying	36	Phase Transitions
7	Nested Doll	17	Another Dimension	27	Cheap Short-Living Objects	37	Thermal Expansion
8	Anti-Weight	18	Mechanical vibration	28	Mechanics Substitution	38	Strong Oxidants
9	Preliminary Anti-Action	19	Periodic Action	29	Pneumatics and Hydraulics	39	Inert Atmosphere
10	Preliminary Action	20	Continuity of Useful Action	30	Flexible Shells and Thin Films	40	Composite Material

Table 4. Improving and worsening features for the oil cap

Desired features	Improving feature	Identified problems	Worsening feature
bidirectional air flow	23- Loss of substance	weakening of sealing quality (no or low filtering impurities)	30- Quantity of substance/ the matter
filtering impurities	26- Quantity of substance/ the matter	blocking bidirectional air flow	33- Ease of operation
advanced sealing	30- Object-affected harmful factors	blocking bidirectional air flow	33- Ease of operation
ease of assembly	34- Ease of repair	weakening of sealing quality	26- Quantity of substance/ the matter

Table 5. Customized contradiction matrix for the oil cap

Improving Feature ↓ / Worsening Feature →		1 Weight of moving object	26 Quantity of substance	30 Object-affected harmful factors	33 Ease of operation	35 Adaptability or versatility
1	Weight of moving object		3, 26, 18, 31	22, 21, 18, 27	35, 3, 2, 24	35, 3, 24, 37
23	Loss of substance	35, 6, 23, 40	6, 3, 10, 24	33, 22, 30, 40	32, 28, 2, 24	28, 35, 10, 23
26	Quantity of substance/the matter	35, 6, 18, 31	+	35, 33, 29, 31	35, 29, 25, 10	13, 29, 3, 27
30	Object-affected harmful factors	22, 21, 27, 39	35, 33, 29, 31		2, 25, 28, 39	22, 35, 13, 24
34	Ease of repair	2, 27 35, 11	2, 28, 10, 25	35, 10, 2, 16	1, 12, 26, 15	1, 32, 10
39	Productivity	35, 26, 24, 37	35, 38	22, 35, 13, 24	1, 28, 7, 10	

2.3. Making decision

In this phase, the inventive principles, which were revealed through customized contradiction matrix (Table 5), were evaluated. In this context;

a) The inventive principles were technically reviewed for checking their applicability to the part design,

b) It was evaluated how the principles identified as applicable could be applied to part design.

As a result of the evaluation performed for 11 inventive principles, 7 principles were found to be applicable on the part design. The evaluations for each inventive principles were shared in Table 6. The explanation of each principle was given under the heading "conception" while the applicability of the principles was evaluated under the heading "applicable".

Table 6. Evaluation of inventive principles in terms of part design.

Inventive principles	Conception	Applicable
2- Taking out	Separation of the offending part of the object or just good leaving the part in the object.	YES
10- Preliminary Action	Perform the operation that will be required on the object in the future in advance.	YES

Table 6. Evaluation of inventive principles in terms of part design (Continue)

Inventive principles	Conception	Applicable
22- Blessing in Disguise	Adding the main harmful action to another harmful action to use in solving the problem.	YES
25- Self-service	Create an object which serves itself by performing useful auxiliary functions.	YES
28- Mechanics Substitution	The use of magnetic, electronic and electromagnetic waves to interact with objects.	NO
29- Pneumatics and Hydraulics	Using liquid and gas particles in objects instead of solid particles.	NO
30- Flexible membranes or thin film	The use of flexible shells and thin strips as a substitute for three-dimensional structures.	YES
33- Homogenity	Ensure that objects are in relationship with other objects made of the same material.	NO
35- Parameter Changes	Changing the density, elasticity, temperature and consistency of objects.	YES
39- Inert Atmosphere	Replacing the normal atmosphere with an inertial atmosphere.	NO
40- Composite materials	Use of composite materials instead of single types of materials.	YES

2.4.Applying TRIZ principles

After evaluating the inventive principles for application on the part design, in this phase an evaluation was performed more precisely in terms of how to apply inventive principles on the part design. The principles were evaluated both on their own and in combination with other principles to determine the best practice. The specific application determined for the part design were summarized in Table 7.

Table 7. Application methods of inventive principles into the part design.

