The identification of contradictions in Cliff: an automatized zipper prototype using the TRIZ method with Root Conflict Analysis (RCA+)

Document status and date:
Published: 14/09/2017

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.
Link to publication

Download date: 27. Jan. 2022

TRIZ*fest* 2017

September 14-16, 2017. Krakow, Poland

THE IDENTIFICATION OF CONTRADICTIONS IN CLIFF: AN AUTOMATIZED ZIPPER PROTOTYPE USING THE TRIZ METHOD WITH ROOT CONFLICT ANALYSIS (RCA+)

Mohamad Zairi Baharom[a,b], Frank Delbressine[a], Marina Toeters[c] and Loe Feijs[a]

[a]*Designed Intelligence Group, Department of Industrial Design, P.O. Box 513, 5600MB Eindhoven, Netherlands*

[b]*Faculty of Mechanical Engineering, Universiti Malaysia Pahang, 26600 UMP Pekan, Pahang, Malaysia*

[c]*by-wire.net, Heemstedelaan 5, 3523 KE Utrecht, Netherlands*

Abstract

This paper presents preliminary results of our efforts performing the TRIZ method with Root Conflict Analysis (RCA+) to solve a particular issue related to the Cliff prototype. The Cliff is an automatized zipper project which designed to overcome the struggle faced by elderly, people with physical impairment, and ladies who have difficulties zipping the back-zipper dress. Cliff got stuck during its movement while moving on the jacket to automatically complete the zipping or unzipping processes. Engineering or design problems need to be analyzed systematically and scientifically to find the useful solution. Therefore, the TRIZ with the use of RCA+ method has been chosen to identify potential solution to solve the automatized zipper prototype problem. This method helps to graphically map all the causes and effects contributed to the traction problem of this automatized zipper which is summarized by the seven contradictions identified. The technical contradictions then are resolved using the TRIZ method based on the utilization of the Altshuller matrix. From the Altshuller matrix, 26 inventive principles are triggered as the potential solutions. After screening all the 26 principles, only 12 principles are suitable with the problems faced by the automatized zipper. The most promising inventive principles triggered are the segmentation, taking out, asymmetry, spheroidality-curvature, and replace the mechanical system. However, potential solutions such as hydraulics and thermal expansion are in conflict with strict safety and product semantics. From the analysis, we found that the TRIZ method with RCA+ is very useful to systematically approach the design problem of the automatized zipper. Further brainstorming will be conducted to improve the current prototype of the Cliff.

Keywords: TRIZ, RCA+, automatized zipper, miniaturization.

1. Introduction

A systematic and scientific approach are essential in analyzing any kind of engineering or design problems. It is important in order to trigger useful potential solution for the problems. The TRIZ method is one of the well-known problem solving technique [1-4]. TRIZ is a Russian acronym which can be expressed in English as 'Theory for the Solution of Inventive Problems'. This method consists of a theory, operating procedures and a range of tools created by Genrich Saulovich Altshuller. Since 1946, the objective of TRIZ is to capture the creative process in

technical and technological contexts, classifying it and making it repeatable and applicable. TRIZ is also described as a proper theory of invention [1]. The systematic working methodology of TRIZ is based on a series of subsequent stages and operating tools to perform the analysis, the structuring of models, and ended with the solution of problems. Up to today, the TRIZ methodology has proved to be the most efficient to solve inventive problems and one which may be easily learned and used without any need for an extraordinary individual creativity [1-3].

The other problem solving techniques are the Six Sigma, the Taguchi method, Quality Function Deployment (QFD), brainstorming, and synectics and the use of analogies. Comparing these methods to TRIZ will bring us to look in overall suitability of the particular method towards our design problem. The TRIZ's extensive database is the key of the successful creative design process which is offered by TRIZ [4,5]. The database allows us to take advantage of knowledge from thousands of the world's patents. Besides that, TRIZ also assist in making the prediction about the future changes which can be made on the product or the features that a new product should have [8]. The variety of analysis tools available in TRIZ for different purposes makes it one of the favourites toolkits used by the engineers and designers to understand and solve their problems. The TRIZ tools will navigate us to find all the feasible ideas or ways to improve or solve the problems [1]. Besides that, TRIZ also helps us to stimulate new ideas, creative thought, and innovative solutions. Therefore, TRIZ with the use of Root Conflict Analysis (RCA+) has been chosen to deal with one of the problems faced by the Cliff, an automatized zipper. The RCA+ is one of the TRIZ's tools which is used to investigate the underlying causes.

