

Solving the Problem of ARIZ Using ARIZ (Algorithm of Inventive Problem Solving): Case Study on Pipeline Maintenance System Design

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Abstract

ARIZ (Algorithm of Inventive Problem Solving) is known as one of the most powerful innovation tools. However, it is too complicated to understand and apply. Various versions of extended and modified ARIZ have been proposed in the past with little success. The aim of this research is to simplify ARIZ by analyzing the problem of ARIZ and solving the key problems using ARIZ itself. As the result, a new version of ARIZ is presented in this paper. It helps facilitate the understanding and usage of problem solvers by integrating the 40 Inventive Principles and the MAR (Modify, Add, Replace) Operator into Part 1 of ARIZ. This makes ARIZ more user-friendly for solving general problems. This new version of ARIZ is effectively demonstrated by using the problem of industrial pipeline maintenance system as a case study in which many practical ideas come up during Part 1 of ARIZ and more ideal solution concept is attained at the latter parts.

Keywords: TRIZ, ARIZ, innovation tools, residual magnetic field, arc welding

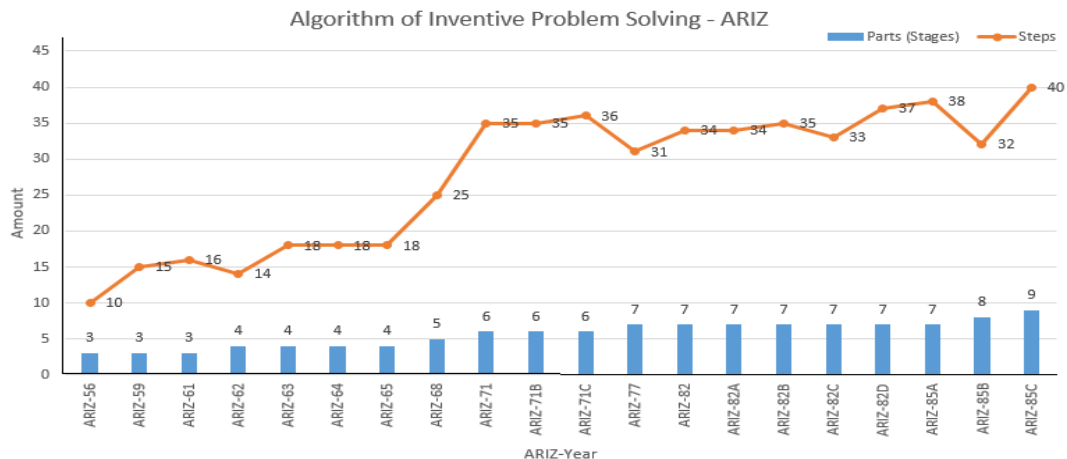
1. Introduction

Nowadays, innovation is one of the most frequently quoted keywords in both the world of business and technology. Unfortunately, most of the quotes are more concerned with “What is” innovation rather than “How to”. There are not so many tools or methods that guide people how to reach innovation. Among them, ARIZ (Algorithm of Inventive Problem Solving) is known as one of the most powerful innovation tools which is logical and scientific in problem solving and idea generation. ARIZ is a step-by-step method of analyzing a problem for the purpose of revealing, formulating, and resolving contradictions. ARIZ was developed by Genrikh Altshuller (1926-1998), the founder of TRIZ (Theory of Inventive Problem Solving) (Altshuller, Zlotin, Zusman, & Philatov, 1998). ARIZ itself is problematic and has evolved into many versions and variants. The last version of ARIZ is ARIZ-85C which contains 9 parts and

totally 40 steps which are complicated and difficult to understand and apply, especially for TRIZ beginners. The author investigates into the development of ARIZ and attempts to propose a new version that will facilitate understanding and usage of problem solvers while preserving the essence and originality of ARIZ-85C by identifying the key problems of ARIZ and solving them by using the process of ARIZ itself. The new version of ARIZ is effectively demonstrated by using the problem of industrial pipeline maintenance system.

1.1. Evolution of ARIZ

The first version of ARIZ was developed in the year 1956 and was named ARIZ-56 according to the year it was developed. ARIZ-56 contains 3 parts and 10 steps after which it has evolved into many versions with more parts and steps (Petrov, 2006) as shown in Fig. 1.



(Source: History of Development of ARIZ, Vladimir Petrov, 2006)

Fig.1. History of Development of ARIZ

It is noticeable that the first Table of Inventive Principles was developed in ARIZ-64 and evolved into 39x39 Contradiction Matrix Table with 40 Inventive Principles in ARIZ-71. But as a result of TRIZ's evolution, the method of 40 Inventive Principles with Contradiction Matrix Table was removed and replaced with System of Standard Solutions and Substance Field Analysis in ARIZ-71B. Altshuller considered System of Standard Solutions to be much more efficient and powerful for idea generation than 40 Inventive Principles and recommended to TRIZ community to stop using the 40 Inventive Principles and Contradiction Matrix Table, and to start using the System of Standard Solutions and Substance Field Analysis instead. But

for TRIZ beginners, especially for those outside the borders of Soviet Union, however, the 40 Inventive Principles with Contradiction Matrix Table is easier to understand and apply than the System of Standard Solutions.

The last version of ARIZ developed by Altshuller is ARIZ-85C in the year 1985 after which he retired himself from involving in ARIZ development and concentrated his efforts in the area of the Theory of Development of a Strong Creative Personality (TRTL) (Zlotin & Zusman, 1999). Many TRIZ practitioners have attempted to simplify ARIZ by extending or modifying it into many versions and variants as shown in Fig. 2.