Inventive principles	Applications on the part design
2- Taking out	Currently consisting of two components, the oil cap was separated into 4 subcomponents having one or more of the desired features.
10- Preliminary Action	Air circulation of the oil cap only occurs during axial movement of the propeller shaft. In this context, air holes were added to some of the oil cap components.
22- Blessing in Disguise	While having an air hole is harmful in terms of sealing, the absence of an air hole act is also a harmful factor because it prevents air circulation. By using these two harmful factors together, a positive effect was created. For this application, multiple cuts on the diaphragm body were made. The cuts are opened only with air pressure, and after air circulation is completed, they close again to protect the seal.
25- Self-service	The oil cap was composed of subcomponents, each of which individually performs a different function.
30- Flexible membranes or thin film	The middle part of the body is a diaphragm structure made of rubber material with a very low wall thickness. For air circulation, homogeneously distributed air cuts were created on the diaphragm structure, and a sponge, as a filter element, was used to benefit from its pores.
35- Parameter Changes	The middle part of the body has been transformed into a flexible structure in the form of a diaphragm.
40- Composite materials	The material of each sub-component that makes up the oil cap is selected differently, considering the component functions (sheet metal reinforced body, polyether filter element, sheet metal cover, etc.)

Finally, the new oil cap was developed by conducting the applications on the part design, by considering the Table 7. As a result of innovative PD studies carried out with TRIZ implementation, the oil cap, which had currently 2 subcomponents, was developed as a product consisting of 4 parts.

Each subcomponent was created by implementing the applications specified in Table 7, including the inventive principles defined as applicable in Table 6. The subcomponents composing the new oil cap are given in Figure 7-a. The cover is obtained by forming sheet metal and contains multiple air holes on it. The main purpose of the cover is to protect the whole structure of the oil cap from external impacts. It allows air circulation with the air holes on it as well. The body has a metal-reinforced rubber structure.

There is a diaphragm structure made of rubber in the middle section of the body. There are cuts on the diaphragm structure that allow air circulation, opening with compressed air and closing when the pressure is off. The air filter is a kind of sponge containing a certain number of pores. Its purpose is to filter impurities coming from outside. It is placed in a slot located at the bottom of the body. The filter holder made of rigid material is used to fix the air filter inside the body. Numerous air holes are created on the filter holder to allow air circulation.

The working principle of the oil cap was illustrated in Figure 7-b. The arrows indicate the path which air follows during circulation. Since air circulation is bidirectional, the direction of the arrows should also be considered for the opposite direction as shown in the picture (only one direction is given as an example in the picture). The location where the new developed oil cap is used is shown in the Figure 8. The oil cap is mounted on the yoke shaft with interference fit, using the outer diameter of the rubber body, and is fixed using a circlip.

2.5.Prototyping

The prototyping phase in the PD process is the step where designs are transformed into tangible products. In this phase, prototypes are created to verify the design physically, test functionality, identify potential problems and ensure the final