The Cliff is a project intended to develop an automatized zipper in response to the struggle by elderly, people with physical disability and ladies who have problems zipping the back-zipper dress [9,10]. Showing in Fig. **6**(a) and Fig. **6**(b) are the Cliff's prototype and the diagram of its traction mechanism, respectively. Cliff's used two gear sprocket wheels as traction mechanism on both sides of the tape to establish the uniform distribution of normal force acting towards the zipper tape. The problem is regarding the movement of the automatized zipper prototype during its operation. The Cliff's prototype stuck while moving on the jacket to automatically zipping or unzipping it.

(a) The Cliff's prototype

(b) The Cliff's traction mechanism
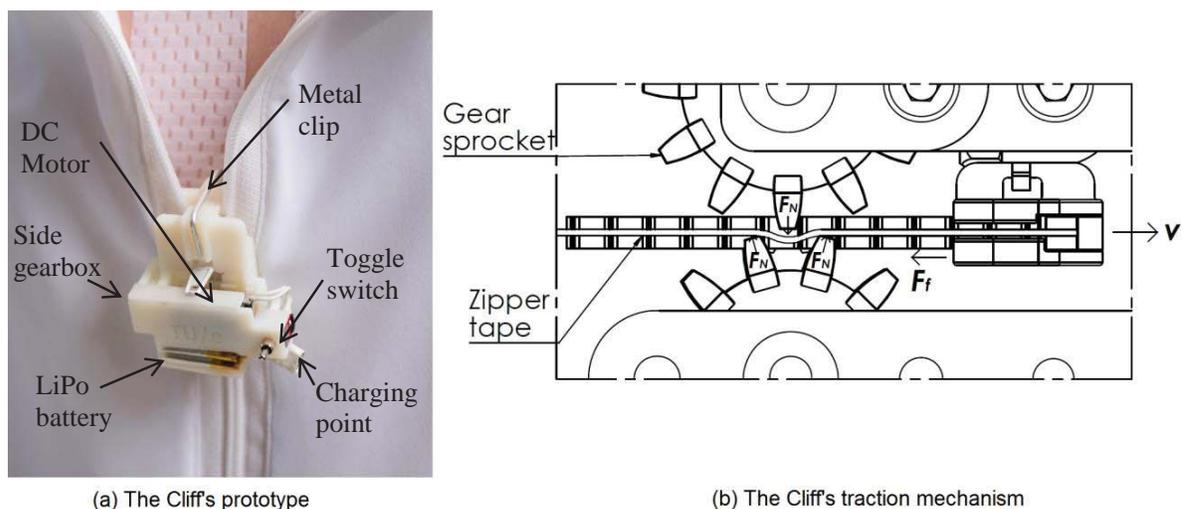
Fig. 6

2. Root Conflict Analysis (RCA+)

Root Conflict Analysis (RCA+) is one of the new addition to the TRIZ tools and technique family [11]. RCA+ can be used to investigate the underlying causes and their interdependencies for an observed effect which can be visualized in a graphical way. Several alternative known methods are Ishikawa diagram (Fishbone diagrams), Root Cause Analysis, Method of five "why's", and the Current Reality Trees in Theory of Constraints [12]. The common drawbacks of these mentioned methods is that they do help in finding the problems but the methods do not provide means to solve problems.

The RCA+ was developed based on three methodologies which are the cause-effects chains, the theory of constraints, and the TRIZ itself [11]. The modelling of the RCA+ is performed within the scope of three tasks; (1) to solve a particular problem related to an individual specific product, service or process, (2) to solve a broad problem related to a whole class of products, processes or services, and (3) to predict and eliminate possible failures within system and processes [11]. The principle of this method is to map all causal chains of causes and effects devoted to a problem, which is represented as a general negative effect. Then, RCA+ will identify the conflicts which can further be resolved using TRIZ. In order to construct the RCA+ diagrams, this method require our effort to keep asking *"what causes this effect to occur"*. By doing this, we may find all the reasons contibuting to the negative effect.

2.1. TRIZ Process with RCA+

Showing in Fig. 7 is the overall process flow of problem solving based on using the Root Conflict Analysis in TRIZ [11]. This technique used for defining and selecting the contradictions in the problem study. The contradiction is defined as "a situation when the same cause causes both positive and adverse effects" [1, 8]. For this study, only the RCA+ will be performed and not the Value-Conflict Mapping. The Value-Conflict Mapping is designed to help with extracting and linking technological, business and market contradictions which are not related to the technical problem of this study [13].

