Resolving a Problem with Cleaning of Tools by the 3I method – a Case Study

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Abstract. This paper shows a case study of the 3I (Innovation by Increasing Ideality) method to resolve a production-related problem with cleaning distance rings. These rings are used to hold the gap between saw blades during the process of cutting hard crystals. The problem is that sediments are created on the rings from the material being cut and rust from blades. By cleaning the sediments, rings are often damaged, and their thickness is changed. By the use of the 3I method, several proposals to resolve this problem were found. As a recommended solution, the use of a cleaning laser was chosen.

Keywords: Problem-solving, Tool maintenance, TRIZ, 3I, Crystal cutting.

1 Introduction

Many problems that need to be resolved are occurring in manufacturing systems. Also, there are many ways to deal with it [1–5]. Most used methods for resolving process-related problems are methods based on brainstorming. Fortunately, also more sophisticated techniques can be found. TRIZ (Theory of Inventive Problem Solving) and a method based on TRIZ principles can provide a more systematic approach to dealing with process-related problems and help find more innovative solutions often in a shorter time.

This paper deals with the use of the 3I (Innovation by Increasing Ideality) method based on TRIZ principles to overcome the problem with cleaning distance rings used in cutting tools in the process of cutting very hard mono-crystals.

2 Methodology

TRIZ is a set of methods and tools based on the evolution of technical systems. It helps to overcome technical problems. From the specific problem, a general problem is defined. From the principles of TRIZ, a general solution to the general problem is found. Then the solver must come up with a specific solution based on the general solution. [6, 7] Applications of the use of TRIZ on problem-solving can be seen by many authors [8–12].

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3I is a method based on the TRIZ principles. It uses the concept of ideality and tries to pursue the ideal state of the process step, where the problem occurs. That should lead to overcoming or resolving the problem. If the innovation idea is too expensive or not suitable, other solutions based on improvements can also be found. The method is divided into several steps, leading the solver through problem and process description, understanding process purpose and its ideal state, and searching for innovative ways to get closer to the ideal state. The steps of the 3I method are listed below:

1. Problem – description of the problem.
2. Process – determination of the process segment where the problem occurs.
3. Purpose – determination of the purpose of the process (process goal).
4. Principle – description of the principle, of how the purpose is achieved.
5. Ideal state – determination of the ideal state (process does not exist, it is made by itself).
6. Question to the ideal state – formulation of the question of how to achieve the ideal state (this is the real task for resolving by TRIZ principles).
7. Trends – searching in trends of evolution of technical systems.
8. Effects – searching in databases of scientific effects.
9. Technical contradiction – determining and resolving technical contradiction(s) by use of inventive principles.
10. Physical contradiction – determining and resolving physical contradiction by separation principles.
11. Standards – searching for standard solutions.
12. Inspiration – searching in other fields for similar solutions or inspiration.
13. Ideas – list of ideas collected from previous steps.
14. Proposals – first proposals for the solution (proposals are discussed and improved, or the problem is redefined).
15. Final solution – choosing a final solution(s).

The method can also be expanded by using other TRIZ tools such as S-Fields analysis, Function modeling, trimming, or others. [13]

The 3I method was applied to the problem of cleaning distance rings for a cutting tool. During the cutting of crystal, saws and crystal are both poured by water with additives to cool down the cutting area. Unfortunately, saws can slightly corrode, and corrosion is then attached in the form of sediment to the distance rings. Also, the crystal's ground material creates sediments attached to the distance rings. Figure (Fig. 1) below shows examples of a distance rings with sediment.

Fig. 1. Examples of distance rings with sediments.

The problem is with the cleaning of the sediment. Currently, sediments are lightly ground in the solution with soap. Unfortunately, it is hard to catch up at the right moment when the sediment is ground. That leads to uncompleted cleaning or, worse, to ground rings. Because of that, the cleaning is done not so often. That leads to rings with sediments and bigger distances between saws. The cut product is bigger and takes more time to process it in the next operations.

One of the original proposals to resolve this problem was to clean the rings in the ultrasonic cleaning bath used for cleaning cut crystals from the glue. Unfortunately, the rings swelled because additives in the cleaning bath reacted with the dural material. That is an unacceptable result.

The 3I method was used to come up with new solutions on how to clean rings effectively. The method's application is summarized in the table (Table 1.) below.

Table 1. Application of 3I method on problem of distance rings cleaning.

