A new model to resolve technical problems

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Abstract. The Algorithm for Inventive Problem Solving (ARIZ) is a very good tool to solve complicated problems. However, it is fussy to get a specific solution under the guides of ARIZ in the Theory of Inventive Problem Solving (TRIZ). A novel approach to getting solutions for inventive problem solving in TRIZ is shown in this paper. A model named 5-R model of finding specific solutions was developed. 5-R model has four steps to obtain specific suggested solutions for technical problems. Reason-occurred-analysis is the first step in this new model. Then a clear statement of the Ideal Final Result is used to encourage breakthrough thinking and get solutions to the problem. After that, suggested resolutions can be obtained with the Contradiction Matrix, the Physical Contradiction, the Substance-Field, the Effects, Function Analysis, System Enhancement route, and Substance-Field Analysis. Finally, a reasonable specific solution for innovative problem solving can be gotten using resource analysis. 5-R model is not difficult to learn and remember. 5-R model improves the efficiency of getting solutions with TRIZ. Finally, a practical engineering problem was solved using this new model successfully.

1. Introduction

The Theory of Inventive Problem Solving, created in the former USSR and simply called TRIZ [1], TRIZ rests on analytical logic and a systematic thinking way to provide a systematic structure for finding solutions to technical problems and innovation systems [2]. The tools in TRIZ are Function Analysis, Resource Analysis, the Contradictions, 40 Principles, the Matrix, and the Laws of Evolution, the Substance-Field Analysis Modeling, Standard Solutions, Ideal Final Solution, Scientific Effects, Feature Transfer, Function Oriented Search, ARIZ, and so on. Based on some empirical results obtained from the TRIZ applications in many companies, Martin G. Moehrle [3] pointed out that it is only some toolset of TRIZ tools are often applied. According to the top 100 indexed publications concerning TRIZ surveyed by Literature [4], it is shown that TRIZ tools have been successfully implemented in many domains, including mechanical, and industrial engineering, biomimetics, information processing, business and services. Amore powerful tool named ARIZ which is a tool in TRIZ shows how and when to apply the tools above motioned of TRIZ during problems solving process. ARIZ is a sequence of operations to analyze problem situations and solve complicated problems effectively [5]. All the major TRIZ tools are included in ARIZ. History of ARIZ development shows that the enhancement of ARIZ continues step by step. The last modification of the algorithm developed by G. Altshuller in 1985 is ARIZ-85-C [6]. Yoshiki Nakamura [7] proposed a new version of ARIZ named YN/ARIZ02, which is combined NM Method with ARIZ in order to increase ARIZ's problem-solving capabilities. Penti Soderlin [8] separated different problems to different routes to be taken. Helena V.G. Navas [9] studied the project management process with
ARIZ. Combining TRIZ with other methods such as functional decomposition and morphology to meet technical requirements in a product concept by Literatures [10-11]. Achille Souili et al. [12] proposed a new approach of automatic retrieval of inventive design methods from patents to better exploit the use of TRIZ tools. M.R.M. Asyraf et al. [13] provided a new approach to making a design. It is combining TRIZ, morphological chart and Analytic Network Process to get the best concept design [13-14]. Amirabbas Najari et al. [15] established a model to study the possibility of adapting the contradiction tool of TRIZ for the early stages of an architectural design process. Though many researchers have tried to improve the TRIZ function, there still has something not perfect enough. Furthermore, professional forecasting analytical procedures developed and successfully used by our laboratory in TRIZ consulting, are complex, labor consuming [16], too complicated and hardly remember. ARIZ should be simplified and restructured [8]. In this paper, a novel model was firstly developed for problem formulating and the routine to resolve problems with TRIZ in a simplified approach. The model included four major steps to look for the actual solutions. Finally, an example is used to verify the validity of the model.

2. 5-R model
The main idea is to separate different TRIZ heuristics to different routes from one model. In the beginning, the cause of the problem which you should deal with must be clear. This means that a specific problem statement phase should be set firstly. Then the ideal final result (IFR) is defined, and TRIZ tools are selected to use. Finally, specific solutions are obtained by using some selected resources. The model is presented in Figure 1. In Figure 1 the left column is the 5-R model. The right column is used to interpret the meaning of each letter of R in 5-R model briefly. The meaning and the use of 5-R model will be expatiated in the next paragraph below.

\[ \text{5-R model has four steps to obtain specific suggested solutions for technical problems.} \]

**Step 1**: Reason.
Firstly, the problem should be developed and defined. The problem can be separated into two types. One is about the improvement of an existing system. The other is to create a new system. Secondly, the reason in root which the problem occurred should be found. According to the problem type which the resolver faced, different TRIZ tools will be selected to use.

**Step 2**: Result (the Ideal Final Result).
The Ideal Final Result has all the benefits that the customer requires, and none of the harm brought by the system. Before solving the problem, a clear statement of the Ideal Final Result will help to lead directly to a solution to the problem at a very high level [17]. Since the technology-independent definition of the Ideal Final Result as a psychological tool that encourages breakthrough thinking by removing the mental constraints of existing solutions and lead the problem solver away from traditional means of solving the problem.

**Step 3**: Suggested Resolution.
If the target is the improvement of an existing system overcoming some drawbacks of the existing system or increasing some new functions, the routes to be followed will be the Contradiction Matrix, the Physical Contradiction, the Substance-Field, or the Effects. When a new system is established on
the basis of the market requirements, it is more suitable to use Function Analysis, System Enhancement route, Substance-Field Analysis and 76 standards.