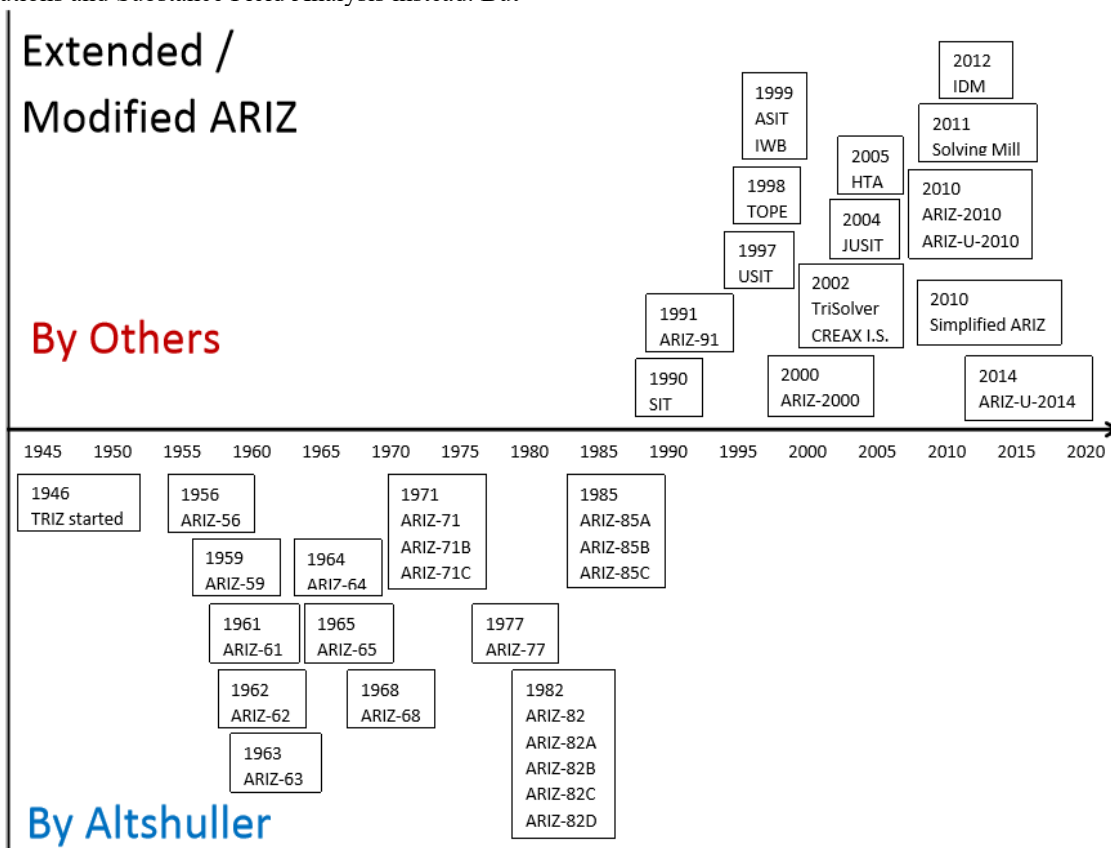


Fig. 2. Extended/Modified ARIZ

The commonly known extended or modified ARIZ which are found in many literatures and websites includes ARIZ-91, ARIZ-SMVA, ARIZ-2000, ARIZ-2010, ARIZ-U-2010, ARIZ-U-2014, SIT (Systematic Inventive Thinking), ASIT (Advanced Systematic Inventive Thinking), USIT (Unified Structured Inventive Thinking), JUSIT (Japanese version of Unified Structured Inventive Thinking), TOPE (TechOptimizer), IWB (Innovation WorkBench), Creax.I.S (CREAX Innovation Suite), HTA (Hierarchical TRIZ Algorithms), TriSolver, Solving Mill, IDM (Inventive Design Method), and Simplified ARIZ (Ball, 2005; Cameron, 2010; Horowitz, 1999; Ideation International Inc., n.d.; Invention Machine Corp., n.d.; Mann, 2002; Nakagawa, 2008; Petrov,

2009; Rubin, 2012, 2014; Sickafus, 1997; Soderlin, 2003; Systematic Inventive Thinking, n.d.; TriS Europe Innovation Academy, n.d.; Target Invention Ltd., n.d.; Time To Innovate, n.d.; Zlotin, Zusman, Litvin, Petrov, et al., 1997).

Among them, ARIZ-91 and ARIZ-SMVA are considered to be the best versions with many enhancements while trying to keep the originality of ARIZ-85C, but the System of Standard Solutions is still applied in Step 1.7 to verify the possibility of solving the problem model created by Step 1.6 which makes it still difficult for TRIZ beginners to apply.

ARIZ-2000 clarifies where the problem statement and refinement ends, and where the actual problem solving or idea creation phase starts,

and rearranges problem solving or idea creation phase into 4 routes with different TRIZ tools after which Substance Field Resources are deployed to generate ideas (Soderlin, 2003).

ARIZ-2010 is modular and adaptive to variety of problem classes. It supports various degrees of time/depth work scope per user needs. While comprehending existing ARIZ versions, it also adds a new stage for choosing the initial problem to start work on (Petrov, 2009).

ARIZ-U-2010 and ARIZ-U-2014 is based on a set of models for functions (useful, insufficient and harmful). It automates the process of formulating requirement contradictions, IFR, selecting standards for inventive problem solving and formulating other ARIZ steps (Rubin, 2012, 2014).

SIT/ASIT/USIT/JUSIT are variants of problem solving tools which have different approach and structure from ARIZ, but are deeply rooted in TRIZ. They are mentioned here for reference with the original ARIZ (Horowitz, 1999; Nakagawa, 2008; Sickafus, 1997; Systematic Inventive Thinking, n.d.).

Hierarchical TRIZ Algorithms is a how-to TRIZ book designed vividly with animated pictures to assist both beginning and advanced users in solving technical problems (Ball, 2005).

Simplified ARIZ is an algorithm describes the process for contradiction problem solving in a TRIZ book called TRIZICS. It is divided into 4 phases with totally 18 steps (Cameron, 2010).

Innovation WorkBench, Solving Mill, TechOptimizer, Creax.I.S (CREAX Innovation Suite), TriSolver, Solving Mill, and IDM (Inventive Design Method) are extended or modified versions of ARIZ which are computerized as TRIZ software tools (Invention Machine Corp., n.d.; Ideation International Inc., n.d.; Mann, 2002; TriS Europe Innovation Academy, n.d.; Target Invention Ltd., n.d.; Time To Innovate., n.d.).

1.2. Problems of ARIZ

Although there are many versions and variants of ARIZ after ARIZ-85C in which many of them are advanced and sophisticated with computer software support, the only accepted version is still ARIZ-85C as listed in TRIZ Body of Knowledge of TRIZ Developers Summit (Litvin, Petrov, and Rubin, 2007) and problem solving using ARIZ-85C is required as a compulsory TRIZ project for TRIZ Specialist certification program at the International TRIZ Association (MATRIZ) (The International TRIZ Association (MATRIZ), n.d.).

Altshuller was quoted as saying that “ARIZ is a complicated tool. Do not apply it to solve new practical problem without at least 80 academic hours of preliminary study” (Altshuller, Zlotin, Zusman, & Philatov, 1998; TRIZ Korea Inc., 2002). According to the research of Altshuller, less than 5 % of the problems encountered in daily engineering activities are problems which are truly unique and cost-effective enough for ARIZ (Zlotin & Zusman, 1999). This is emphasized by further claim that only 1 % of the problems required the use of ARIZ (Savransky, 2000).

Although ARIZ is widely known as an innovation tool, it is used just only by a few TRIZ specialists, and even though ARIZ is the main tool of TRIZ which integrates all other tools and knowledge base, it is not as popular as other stand-alone tools.

With respect to the spirit of Altshuller who has devoted his life to the development of TRIZ as a science for mankind (Altshuller, 1984), the author attempts to identify the key problems of ARIZ and proposes a new version that will facilitate understanding and usage of problem solvers while preserving the essence and originality of ARIZ-85C which from now on will be referred as ARIZ.

2. Method

The problem of ARIZ is first analyzed by using the method of FA (Function Analysis) and CECA (Cause-Effect Chains Analysis) to identify the key problem after which ARIZ is deployed to solve the key problems and search for ideal solutions.