This study uses RCA+ to identify and select the contradictions, and then will be divided into two flows. The first flow is based on the application of basic TRIZ tools which comprises of the Altshuller Matrix and the 40 Inventive Principles. An engineering contradiction is a condition in which an attempt to improve one parameter of a system leads to the worsening (impairment) of another parameter [1]. It can be reflected in a positive and negative interaction between two or more components. By using the contradiction matrix, we can see which of the 40 inventive principles are relevant to our problem. The 40 Inventive principles is a basic generalized rule that is accepted as facts, works in the same way consistently and usually followed as a basis of reasoning or explanation of the invention. Altshuller screened 200,000 patents to find out what kind of contradictions were resolved by each invention and the way it was achieved. He synthesized down to 40,000 patents, and then he developed a set of the 40 inventive principles [14]. Finally, from the potential solutions given by the matrix, we need to use our brain to make it a useful one. It is then the task of problem solvers to make use of these TRIZ solutions triggered to find fruitful and detailed solutions to each of their problems. The second flow will take place if the problem is not solved using the application of Altshuller matrix. The process will be continued using the advanced TRIZ tools such as ARIZ (Algorithm of Inventive Problem Solving), Inventive Standards, Separation Principles, and so forth. The selection of flow also depends on the degree of TRIZ expertise of the problem solver [11].
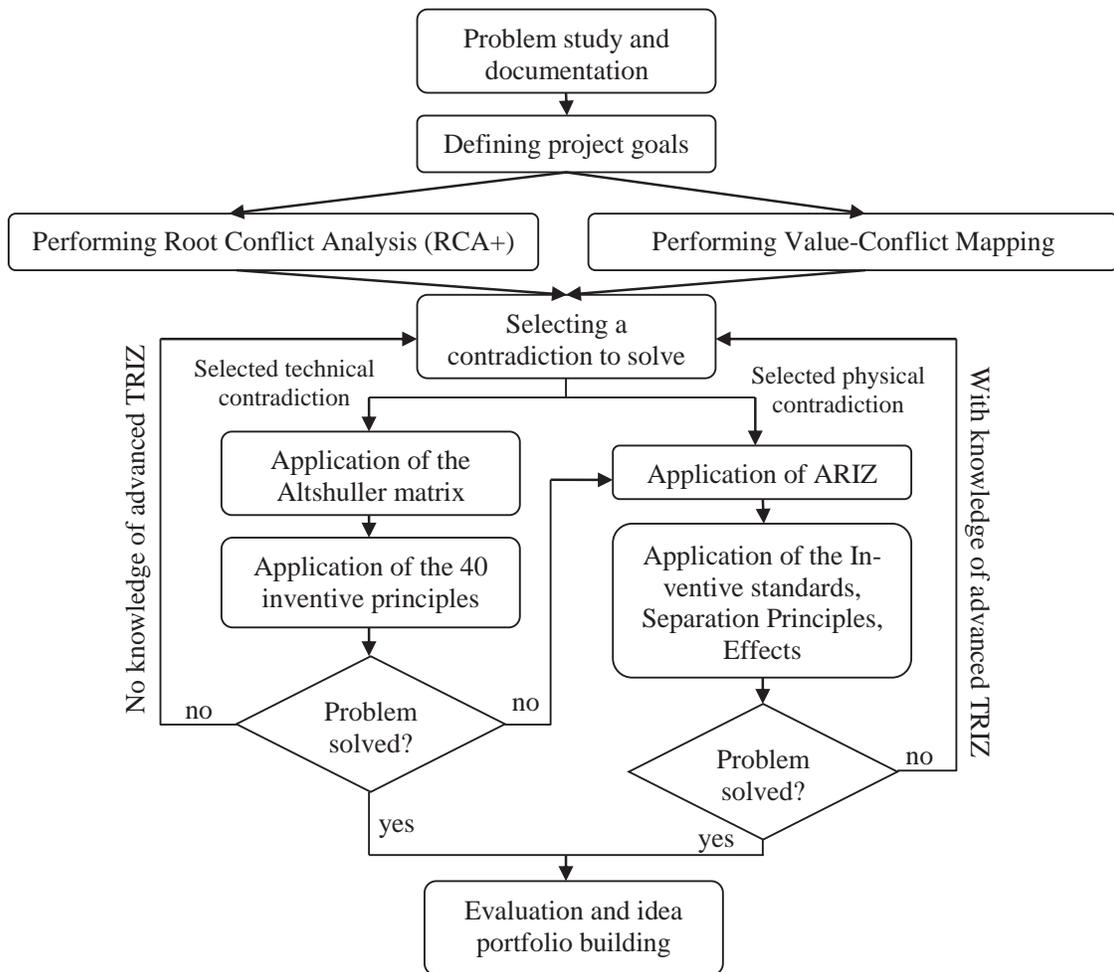
Fig. 7. The Overall TRIZ Process with RCA+ [11]