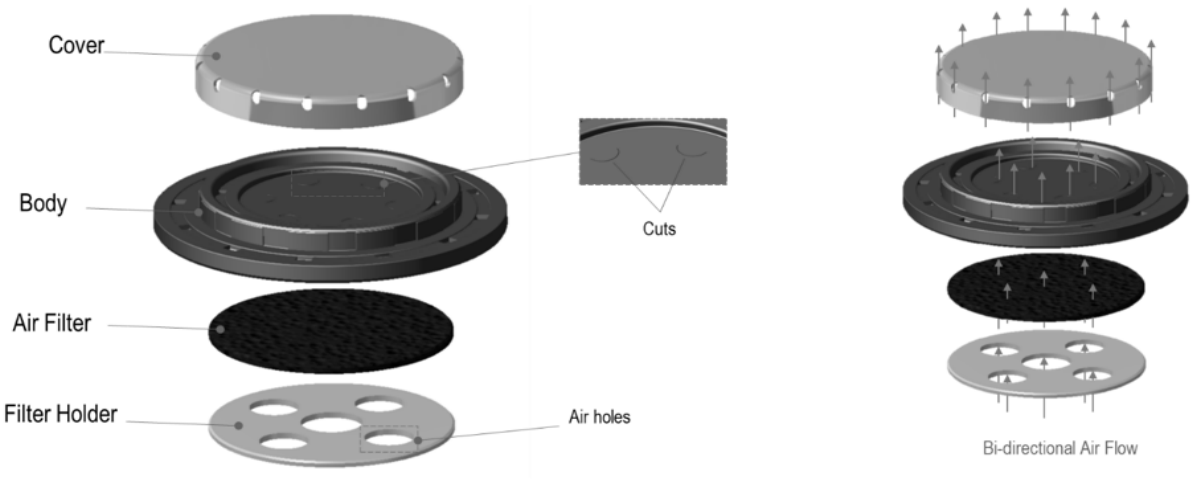

Figure 7. The new developed oil cap: a) subcomponents, b) air flow.

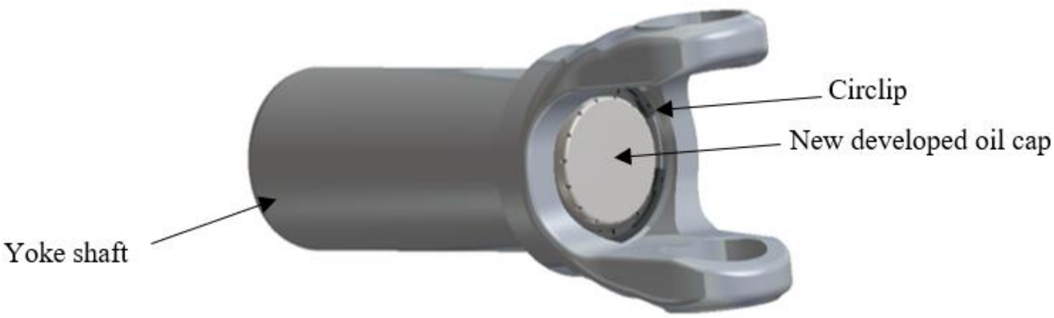

Figure 8. The new developed oil cap and its location.

product meets user needs and quality standards before serial production. In this context, prototypes were produced under conditions close to mass production, rather than rapid prototyping, in order not to affect the functionality of the product.

Each subcomponent composing the oil cap was produced with separate production methods and appropriate materials, and then assembled with each other to obtain the oil cap. A prototype which was produced in accordance with the technical drawing, was given Figure 9.

Figure 9. A prototype of the new developed oil cap

2.6. Validation

The validation phase is the stage in the PD process where the prototypes are evaluated to ensure they meets the required standards and requirements. During this phase, the product is subjected to functional and performance test to verify its performance and reliability. The main aim of product validation is to confirm that the product fulfils the desired purpose, meet user needs and expectations, and complies with regulation and standards. As a result of validation phase, successful results ensures that the new developed product is ready for market launch.

The validation for the oil cap was completed by performing two separated tests on the prototypes as in Figure 10, which were mud test and high pressure washing resistance tests. Mud test, which is performed on a special testing machine, involves spraying mud to reflect the tough operating conditions of the motor vehicle onto the part running on certain speeds and times.

Another test, high pressure washing resistance, involves spraying water onto the part at a high pressure for a certain period of time. The success criterion for both tests is the absence of water and mud penetration through the oil cap.

a) b)

Figure 10. Design validation test on prototypes, a) mud test, b) high pressure washing resistance test

3. Results and Discussion

In the innovative product development study in which TRIZ was adapted, the innovative solutions proposed by TRIZ were examined and how they could be adapted to the design was evaluated. It was decided that 7 of the 11 inventive principles would be used in the design. A product has been designed by using these principles. Then, prototypes were produced, and the produced prototypes were subjected to two separate tests, mud test and high pressure washing resistance tests, for design validation. No contamination was found in either test performed. According to this feedback from the tests, PD process have been completed successfully. The new developed product has been commercialized thanks to the innovative features added to the product by means of TRIZ.

The six-phase TRIZ integrated product development approach given in the Figure 2 has proven its effectiveness with the validation tests beside the commercialized product.