2.1. Function Analysis and Cause-Effect Chains Analysis

ARIZ itself can be considered as a technological system which evolves in accordance with TRIZ's Laws of Technological System Evolution. The main useful function of ARIZ is to guide problem solvers through creative thinking process in solving problems and to attain innovative solution concepts. The system of ARIZ comprises 9 parts and 40 steps for analysis and idea generation incorporated with TRIZ tools, knowledge base, resources, scientific effects and Solution Park where solution concepts generated during the process are parked. The function model of ARIZ-85C can be described as in Fig. 3 and the functions of each part can be broken down into the functions of steps as in Fig. 4.

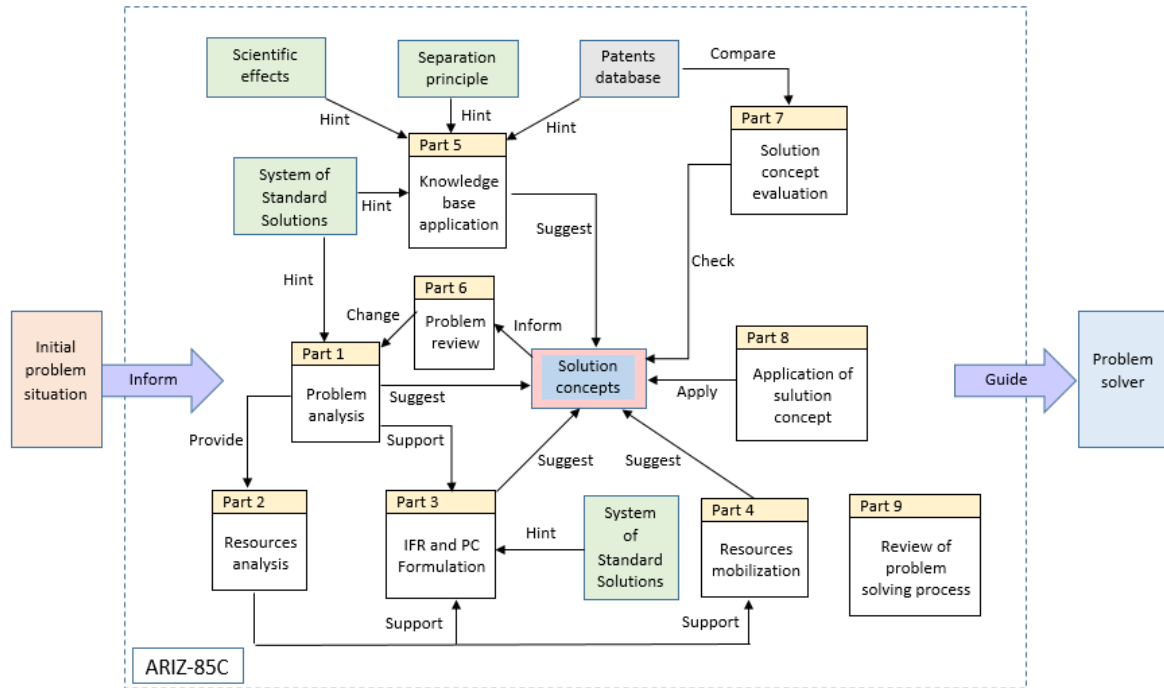


Fig. 3. Function Model of ARIZ-85C

Part 1. Analyzing the problem	Part 2. Analyzing the problem model	Part 3. Formulating the ideal final result and physical contradiction	Part 4. Mobilizing and utilizing substance-field resources	Part 5. Applying the knowledge base to solve physical problem	Part 6. Changing or substituting the problem : If the problem is not solved	Part 7. Analyzing the method for resolving the physical contradiction	Part 8. Capitalizing on the solution concept	Part 9. Analyzing the problem-solving process
Step 1.1. Formulate the mini-problem	Step 2.1. Define the operational zone	Step 3.1. Identify the formula for ideal final result (IFR) 1	Step 4.1. Simulation with smart little people	Step 5.1. Applying the system of standard solutions	Step 6.1. Transfer the theoretical solution into a practical one	Step 7.1. Check the solution concept	Step 8.1. Define how the super-system that encompasses the changed system should be changed	Step 9.1. Compare the real process of problem solving with the theoretical one
Step 1.2. Define the conflicting elements	Step 2.2. Define the operational time	Step 3.2. Intensify the formula for ideal final result 1	Step 4.2. "Stepping back" from the IFR	Step 5.2. Applying solution concepts to non-standard problems that have already been solved using ARIZ	Step 6.2. Check to see whether the description in step 1.1 represents a combination of several problems	Step 7.2. Preliminary estimate of the solution concept	Step 8.2. Check whether the changed system or super-system can be applied in a new fashion	Step 9.2. Compare the solution concept to the information in the TRIZ knowledge base
Step 1.3. Build graphical models for the Technical Contradictions	Step 2.3. Define substance and field resources	Step 3.3. Formulate the physical contradiction for the macro-level	Step 4.3. Using a mixture of substance resources	Step 5.3. Solving physical contradiction by Utilizing the separation principles	Step 6.3. Change the problem by selecting another technical contradiction in step 1.4	Step 7.3. Check the novelty of the solution concept via patents search	Step 8.3. Apply the solution concept for solving other problems	
Step 1.4. Select a graphical model for further analysis		Step 3.4. Formulate the physical contradiction for the micro-level	Step 4.4. Using empty space	Step 5.4. Solving physical contradiction by Utilizing the library of natural effects and phenomena	Step 6.4. Return to step 1.1 and reformulate the mini-problem with respect to the super-system	Step 7.4. Note possible sub-problem which might require invention, design, calculations, etc.		
Step 1.5. Intensify the conflict		Step 3.5. Formulate the ideal final result 2	Step 4.5. Using derived resources					
Step 1.6. Formulate the problem model		Step 3.6. Consider solving for the new physical problem	Step 4.6. Using an electric field					
Step 1.7. Apply the system of standard solutions			Step 4.7. Using a field and field-sensitive substance					

Fig. 4. Parts and Steps of ARIZ-85C

The function analysis of ARIZ-85C shows no undesirable effects such as insufficient or excessive useful function or harmful function, as long as the problem solver is well trained and specializes in using ARIZ. For the general problem solver with little experience however, ARIZ is difficult to understand and apply which makes ARIZ not so popular among them.

With the Cause Effect Chains Analysis as shown in Fig. 5, the key disadvantages or key problems of ARIZ are identified as follows,

- 1) ARIZ is not suitable for the general problems
- 2) ARIZ takes too much time to learn
- 3) ARIZ is mostly used in business consulting service

Note: By the general problems, the author means the problems encountered by general problem solvers who are either TRIZ experts or TRIZ beginners. The characteristics of the problem can be either complex (advanced) or less complex (basic).