2.2. Modelling and building the RCA+ Diagram

Showing in Fig. 8 and Fig. 9 are the RCA+ diagram for the negative effect which is specified as "the Cliff did not move (stuck) on the fabrics". This diagram has been drawn in a top-down manner by keep asking "what causes this effect to occur?" during the problem mapping process. There are four types of causes/effects in an RCA+ diagram. The Negative (-) are the causes/effects which is entirely negative and we would like to eliminate it. The second one is the Positive (+) effect, which is there is no need to change. The Combined Negative and Positive (+/-) is the same cause results in both positive and adverse effects. Lastly, the Non-Changeable (--) is the cause contributes negatively but can not be eliminated, or modified since it is beyond our control within a given problem scope.

As can be seen from both Fig. 8 and Fig. 9, there are seven contradictions identified which will be discussed in the following section. The contradiction is defined as a situation when the same cause causes both positive and negative effects. The Non-changeable causes (NC) won't be analyzed further since it is beyond our control.
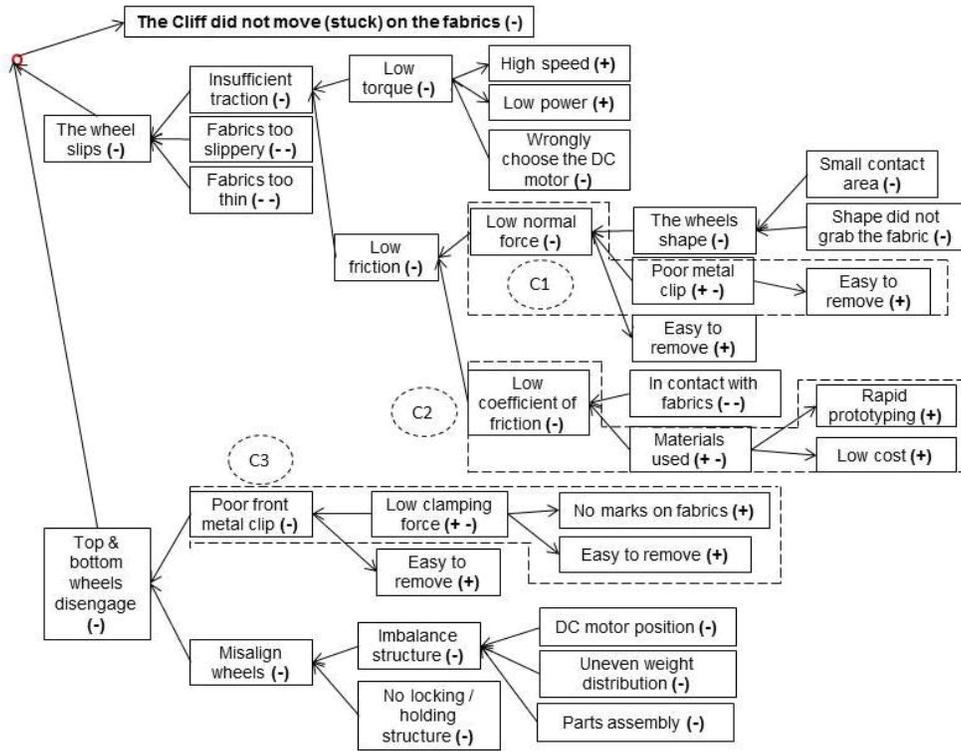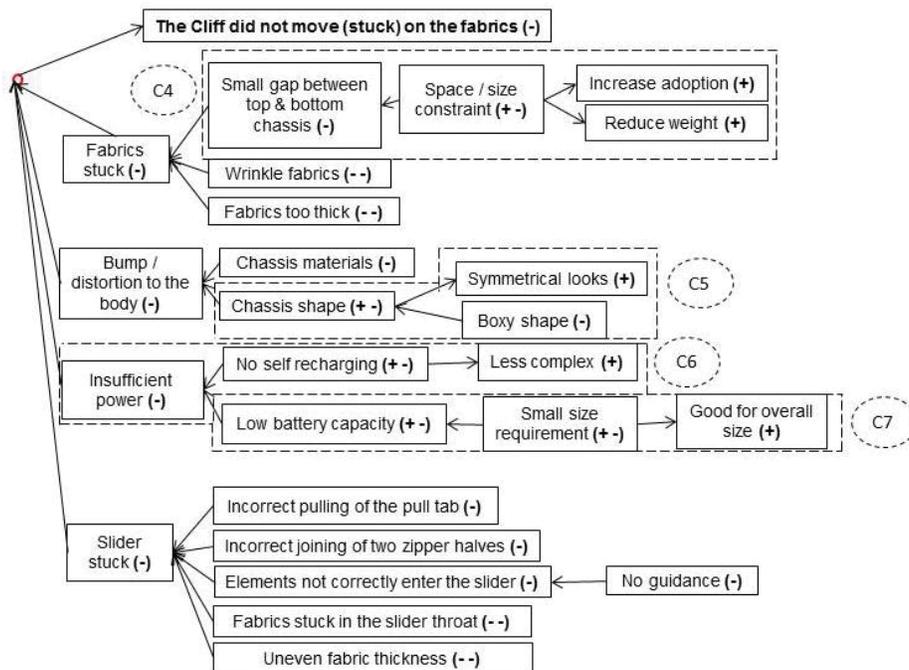
410