**Step 4:** Final Resolution with Resources.

In TRIZ, a resource is broadly defined as everything that can be used for developing a problem and improving the system. In TRIZ resource analysis, there are six types of resources that should be analyzed, those are substances, fields, space, time, informational, and functional resources [7]. It is important for knowing how to use resources available to get a reasonably specific solution for innovative problem solving. Resources can be internal or external to the system and belong to the conflicting pair of elements in the system. In this step, in order to solve the problem without any heavy expenses and make good use of cost-free resources, resources should be searched out wholly. Then attempt to get a specific solution to satisfy the Ideal Final Result defined in step 2 under the guild of the suggested solutions obtained in step 3.

3. **5-R model inaction**

In order to verify the validity of the model, a solution to the problem about how to improve nozzle life will be obtained used this new model. High speed rotating atomizer in desulphurizing system is used to get desulfurized slurry. The rotating speed of the atomizer is about 9000 revolutions per minute. The slurry under the action of centrifugal force will produce tiny droplets. At the same time, tiny droplets will be ejected out from atomizer nozzles, which are installed on the high-speed rotating wheel of the atomizer. The tiny droplets which are containing 20% solid particles will hit the nozzle surface. So, the life of the nozzle will be reduced. The cost of the atomizer nozzles will be increased.

The ordinary nozzle structure is shown in Figure 2.

![Figure 2. The structure of the ordinary nozzle.](image)

In the following, the whole process of getting a specific solution using 5-R model constructed in the previous section in this paper is depicted step by step.

**Step 1:** Reason.

Firstly, it should be defined that the type of the problem. In this problem, the goal is to increase the nozzle life. So, it is one problem with the improvement of an existing system. Secondly, the reason that the nozzle wear should be analyzed. The tiny droplets containing 20% solid particles will hit the nozzle surface when the slurry gets out from the atomizer through the nozzles. The hitting force and friction force will damage the surface of the nozzle and decrease the nozzle life. This is the reason in root which the problem occurs.

**Step 2:** Result (the Ideal Final Result).

In this step, the Ideal Final Result should be defined. The nozzle can let the slurry and the tiny droplets out freely and the surface of the nozzle can not be worn, which is the final aim. The ideal final result can be stated as follows. The surface of the nozzle can be securely protected by itself when the slurry and the tiny droplets pass through the nozzle.

**Step 3:** Suggested Resolution.

The problem will be solved using the Contradiction Matrix and 40 principles. It is can be assumed that the shape and structure of the nozzle need to be modified – in order to make the nozzle work perfectly. A more complex construction design with a few specialized functional parts is perhaps
possible. Here we want the nozzle will be protected by itself without any cost. The nozzle will be protected by itself. So, the improving feature is "Extent of automation" (38). The worsening feature is "Device complexity" (36). At the intersection of this row and column in the Contradiction Matrix are three recommended principles for resolving the indicated contradiction:

**Principle 15. Dynamics.**
- A. Allow (or design) the characteristics of an object, external environment, process, or system to change to be optimal or to find an optimal operating condition.
- B. Divide an object or system into parts capable of movement relative to each other.
- C. If an object or system is rigid or inflexible, make it movable or adaptive.
- D. Increase the degree of free motion.

**Principle 24.**
- A. Use an intermediary carrier article or intermediary process.
- B. Merge one object or system temporarily with another (which can be easily removed).

**Principle 10. Preliminary Action.**
- A. Perform, before it is needed, the required change of the object or system (either fully or partially).
- B. Pre-arrange objects or systems such that they can come into action from the most convenient place and without losing time for their delivery.

Combining Principle 15 and Principle 24, it is the most appropriate for solving the problem. The nozzle itself promotes the best protection to the nozzle surface when the slurry and the tiny droplets pass through the nozzle.

**Step 4: Final Resolution with Resources.**

Some practical ideas can be immediately found under the guiding of principle 15 and principle 24. A substance is formed on the inner hole of the nozzle. When the slurry is ejected through the inner hole of the nozzle, the slurry and the tiny droplets only contact with this substance, not with the inner wall of the nozzle. Therefore, the slurry and the droplets will not make the nozzle surface wear, and the service life of the atomizer nozzle is improved. The actual solution shows in Figure 3. The new nozzle is a hollow structure. The new nozzle consists of the following parts, including Air inlet 1, Air storage chamber 2, High-pressure air outlet 3, Slurry entrance 4, Flow channel 5, and Final outlet 6. There is an acute angle between the surface of the inner hole of the nozzle and the direction of the High-pressure air outlet 3. When the atomizer begins to work, high-pressure airflow goes into Air storage chamber 2 from Air inlet 1. The high-pressure airflow will go to Final outlet 6 passing through Flow channel 5. At the same time, the high-pressure airflow will form an air layer on the surface of the inner hole of the nozzle. This air layer will prevent the slurry and the droplets from contacting the inner wall of the nozzle when the slurry and the droplets get out from Slurry entrance 4 to Final outlet 6. Since the slurry and the droplets do not contact with the inner wall of the nozzle, so the slurry will not damage the nozzle. The nozzle is protected.

![Figure 3. The structure of the new nozzle.](image_url)
Some Literatures such as [18] and [19] provide metrics and methods to assess novelty and creativity of the solution. If there are several solutions, those methods can be used to select the best solution.

4. Conclusions
In this paper a 5-R model of finding special solutions using TRIZ tools was first established. The 5-R model can provide a method to get solutions instead of ARIZ. However, the 5-R model still has limitations. For example, this 5-R model could not replace all the parts of ARIZ. Since the 5-R model does not provide the method to identify the specific contradiction to solve. Whereas the specific contradiction can be reduced from Function Analysis. Under the guide of 5-R model, different tools were selected to solve two kinds of problems. 5-R model makes things easier to learn and remember. To verify the validity of the model, an application of the atomizer nozzle was conducted. An ideal special solution was obtained in the end. The solution is well to protect the nozzle.

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