3I step	content
Problem	Sediments and corrosion on the distance rings lead to an increase in rings thickness.
Process	Setting up the tool for cutting crystals.
Purpose	Defining the gaps between the saw blades.
Principle	Dural rings with precise thickness are put manually between saw blades on the rod.
Ideal state(s)	- Saws are holding the gap by themselves. - No sediments are attached to rings. - Sediment can be easily clean without changing the thickness of the ring.
Question(s) to the ideal state	- How to hold the gap between blades without distance rings? - How to hold the distance between blades by the blades themselves? - How to achieve that sediments are not attaching to the rings? - How to clean the sediments easily without damaging rings?
Trends	Segmentation; dynamization; transition from macro to micro; transition to super-system; mono-bi-poly;

Effects	hold – solid: shape memory; hooks; mechanical fasteners; adhesives; foam; ferromagnetism; welding or soldering; casting; heat expansion; nano-velcro; clean/remove – solid: ultrasonic vibrations; acoustic vibrations; laser evaporation; electrolysis; dissolving; fluid spay; magnetism; brushes;
Technical contradiction(s)	TC1: want to hold the gap between blades; by the ring; sediments are attached to it, which leads to inaccuracy. TC2: want to clean the sediment but without damaging the ring want to use water to cool the process, but avoid to corrosion appearance
Physical contradiction	WANT: water to cool down the cutting area; DO NOT WANT: water to avoid corrosion creation and sediments attachment
Separation principles	time; space; (use of protective layer)
Standards	-
Inspiration	cleaning laser; pressure water jet; steam, dissolvers; possibilities of rust removal; possibilities of protection;
Ideas	Ultra-sonic vibration in a bath; acoustic vibration; laser evaporation; use of brushes; segmentation of rings; coating (protective layer) of rings; composite materials; ceramics;

3 Results and Discussion

From the collected ideas and ways of evolution defined by inventive principles, trends, and effects, proposals for the solution could be determined. See table (Table 2).

Table 2. A list of proposed solutions.

proposal		description
Cleaning the sediment	cleaning laser	Use a laser beam to evaporate sediments without damaging the ring material
	water jet	Use of pressure water jet to clean the sediments
	dissolving	Dissolve sediments without damaging dural
Sedimentation prevention	protective layer	Use a protective layer to seal the rings out of water and sediments
Change of material	one-use rings	Use rings for only one use
	ceramics	Use ceramic rings (ease of cleaning)
	composites	Use special composite rings (ease of cleaning)
	plastic	Use plastic rings (ease of cleaning)
Change of the blades holding	gluing	Glue (or solder) the blades on the rod without rings
Change the cutting technology	no need for distance rings	Change the technology of cutting to a new one without the need for blades and distance rings
Optimization/ standardization	Standards of cleaning	After every cut, blades will be disassembled and cleaned by brushes

The proposals were then discussed in a way to choose the best suitable solution. Some of the proposals were also tested for suitability. For example, the result of the test cleaning by the laser beam is shown in the figure (Fig. 2).

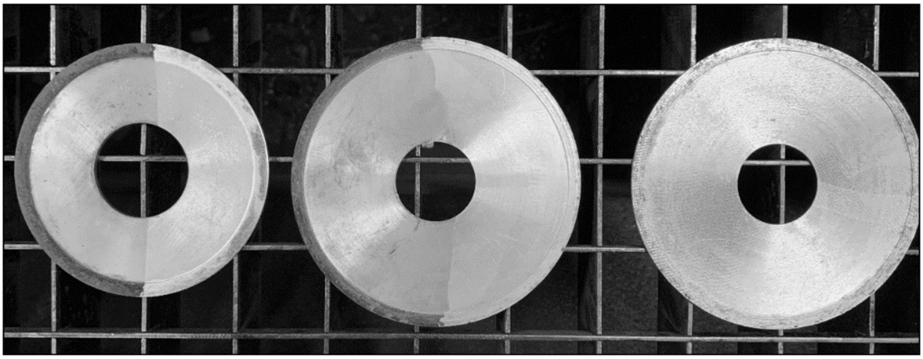

Fig. 2. Cleaning laser test results.

The laser cleaning works perfectly, the sediments are evaporated, and rings are without any damage. Optimal parameters of the laser just must be found for optimal time/cleaning effectivity. The disadvantage of this technology is that the laser device is quite expensive.

Special plastic rings can be seen in the figure (Fig. 3) below. Plastic material is much more resistant to the attachment of sediments and rust. The problem is that thin rings are not flat – they are curved.

Fig. 3. Plastic distance rings.

Other materials are expensive, and with dissolving, there are problems with the ecology of the process. To seal the ring in a protective layer does not work well because the sealing layer causes a reduction of the cutting workspace. Also, it is not durable in case of part of the crystal breaks. Gluing would work well, but if one of the blades would damage – the changing would be much more complicated than now. The cheapest way is to standardize cleaning after every cut, but that takes much effort to disassemble and assemble tools repetitively.