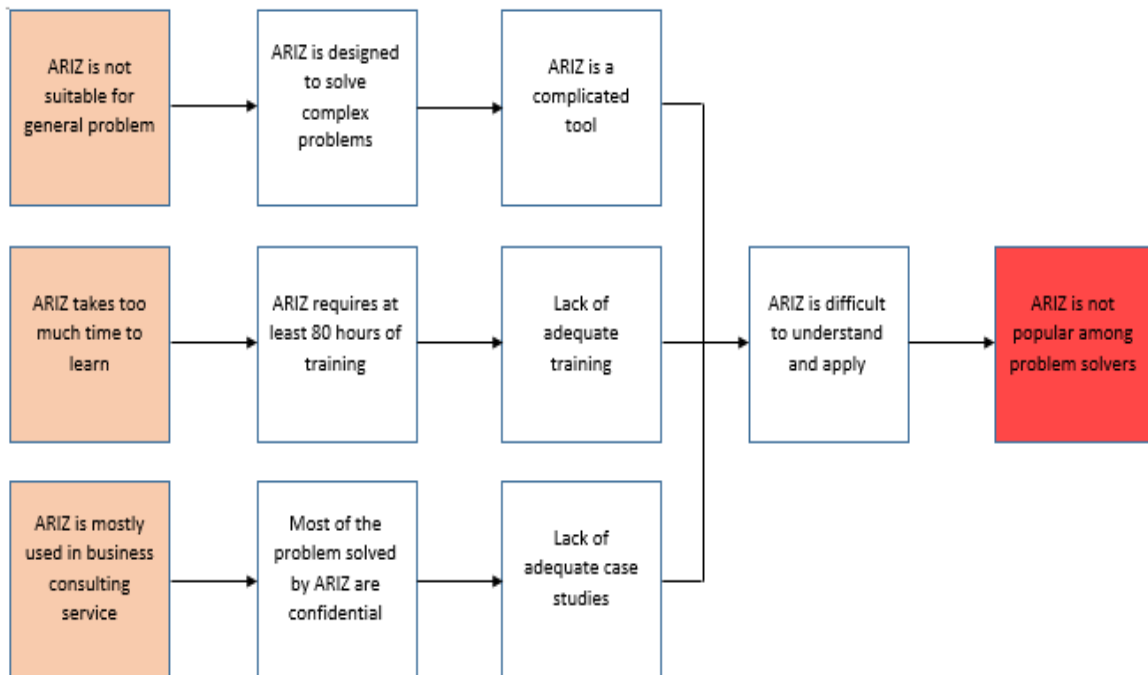


Fig. 5 Cause Effect Chains Analysis of ARIZ

In order to make ARIZ more popular among general problem solvers, the author aims to solve the key problems of how to make ARIZ also suitable for general problems (besides its strong points for solving complex problems), how to shorten the learning curve of ARIZ with more supporting resources, and how to make ARIZ widely adopted by both the industries and the academic world (not just only by consulting firms) so that there will be more disclosed application of ARIZ to be referred to as case studies.

The algorithm of ARIZ-85C is deployed to solve the problem of ARIZ. The process and results are explained in the following chapter.

3. Results

Due to the page limit, only some important steps will be explained as follows,

3.1. Part 1. Analyzing the Problem

Step 1.1 Formulate the Mini-Problem

The mini-problem of ARIZ is formulated as follows. The technical system for guiding problem solver includes initial problem situation, parts and

steps of ARIZ, TRIZ tools, knowledge base, resources, scientific effects and solution concepts.

It is necessary, with minimum changes to the system, to facilitate the understanding and usage (of problem solver) without lessening the essence and originality (of ARIZ-85C).

Technical Contradiction 1 (TC-1): If modification is extensive, then it facilitates the understanding and usage, but it lessens the essence and originality.

Technical Contradiction 2 (TC-2): If modification is mild, then it preserves the essence and originality, but it insufficiently facilitates the understanding and usage

Step 1.2 Define the Conflicting Elements

The Conflicting Elements includes Product and Tool which, are defined as follows,

- Products: 1. Understanding and Usage and 2. Essence and Originality
- Tool: Modified ARIZ

Step 1.3 Build Graphical Models for the Technical Contradictions

Graphical Models for the Technical Contradictions are built as shown in Fig. 6.

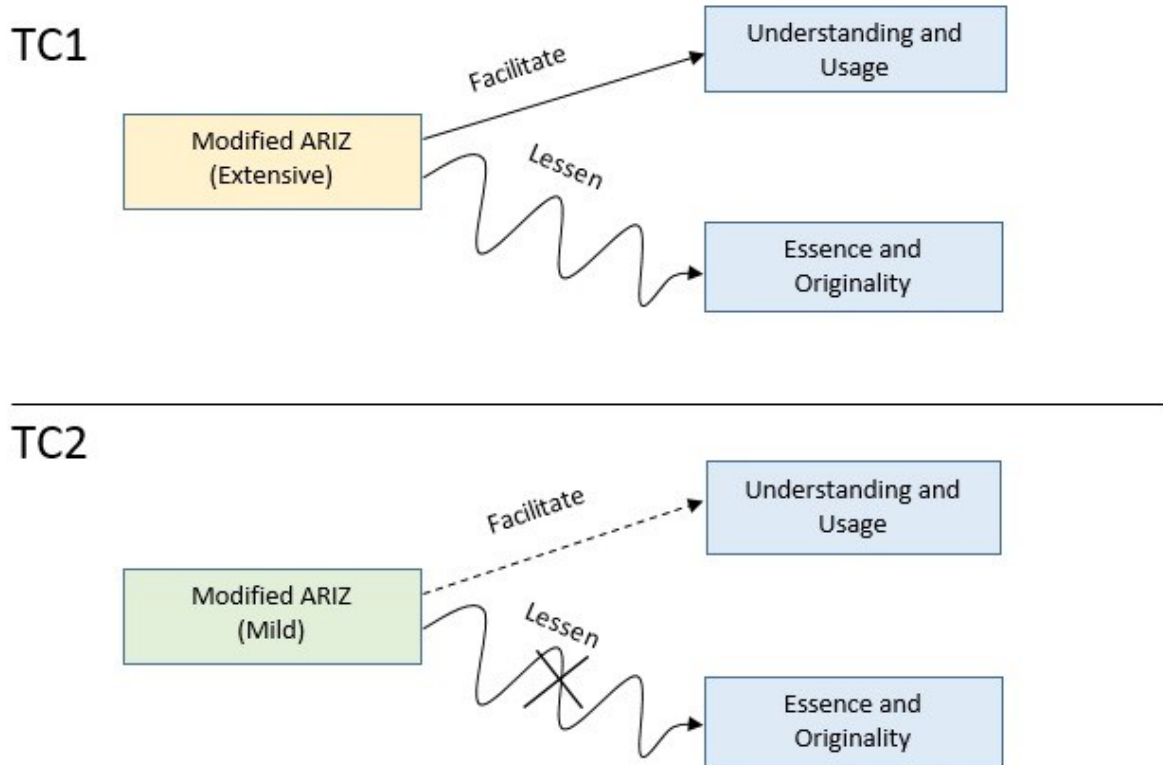


Fig. 6. Graphical Models for the Technical Contradictions

Step 1.4 Select a Graphical Model for Further Analysis

Since the main function of the ARIZ system is to guide problem solver with good quality of algorithm, the Essence and Originality must not be lessened by the Modification. Thus, we select TC-2 which states that if modification is mild, then it preserves the essence and originality, but it

insufficiently facilitates the understanding and usage.