Fig. 8. RCA+ diagram (Part 1)

Fig. 9. RCA+ diagram (Part 2)

3. The Contradictions Discussion

3.1. Technical Contradictions and the Source of the Physical Contradiction

The Technical Contradiction defined as "*formed by a couple of negative effect vs. positive effect*" [11]. These two effects can be directly matched against positive and negative parameters in the contradiction matrix (Altshuller Matrix). Meanwhile, the source of physical contradiction is described as "*two opposite states of a cause which is a source of the physical contradiction. One state of the cause should provide a positive effect whereas its state should be opposite at the same time to avoid the appearance of a negative effect*" [11]. Such contradictions can be solved either with Principles for Physical Conflict Separation or ARIZ. Listed below are the technical contradictions identified:

C1: "*The metal clip should be strong to provide a sufficiently large normal force to avoid the wheels slips, and not too large force to make it easy to be removed*".

C2: "*The material used as the wheels need a high coefficient of friction to avoid the wheels slips, and not too costly & time-consuming to manufacture it*".

C3: "*The low clamping force is not right for the front clip, but it will make the device to be easily removed and leave no marks or damage the fabrics*".

C4: "*The space/size constraint could increase the adoption of this device and reduce the weight, but it could produce a small gap between the chassis and the fabrics which could cause the fabrics to stuck in between*".

C5: "*Poor design of the chassis shape could produce bump/distortion to the human body, and at the same time provide the symmetrical looks to the Cliff*".

C6: "*Without self-recharging function, it will reduce the system complexity, but might lead to insufficient power problem*".

C7: "*The small size requirement is perfect for the overall size, and at the same time smaller battery might result in low battery capacity and insufficient power problem*"

3.2. The negative causes

There are few negative causes without an underlying contradiction identified, which we will try to solve the problem by eliminating the cause. Firstly, the misalign wheels problem contains set of negative causes only. It is possible to solve it by eliminating the causes which are the imbalance structure and no locking/holding structure. Therefore, the parts assembly need to be improved to ensure weight distributed evenly on the structure. Secondly, the slider stuck problem involves few negative causes. The causes are incorrect pulling of the pull tab (caused by the stopper beneath of the bail), the incorrect joining of the two zipper halves, and the elements did not correctly enter the slider which is happened because of no guidance. Therefore, the next design iteration will consider to include the guider, to ensure the elements correctly enter the slider throat.

4. Contradiction Selection

Table 1

Summary of the Technical Contradictions for selection

	Cause	Positive Effect	Negative Effect	Part(s)	Property / Parameter	Time of Conflict
C1	Poor metal clip	Easy to remove	Low normal force	Front metal clip	Normal force, clamping effect	During the operation
C2	Material used (wheels)	Low cost, rapid prototyping	Low coefficient of friction	Rotating wheels	Coefficient of friction	During the operation
C3	Low clamping force	Easy to remove, no marks / damage to fabrics	Poor metal clip	Front metal clip	Clamping force, normal force	During the operation
C4	Space/size constraint	Increase adoption, reduce weight	Small gap between chassis & fabrics (increase resistance)	Wheels, top & bottom chassis	Size, space, weight, resistance	When moving on thick fabrics
C5	Chassis shape	Symmetrical looks	Bump / distortion to the body	Chassis	Shape, material	During the operation
C6	No self recharging	Reduce complexity	Insufficient power	Battery	Power, recharge method	All the time
C7	Small size requirement	Good overall size	Low battery capacity	Battery	Overall size	All the time

The process continues with the contradiction selection.