As a final recommended solution, a laser cleaning technology was chosen. The expenses can be alternated by using the laser to clean parts and tools in other production system processes. As a possible low-cost alternative, there is a possible transition to plastic rings (only on thick ones possible) together with regular cleaning standards by brushes.

As a solution for the next step, searching for a new technology for cutting the crystals is the best and most innovative way. By changing the technique, there would not be a need for rings, so the cleaning problem would disappear.

4 Conclusion

The 3I method was demonstrated in the case study of cleaning the distance rings for the cutting tool. By the use of TRIZ principles, several creative ideas were found for dealing with the cleaning problem. After verifying the proposals, the recommendation to use the cleaning laser beam to evaporate the sediments was chosen as the best solution. Also, in future work, the search for new cutting technology without the need for distance rings (or saw) is recommended to achieve highly innovative improvement of the overall production process and eliminate the cleaning problem entirely.

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References

1. Camarillo, A., Ríos, J., Althoff, K.-D.: Knowledge-based multi-agent system for manufacturing problem solving process in production plants. Journal of Manufacturing Systems. 47, 115–127 (2018). https://doi.org/10.1016/j.jmsy.2018.04.002.
2. Kumar Phanden, R., Sheokand, A., Kumar Goyal, K., Gahlot, P., Ibrahim Demir, H.: 8Ds method of problem solving within automotive industry: Tools used and comparison with DMAIC. Materials Today: Proceedings. S2214785322036859 (2022). https://doi.org/10.1016/j.matpr.2022.05.383.
3. Meister, M., Böing, T., Batz, S., Metternich, J.: Problem-solving process design in production: Current progress and action required. Procedia CIRP. 78, 376–381 (2018). https://doi.org/10.1016/j.procir.2018.08.316.
4. Meister, M., Beßle, J., Cviko, A., Böing, T., Metternich, J.: Manufacturing Analytics for problem-solving processes in production. Procedia CIRP. 81, 1–6 (2019). https://doi.org/10.1016/j.procir.2019.03.001.

5. Popowska, M., Marzec, N., Trojanowska, J.: 8D Methodology for Solving Problems in the Production of PVC Pipes. In: Ivanov, V., Trojanowska, J., Pavlenko, I., Rauch, E., and Peraković, D. (eds.) Advances in Design, Simulation and Manufacturing V. pp. 73–83. Springer International Publishing, Cham (2022). https://doi.org/10.1007/978-3-031-06025-0_8.
6. Altshuller, G.: The innovation algorithm: TRIZ, systematic innovation and technical creativity. Technical Innovation Center, Worcester, Mass (2000).
7. Gadd, K.: TRIZ for Engineers: Enabling Inventive Problem Solving: Gadd/TRIZ for Engineers: Enabling Inventive Problem Solving. John Wiley & Sons, Ltd, Chichester, UK (2011). https://doi.org/10.1002/9780470684320.
8. Alves, J.F., Navas, H.V.G., Nunes, I.L.: Application of TRIZ Methodology for Ergonomic Problem Solving in a Continuous Improvement Environment. In: Arezes, P. (ed.) Advances in Safety Management and Human Factors. pp. 473–485. Springer International Publishing, Cham (2016). https://doi.org/10.1007/978-3-319-41929-9_43.
9. Kose, I., Guner, S.: A new approach that proposes TRIZ as a creative problem solving technique in health services. Pressacademia. 7, 67–79 (2020). https://doi.org/10.17261/Pressacademia.2020.1200.
10. Lepšík, P.: Innovation of Device for Nanofibers Production Using TRIZ. In: Medvecký, Š., Hrček, S., Kohár, R., Brumerčík, F., and Konstantová, V. (eds.) Current Methods of Construction Design. pp. 605–610. Springer International Publishing, Cham (2020). https://doi.org/10.1007/978-3-030-33146-7_69.
11. Li, J.B.: Application of TRIZ theory in steel rolling production. IOP Conf. Ser.: Mater. Sci. Eng. 668, 012012 (2019). https://doi.org/10.1088/1757-899X/668/1/012012.
12. Şen, N., Baykal, Y.: Development of car wishbone using sheet metal tearing process via the theory of inventive problem-solving (TRIZ) method. J Braz. Soc. Mech. Sci. Eng. 41, 390 (2019). https://doi.org/10.1007/s40430-019-1884-7.
13. Sojka, V., Lepsik, P.: Innovation by Increasing Ideality – A New Method for Overcoming Process Related Problems. QIP Journal. 25, 78–94 (2021). https://doi.org/10.12776/qip.v25i2.1578.