Step 1.5 Intensify the Conflict

In order not to compromise (trade off) useful function with harmful effect, we intensify the conflict by considering that instead of “Mildly Modified ARIZ”, it is replaced by a “No Modified ARIZ” in TC-2 as shown in Fig. 7.

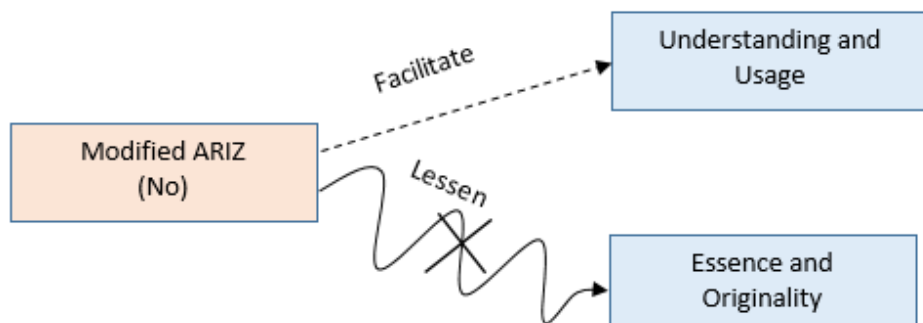


Fig. 7. Intensified Graphical Model

Step 1.6 Formulate the Problem Model

Find an element “X” that maintains the feature of No Modified ARIZ for preserving the essence

and originality while also facilitating the understanding and usage as shown in Fig. 8.

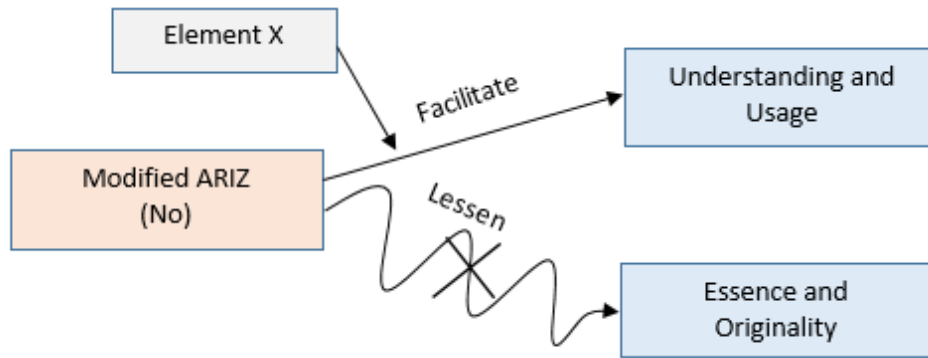


Fig. 8. New Problem Model

Step 1.7 Apply the System of Standard Solutions

In this step the graphical model is analyzed using Substance-Field Modeling and Analysis (Belski, 2007) along with System of Standard Solutions (Altshuller,1985) to find element “X” as follows.

The initial Substance-Field Model is created with S1(object) as Understanding and Usage, S2(tool) as No Modified ARIZ, F1 as Human Intelligence or Biological Field. While solving problem, problem solver exerts Human Intelligence on No Modified ARIZ to insufficiently facilitate the Understanding and Usage as shown in Fig. 9(a).

In order to improve the efficiency of the system, the standard solution which best corresponds to the

above initial model is standard solution 2.1.2 which states as follows.

Standard solution 2.1.2 “Synthesis of a Dual Substance Field System”

If it is necessary to improve the efficiency of substance-field system and the replacement of substance-field system element is not allowed, the problem can be solved by the synthesis of a dual substance-field system through introducing a second field which is easy to control.

Idea 1: Use optical field through computer software (F2) to improve the efficiency of facilitating the understanding and usage for problem solver. The computer software helps to create a double substance field system and can be easily controlled as shown in Fig. 9(b).

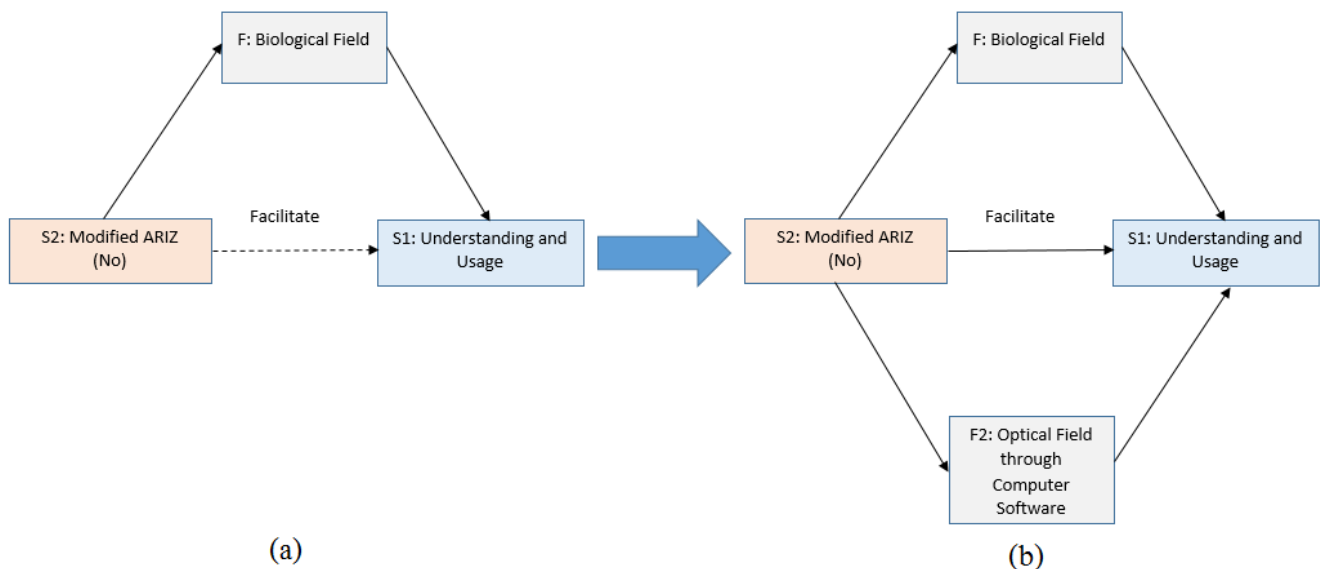


Fig. 9. Substance-Field Modeling and Analysis

Although nowadays computer is a cheap resource which can be easily acquired, it is preferable to consider internal resources inside the system and environment to utilize and generate more ideal solution concepts, so we move on to Part

2 Resources Analysis and Part 3 Formulation of the Ideal Final Result and Physical Contradiction.

3.2. Part 2. Resources Analysis

If the problem is easily solved within Part 1, there is no need to go further into Part 2.

Part 2 and other Parts that follow will deal with solving complex problem as in the following steps.

Step 2.1 Define the Operational Zone (OZ)

In the problem of using ARIZ, the Operational Zone is defined to be the ARIZ system and its interface with problem solver.