Table *1* summarized the summary of the technical contradictions for selection purpose. These selection criteria are performed by listing its cause, positive effect, the parts involved in the contradiction, property (parameter) which forms a physical contradiction, and time when it occurs. As we can see, there are few contradictions which are related to each other. The first one is C1 and C3 which is regarding the front metal clip. This part is an essential component in the prototype which provides the normal force or clamping effect to ensure the rotating wheels is in contact with the fabrics to produce traction. Besides that, the metal clip also allows the automatized zipper to be easily removed from the jacket. Secondly, C4 and C7 contradictions are

all about the overall size of the automatized zipper. The size limitations will lead to a small gap between top and bottom chassis (which thick fabrics can get caught in between) and also a tough challenge to select tiny electronic parts such as the battery, switch, etc. In another dimension, if we manage to overcome this problem, it can increase the adoption of this device among the users and reduce its total weight.

The second contradiction (C2) deals with the materials used for the rotating wheels. Using the rapid prototyping material (plastic) bring benefits regarding the cost and save time for prototyping cycle. In the other hand, the use of plastic which has a low coefficient of friction will not help to improve the traction of the automatized zipper. Another contradiction which is C5 is about the chassis shape especially the bottom side which has potential to be in contact with the human skin. This situation could produce bump/distortion to the body which might be a negative effect for most of the users. The current shape allowed the Cliff to have a symmetrical look. Lastly, the self-recharging issue (C6) is in line with the concern of insufficient power to the system which could bring a problem to the traction system. Without the self-recharging function, this device complexity is lesser which in turn can reduce the development time. Since few contradictions are related to each other, we now have in total of five contradictions. Therefore, only five contradictions will be selected which are C1+C3, C4+C7, C2, C5 and C6.

For the parameters selection from the Altshuller matrix in the following section, Cliff will be considered as a moving object. TRIZ defines moving objects as an "objects which can easily change position in space, either on their own or as a result of external forces" [1]. The vehicles and devices/products that designed to be portable are the basic members of this class [1].

5. Apply the Alsthuller Matrix Selection

To improve a system which there are two apparently reliant or linked features, one need to be replaced or improved. Improving one parameter/feature might effect another aspect to get worsed. Therefore, the use of the Altshuller Matrix (the contradiction matrix) is to identify potential ways to improve one parameter without deteriorate the others. Based on the contradictions identified previously, Table 2 describes the parameters selection from the Altshuller matrix for each contradiction, and the inventive principles suggested by the matrix. Fig. 10 maps the inventive principles suggested for every contradictions identified.
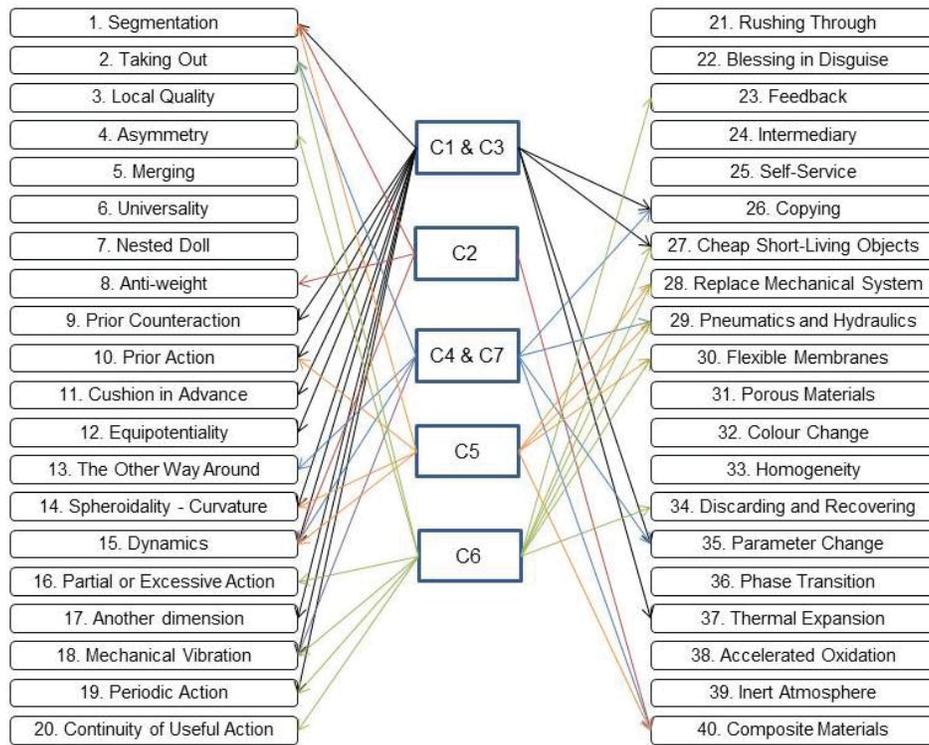
Fig. 10. The mapping of each contradiction with the suggested inventive principles