4. Conclusion

Considering that companies have easier access to the latest technology, it becomes clear that innovative products are vital for companies to survive, regardless of their field of activity. Based on this, an innovative product development study was presented in which the TRIZ methodology was implemented, which was successfully completed for an oil cap used in the propeller shaft. Important outputs of the study are as follows:

1. A new product, beyond the existing product with its features, has been developed, commercialized. This also indicate that TRIZ supports creation of innovative products. When considering that there was little theoretical knowledge that clearly articulates the benefits and uses of idea generation techniques such as study by J. J. Shah, N. V. Hernandez [16]**,** a practical guide based on real studies, which designers could easily apply in innovative product development, was presented by this study.

2. It was seen that TRIZ assisted designers to generate innovative solutions by means of the contradiction matrix.

3. Unlike many studies in literature, in our study, after the PD process carried out with the implementation of TRIZ, physical prototypes were manufactured and tested. And so, the effectiveness of the method in the innovative product development was objectively demonstrated.

4. For further study, TRIZ tools can be compared to each other after implementation in a case study.

Article Information Form

Acknowledgments
This study was carried out with the facilities and support of Tirsan Kardan A.Ş - R&D Center.

Funding
The author has no received any financial support for the research, authorship or publication of this study.

Authors' Contribution
The author contributed to all of the study.

The Declaration of Conflict of Interest/ Common Interest
No conflict of interest or common interest has been declared by the authors.

The Declaration of Ethics Committee Approval
This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

Copyright Statement

References

[1] E. Baraldi, P. Kaminski, "Reference Model for the Implementation of New Assembly Processes in the Automotive Sector", Cogent Engineering, vol. 5, no. 1, 2018.

[2] J. Van den Ende, L. Frederiksen, A. Prencipe, "The Front End of Innovation: Organizing Search for Ideas", Journal of Product Innovation Management, vol. 32, pp. 482–487, 2015.

[3] G. Altshuller, "Creativity as Exact Science: The Theory of the Solution of Inventive Problems", New York, Gordon and Breach Science Publisher,1988.

[4] D. Akay, A. Demiray, M. Kurt, "Collaborative Tool for Solving Human Factors Problems in the Manufacturing Environment: The Theory of Inventive Problem Solving Technique (TRIZ) method", International Journal of Production Research, vol. 46, no.11, pp. 2913–2925, 2008.

[5] G. Altshuller, "And Suddenly the Inventor Appeared: TRIZ, the Theory of Inventive Problem Solving", Worcester, Technical Innovation Center Inc., 1996.

[6] L. S. Chen, S. H. Chen, "Using TRIZ Techniques to New Product Function Development of Smart Phones", Industrial Engineering & Management Systems, vol.10, no. 3, pp. 179-184, 2011.

[7] I. M. Ilevbare, D. Probert, R. Phaal, "A review of TRIZ, and its Benefits and Challenges in Practice", Technovation, vol. 33, pp. 30-37, 2013.

[8] G. Altshuller, "The Innovation Algorithm: TRIZ, Systematic Innovation and Technical Creativity", Worcester, Technical Innovation Center Inc., 2000.

[9] J. Marconi, "ARIZ: The Algorithm for Inventive Problem Solving- An Americanized Learning Framework", The TRIZ Journal, vol. 4, 1998.

[10] C. L. Yang, R. H. Huang, W. L. Wei, "Applied Modified TRIZ for New Product Development Project", Web Journal of Chinese Management Review, vol. 16, no. 4, 2013.

[11] O. Y. Abramov, "TRIZ-assisted Stage-Gate Process for Developing New Products", Journal of Finance and Economics, vol. 2, no. 5, pp. 178-184, 2014.

[12] P. Kotler, K. L. Keller, "Marketing Management (15 ed.)", N.J., Prentice Hall, 2012.

[13] G. Castellion, S. K. Markham, "Perspective: New Product Failure Rates: Influence of Argumentum ad Populum and Self-Interest", Journal of Product Innovation Management, vol. 30, no. 5, pp. 976–979, 2012.

[14] G. Altshuller, L. Shulyak, S. Rodman, "40 Principles: TRIZ Keys to Technical Innovation (Triztools)", Worcester, Technical Innovation Center Inc., 2022.

[15] K. Tate, E. Domb, "40 Inventive Principles with Examples", The TRIZ Journal, vol. 7, 1997.

[16] J. J. Shah, N. V. Hernandez, “Evaluation of Idea Generation Methods for Conceptual Design: Effectiveness Metrics and Design of Experiments”, Journal of Mechanical Design, pp. 377-384, 2000.