Step 2.2 Define the Operational Time (OT)

In the problem of using ARIZ, the Operational Time is defined to be the period of time during using ARIZ.

Step 2.3 Define the Substance Field Resources

A list of Substance-Field Resources with their parameters is created as in Table 1.

Table 1. Substance-Field Resources (Bukhman, 2012)

Source	Substance-Field Resources	Type	Parameter
Internal Resources	Parts of ARIZ	Substance	Amount, Level
	Steps of ARIZ	Substance	Amount, Level
	40 Inventive Principles	Substance	Amount
	Contradiction Matrix Table	Substance	Size
	System of Standard Solutions	Substance	Amount, Level
External Resources	Computer	Substance	Speed, Space
	Internet Access	Field	Speed, Bandwidth

3.3. Part 3. Formulation of the Ideal Final Result and Physical Contradiction

Step 3.1 Identify the Formula for IFR-1

Ideal Final Result (IFR) (Domb, 1998) is used to define the problem to be solved. The Ideal Final Result by introducing the element “X” is defined as follows,

While neither complicating the system nor causing harmful effects, element “X” improves the useful function of the no modified ARIZ to facilitate the understanding and usage during operational time (the period of using ARIZ) within the conflict zone (the ARIZ system and its interface with problem solver) while preserving the essence and originality of ARIZ.

Step 3.2 Intensify the Formula for IFR-1

We intensify the formula of IFR-1 by introducing an additional requirement that the element “X” comes from substance field resources. In this case, “Parts of ARIZ” is considered to replace the element “X”.

Step 3.3 Formulate the Physical Contradiction for the Macro-Level

The Physical Contradiction (Kaplan, 1969) for the Macro-Level is formulated as follows, Parts of ARIZ in the the ARIZ system and its interface with problem solver during the period of using ARIZ, has to be simple in order to perform facilitating the understanding and usage, and has to be complicated (advanced) to perform preserving the essence and originality.

Idea 2: Use Principle of Separation in Space

Part 1 which concerns with problem analysis should be made simple to analyze and generate ideas for the general problem. If the problem is too complicated and the generated ideas are not satisfactory, then the problem can be moved

forward to the latter parts of ARIZ which deals with complex problem.

Step 3.4 Formulate the Physical Contradiction for the Micro-Level

In this case, Steps of ARIZ of each part can be considered as the micro-structure of ARIZ. The Physical Contradiction for the Micro-Level is formulated as follows.

There should be Steps of ARIZ that is simple in the the ARIZ system and its interface with problem solver in order to provide simple Parts of ARIZ, and Steps of ARIZ should be complicated in order to provide complicated (advanced) Parts of ARIZ.

Idea 3: Use Principle of Separation in Structure

Some Steps of ARIZ should be made simple for TRIZ beginner, but ARIZ as a whole still preserves its essence and originality to deals with complex problem.

Since, from Idea 2, Part 1 should be made simple, therefore the steps of ARIZ to be made simple should come from Part 1. Steps of Part 1 are analyzed and simplified using the existing resources. The author has come up with more ideas as follows,

Idea 4: Use the Contradiction Matrix Table and 40 Inventive Principles which are the existing resources to generate ideas for resolving the technical contradiction selected in Step 1.4

Although the user-friendly Contradiction Matrix Table and 40 Inventive Principles (Altshuller, 1997) are removed from ARIZ and replaced with System of Standard Solutions, most TRIZ practitioners consider them to be complementary to each other. Therefore, the author simplifies Step 1.4 by using 40 Inventive Principles and leaves the complicated (advanced) System of Standard Solutions to be used in the latter Parts of ARIZ (Step 3.6 of Part 3 and Step 5.1 of Part 5). But the System of Standard Solutions is also

required in Step 1.7 of Part 1 which makes Part 1 too complicated for TRIZ beginners. The author has come up with some ideas to simplify the System of Standard Solutions at this step as follows,

Idea 5: Instead of using the full scale of the System of Standard Solutions, some minimum set of the System of Standard Solutions might be prepared to facilitate the understanding and usage of the problem solver.

As most of the problems in Substance-Field Model are typically concerned with the insufficient useful function or undesirable effects of the system, the solution standards in subclass 1.1, 2.1 and 2.2 which deal with improving the useful function and subclass 1.2 which deal with eliminating harmful

interaction are frequently used and can be prepared according to Idea 5. But it is still difficult for the TRIZ beginners who might be unfamiliar with the contents and technical terms used in each standard solution.

Since the System of Standard Solutions is concerned with manipulating components in the system and its environment for the purpose of transforming the initial Substance-Field Model into a problem-free model, the author tried to look into the contents of each standard solutions in subclass 1.1, 1.2, 2.1 and 2.2 which consist of totally 21 solutions, to analyze the frequently used actions and the components that are manipulated.

The result is shown in Table 2.

Table 2. Actions and Components of System of Standard Solutions

Solution Number	Standard Solution Name	Action			Component	
		Modify	Add	Replace	Substance	Field
1.1.1	Building of Substance-Field Model		X		X	X
1.1.2	Improving interactions by introducing additives into the objects		X		X	
1.1.3	Improving interactions by introducing additives into a system		X		X	
1.1.4	Use of environment to improve interactions		X		X	X
1.1.5	Modification of environment to improve interactions	X	X		X	X
1.1.6	Providing minimum effect of action		X		X	X
1.1.7	Providing maximum of effect of action		X		X	
1.1.8(a)	Providing selective effect by maximum field and Protective substance		X		X	
1.1.8(b)	Providing selective effect by minimal field and active substance		X		X	
1.2.1	Elimination of harmful interaction by a foreign substance		X		X	
1.2.2	Elimination of harmful interaction by modification of an existing substance	X			X	
1.2.3	Elimination of a harmful effect of a field		X		X	
1.2.4	Elimination of a harmful effect by a new field		X			X
1.2.5	Elimination of a harmful effect caused by magnetic field		X			X
2.1.1	Synthesis of a Chain Substance-Field System		X		X	X
2.1.2	Synthesis of a Dual Substance-Field System		X			X
2.2.1	Replacing poorly controlled field with a well controlled			X		X
2.2.2	Increasing a degree of fragmentation of substance components	X			X	
2.2.3	Transition to capillary porous objects			X	X	
2.2.4	Increasing a degree of system dynamics		X		X	
2.2.5	Changing structure of a field			X		X
2.2.6	Changing structure of a substance object			X	X	

As shown in Table 2, the actions of each standard solution in subclass 1.1, 1.2, 2.1 and 2.2 can be categorized into 3 types namely, Modify, Add and Replace which act on the components

(substance and/or field) of the initial Substance-Field Model and/or its environment. The author has summarized it into a table called the MAR Operator as shown in Table 3.

Table 3. The MAR Operator

Number	Operator Name	Description
1	M: Modify	Modify the existing substance and/or field in the initial Substance-Field Model and/or its environment.
2	A: Add	Add new substance and/or field into the initial Substance-Field Model.
3	R: Replace	Replace the existing substance and/or field in the initial Substance-Field Model with new substance and/or field.