Table 2

Parameters selection and the inventive principles suggested by the Altshuller Matrix

Contradiction	Contradictions to solve	Inventive Principles
C1 & C3	(10-14): To improve the *force* without worsening the *strength.*	35, 10, 14, 27
	(10-19): To improve the *force* without worsening the *use of energy by a moving object.*	19, 17, 10
	(10-34): To improve the *force* without worsening the *ease of repair.*	15, 1, 11
	(10-7): To improve the *force* without worsening the *volume of a moving object.*	15, 9, 12, 37
	(10-36) : To improve the *force* without worsening the *device complexity.*	26, 35, 10, 18
C2	(14-1) : To improve the *strength* without worsening the *weight of a moving object.*	1, 8, 40, 15
C4 + C7	(7-1): To improve the *volume of a moving object* without worsening the *weight of moving object.*	2, 26, 29,40

	(7-35): To improve the *volume of a moving object* without worsening the *daptability or versatility.*	15, 29
	(19-7) : To improve the *use of energy by a moving object* without worsening the *volume of a moving object.*	35, 13, 18
C5	(12-35): To improve the *shape* without worsening the *adaptability or versatility.*	1, 15, 29
	(12-36): To improve the *shape* without worsening the *device complexity.*	16, 29, 1, 28
	(12-14) : To improve the *shape* without worsening the *strength.*	30, 14, 10, 40
C6	(19-26): To improve the *use of energy by a moving object* without worsening the *quantity of substance/matters.*	34, 23, 16, 18
	(19-36): To improve the *use of energy by a moving object* without worsening the *device complexity.*	2, 29, 27, 28
	(21-26): To improve the *power* without worsening the *quantity of substance/matters.*	4, 34, 19
	(21-36): To improve the *power* without worsening the *device complexity.*	20, 19, 30, 34

6. Results and Discussions

Based on the results obtained in the previous section, the TRIZ analysis using the RCA+ managed to trigger 26 inventive principles as the potential solutions for seven contradictions identified. From the total of the 26 inventive principles triggered, we found that 12 inventive principles have potential to be used in improving the design, while the other 14 principles are not applicable for our design case. Out of the 12 potential inventive principles, 9 of it has a high chance to be further analyzed. The 9 principles are: segmentation, taking out, asymmetry, the other way around, spheroidality-curvature, dynamics, another dimension, copying, and replace the mechanical system. The other 3 which is also to be considered are the cushion in advance, feedback, and composite materials. The other 14 principles that we think are not applicable for our design case are: anti-weight, prior counteraction, prior action, equipotentiality, partial or excessive action, mechanical vibration, periodic action, continuity of useful action, cheap short-living objects, pneumatics and hydraulics, flexible membranes, discarding and recovering, parameter change, and thermal expansion.

Firstly, the segmentation principle triggered us to think about making the Cliff into a sectional object to make it easy to assemble or disassemble it. Secondly, the taking out principle which suggests us to extract or remove the disturbing part is also useful to improve the traction problem of the automatized zipper by removing the side gearbox from the fourth iteration prototype.

It is also in conjunction with another principle triggered which is to replace the mechanical system with the magnetic system. Using the attraction force between two magnets could be another option to replace the front metal clip to provide the normal force for the clamping function. The asymmetry and the other way around principle will lead us to think about changing the view of making a symmetrical design to an asymmetrical one, and also to looks for improvement from the other side or angle. For instance, moving the front metal clip to the other side of the chassis with the same intention which is to provide the normal force for clamping purpose. The next potential principles to be applied is the spheroidality-curvature. The current boxy looks of the Cliff can be changed to a smoother and curvature shape along the top and bottom chassis. By doing this, it can reduce the sharp edge and improve the looks of the Cliff itself.