In summary, the problem of ARIZ has been analyzed and solution concepts have been attained for facilitating the understanding and usage of the problem solvers without lessening the essence and originality of ARIZ. Principle of Separation in Space and in Structure have been used to resolved the Physical Contradictions in Macro and Micro Level by Separating Parts and Steps of ARIZ to be simple (basic) and at the same time, complicated (advanced). Originally, Part 1 of ARIZ is deemed to test the complexity of the problem. If the problem is easily solved at the end of Part 1, then it is considered to be non-complex and not necessary to move on to the latter parts of ARIZ. However, there is no easy tool in Part 1 to help TRIZ beginners to generate ideas as the user-friendly 40 Inventive Principles has been removed from ARIZ-85C and

replaced with the complicated System of Standard Solutions.

The author attempts to revitalize the Contradiction Matrix Table and 40 Inventive Principles which can be considered as internal resource by incorporating them into Step 1.4 of Part 1 to resolve the Technical Contradiction selected for further analysis, and has simplified the subclass 1.1, 1.2, 2.1 and 2.2 of System of Standard Solutions which deal with improving the useful function and eliminating harmful interaction by grouping them into 3 types of actions e.g. Modify, Add and Replace which is named MAR Operator. The MAR Operator is suggested to solve the problem model in Step 1.7 of Part 1 instead of using the System of Standard Solutions as shown in Fig. 10.

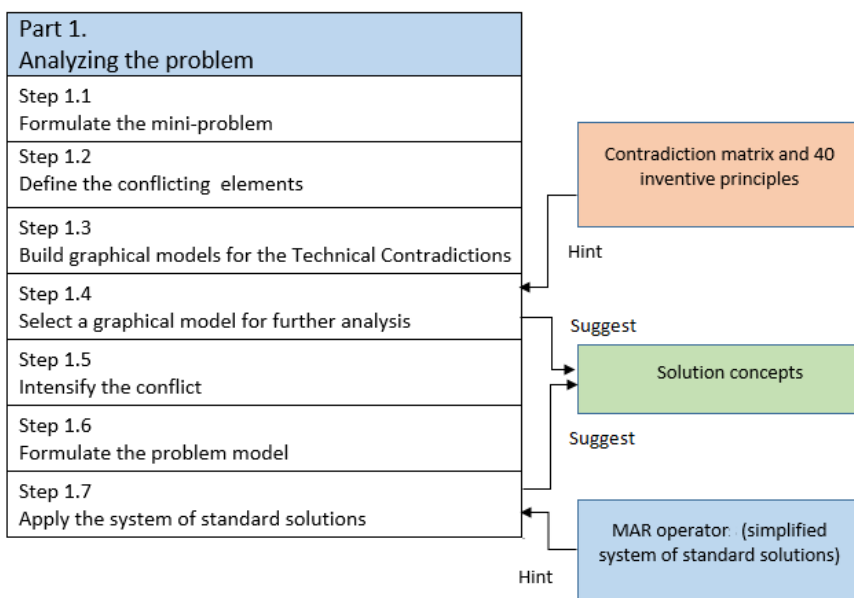


Fig. 10. The Proposed Algorithm of Part 1

The individual operator or the combination of operator can help the problem solvers to generate ideas for solving their problem and relieves them from the burdens of looking into the details of the complicated System of Standard Solutions. However, when the problem solvers have more confidence, they can come back to look at the

detailed situations and conditions described in each standard solution and refine their solution concepts using full scale of the System of Standard Solutions as deployed in Step 3.6 and Step 5.1 of ARIZ.

4. Case Study

The previously solved complex problem of low quality arc welding on industrial pipeline maintenance system (Benjaboonyazit, 2014) is used to test the effectiveness of the proposed algorithm. Some of the related steps are described as follows,

4.1. Initial Problem Situation

In pipelines maintenance system, a Magnetic Flux Leakage (MFL) device with strong magnetic field is used to magnetize the pipe wall to nearly saturation level while traveling through the pipelines. Magnetic field leakage at the corrosion part will be detected by magnetic sensors on the MFL device. After corrosion part of the pipeline is located, the damaged segment is cut off and replaced with the new one by welding it to the

existing pipeline, the problem occurs with the welding rod and arc column subjected to the magnetic force that causes it to deviate from the right position, thus render the low quality of arc welding.

Step 1.3 Build graphical models for the technical contradictions.

Technical Contradictions (TC) are formulated as follows:

TC-1: If the Residual magnetic field is strong, it is easy to detect corrosion part. On the other hand, the arc column will be deviated.

TC-2: If the Residual magnetic field is weak, the arc column can be positioned correctly. However, it is difficult to detect corrosion part.

The Graphical Models for the Technical Contradictions are built as shown in Fig. 11.

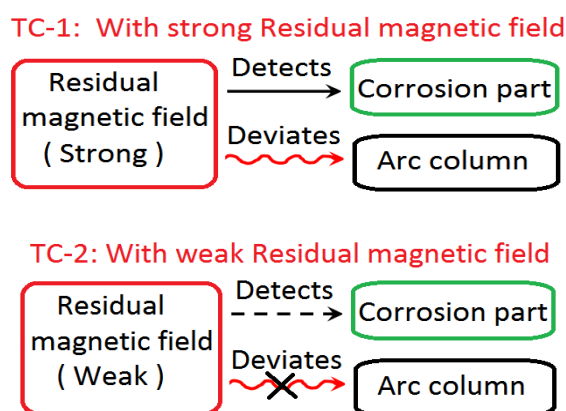


Fig. 11. Graphical models for the technical contradictions.

TC-1 is selected as Graphical Model for further analysis. In this case, with strong Residual magnetic field, it is easy to detect corrosion part. However, the arc column will be deviated. So we try to solve the technical contradiction at Step 1.4 with 40 Inventive Principles and eliminate harmful effect of Residual magnetic field at Step 1.7 with the MAR Operator in the proposed algorithm.

In Step 1.4, the Contradicting Parameters can be viewed as 21.Power VS 31.Object-generated Harmful Factors and 28.Measurement Accuracy VS 31.Object-generated Harmful Factors, the ideas generated with the suggested Inventive Principles are shown in Table 4.

Table 4. Contradiction Matrix Table with 40 Inventive Principles and Ideas generated

Contradicting Parameters	Inventive Principles	Ideas generated
21.Power VS 31.Object-generated Harmful Factors	2. Taking out	Demagnetize the residual magnetic field
	35. Parameter changes	-
28.Measurement Accuracy VS 31.Object-generated Harmful Factors	18. Mechanical vibration	Vibrate the pipeline to disalign magnetic domains
	3. Local quality	Demagnetize only the welding zone, no need to demagnetize the entire pipeline
	33. Homogeneity	-
	39. Inert atmosphere	-
	10. Preliminary action	Demagnetize the pipeline before the welding process

In Step 1.7, the initial Substance-Field Model is constructed with S1 (object) as Pipeline, S2 (tool) as Arc column, F1 as Residual magnetic field and F2 as Welding current. While welding Pipeline with Welding current (F2) through Arc column, Residual

magnetic field (F1) causes a harmful function by exerting force through the pipeline to deviate the arc column. The useful function (weld) becomes insufficient (Dashed line) as shown in Fig. 12.