The use of TRIZ during the iterative research through design process has shown that this method is very useful. It helps the designer to brainstorm/look for the new ideas or potential ideas. Making prototypes will help the designers to simultaneously discover how to approach any problems in a handy way with close observation. The research through design method encourages the designer to continuously make something (prototype) and reflect to the problems occurred [15]. It might require multiple cycles to achieve the ultimate goals. The perfect solution usually not happen during the first attempt of the design process. The introduction of the TRIZ method in this process offers a lot of potentials especially to systematically and scientifically approach the design problems during the making and reflection stage. TRIZ could assists the brainstorming and exploration process to solve the design problem faced. Hence, it will also reduce the cycle times to develop the next iteration design. Besides that, TRIZ also will brings us to another dimension or different viewing angle to solve a problem.

7. Conclusions

The TRIZ analysis with RCA+ has given a few promising directions to improve the problem of the Cliff: an automatized zipper. Even though we have not decided on the final design of the automatized zipper, the TRIZ method brings us the few potential directions based on the inventive principles triggered such as the segmentation, taking out, asymmetry, substitution the mechanical system with the magnetic system, the other way around, the spheroidality-curvature, dynamics, copying, and another dimension. These potential solutions will be further discussed and applied to improve the current prototype. However, there are also a few potential solutions such as the hydraulics and thermal expansion which will not be considered since those principles are in conflict with strict safety and product semantics. Based on our experience using the TRIZ analysis with RCA+ for this study, we found that TRIZ with RCA+ is useful to be practiced along with the iterative research through design method. It because the TRIZ method will help to systematically organize the making and reflection process during the iterative process itself.

Acknowledgements

References

1. K. Gadd, *TRIZ for Engineers: Enabling Inventive Problem Solving*, 1st ed. Wiley Publishing, 2011.

2. L. Haines-Gadd, *TRIZ for Dummies*. Wiley Publishing, 2016.

3. D. S. Madara, "Theory of inventive problem solving (TRIZ): his-story.," *International Journal of Innovative Science, Engineering & Technology*, vol. 2, no. Issue 7, pp. 86–95, 2015.

4. L. Chechurin and Y. Borgianni, "Understanding TRIZ through the review of top cited publications," *Computers in Industry*, vol. 82, pp. 119–134, 2016.

5. V. Souchkov, "Accelerate Innovation with TRIZ," *ICG Training & Consulting*, 2007.

6. C. Dobrusskin, "On the Identification of Contradictions Using Cause Effect Chain Analysis," *Procedia CIRP*, vol. 39, pp. 221–224, 2016.

7. G. Thompson and M. Lordan, "A review of creativity principles applied to engineering design," *Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering*, vol. 213, no. 1, pp. 17–31, 1999.

8. B. Cerit, G. Küçükyazıcı, and D. Şener, "TRIZ : Theory of Inventive Problem Solving and Comparison of TRIZ with the other Problem Solving Techniques," *Balkan Journal of Electrical and Computer Engineering*, vol. 2, no. 2, pp. 66–74, 2014.

9. M. Z. Baharom, M. Toeters, F. Delbressine, C. Bangaru, and L. Feijs, "Cliff : the automatized zipper," in *Global Fashion Conference*, 2016.

10. M. Z. Baharom, F. Delbressine, and L. Feijs, "Kinematics Analysis of A Robotic Zipper Prototype For Miniaturization," *International Journal of Mechanical Engineering & Robotics Research*, vol. 5, no. 4, pp. 305–310, 2016.

11. V. Souchkov, "A Guide to Root Conflict Analysis (RCA+)," *ICG Training & Consulting*, 2011.

12. V. Souchkov, "Root Conflict Analysis (RCA+): Structured Problems and Contradictions Mapping," in *ETRIA Conference TRIZ Future*, 2005, pp. 1–8.

13. V. Souchkov, "TRIZ-Based SYSTEMATIC Value-Conflict Mapping (VCM)," *ICG Training & Consulting*, 2008.

14. V. Souchkov, "A Brief History of TRIZ," *ICG Training & Consulting*, 2015.

15. M. Toeters, M. ten Bhömer, E. Bottenberg, O. Tomico, and G. Brinks, "Research through Design: A Way to Drive Innovative Solutions in the Field of Smart Textiles," *Advances in Science and Technology*, vol. 80, pp. 112–117, 2012.

Corresponding Author:

Mohamad Zairi Baharom: m.z.baharom@tue.nl