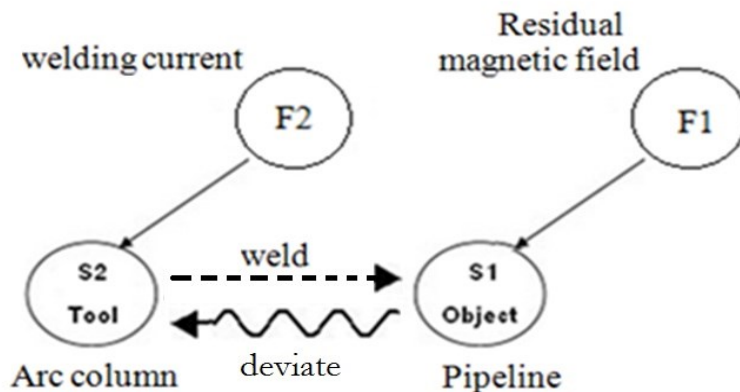


Fig. 12. Substance-Field Model of industrial pipeline maintenance problem

Instead of using the complicated System of Standard Solutions to find the solution for the above Substance-Field Model, the MAR Operator

are deployed to manipulated the components in the system and its environment and the ideas are generated as in Table 5.

Table 5. The MAR Operator and Ideas generated

The MAR Operator	Component manipulated	Ideas generated
Modify	Field	Use Alternating Current instead of Direct Current for welding
	Substance	-
Add	Field2	Heat (thermal Field) or strike (mechanical Field) the pipeline to disalign magnetic domains
	Substance	-
Replace	Substance and Field	Replace electric welding machine with torch welding machine

The ideas generated in Step 1.4 and Step 1.7 can be combined to form solution concepts that are practical enough to solve the problem such as “burn or strike the pipeline locally at the welding zone before welding to disalign magnetic domains” or “Replace DC electric welding machine with other welding machine”. Unfortunately, sometimes the situation or condition of the problem might not allow the problem solver to change components freely or the solution concepts might not be ideal enough. That is why ARIZ emphasizes on the necessity of formulating “Mini-Problem” on the first Part and analyzing the resources in the system and its environment in the second Part that might be used to solve the problem internally without introducing external resources.

The following steps show how this problem can be solved ideally with the latter parts of ARIZ. Step 3.4 Formulate the Physical Contradiction for the Micro-Level

The Physical Contradiction for the Micro-Level is formulated as follows, “Free electrons” should flow around the pipe in the welding zone to create proper intensity and direction of magnetic field during welding time to eliminate the harmful effect of the very strong residual magnetic field, and should not flow around the pipe in the welding zone during pre-welding time to preserve the ability of the very strong residual magnetic field to detect corrosion part as shown in Fig. 13.

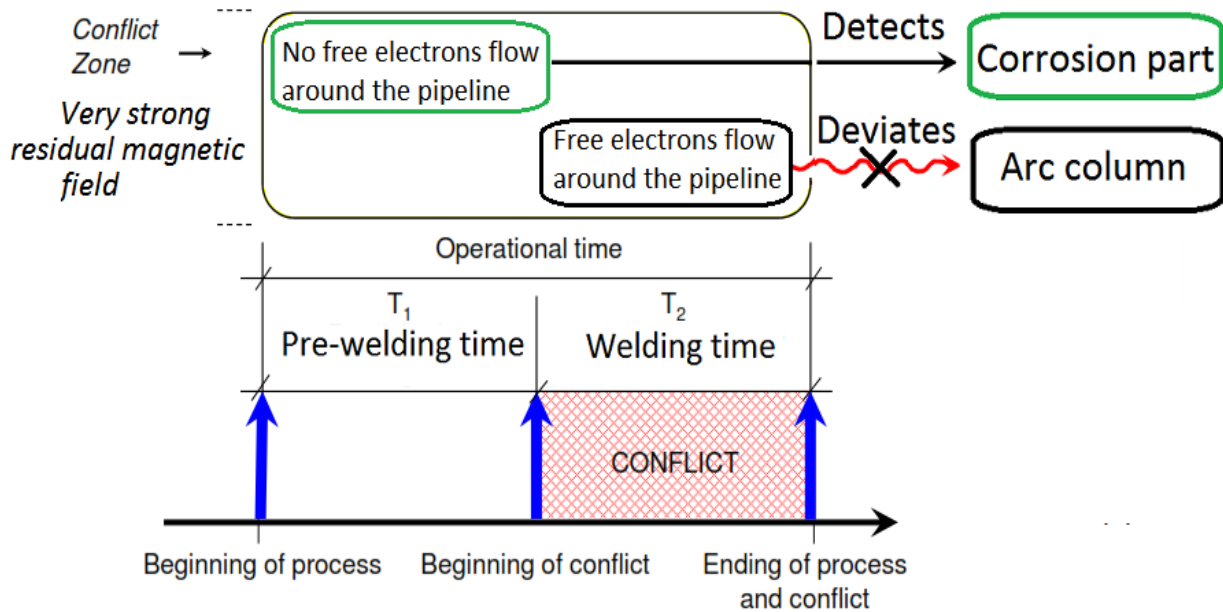


Fig. 13. Physical Contradiction for Micro-Level

Step 3.5 Formulate the Ideal Final Result (IFR-2)

The Ideal Final Result (IFR-2) from the Physical Contradiction for the Micro-Level is formulated as follows,

IFR-2: “Free electrons” should, on their own, flow around the pipe in the welding zone to create proper intensity and direction of magnetic field during welding time to eliminate the harmful effect of the very strong residual magnetic field, and should be, on their own, neutralized during pre-welding time to preserve the ability of the very strong residual magnetic field to detect corrosion part.

Step 3.6 Consider Solving the New Problem using the System of Standard Solutions

Consider Solving the New Problem in step 3.5 using Standard solution 1.2.5 with magnetic field from welding current as resource to generate ideas. Standard solution 1.2.5 “Switching Off” a Magnetic Influence: which states that If it is necessary to eliminate the harmful effect of a magnetic field in a Substance-Field Model, the problem can be solved by applying the physical effects which are capable

of “switching off” the ferromagnetic properties of substances, for example, by demagnetizing during an impact or during heating above the Curie point.

Potential solution: Use “Magnetic field from welding current”.

Magnetic field from welding current is a derived resource in the system and can be utilized to counteract the residual magnetic field in the pipeline locally at the welding zone during the welding time. By winding the electrode lead and grounding wire around the pipe near the welding zone with proper amount of turns and direction, the free electrons will, on their own, flow around the pipe in the welding zone to create proper intensity and direction of magnetic field during welding time as soon as the arc column is initiated, and during the non-destructive inspection process before the welding time, no free electron is flowing around the pipe, thus, the ability of the residual magnetic field to detect corrosion part can be preserved as shown in Fig 14.

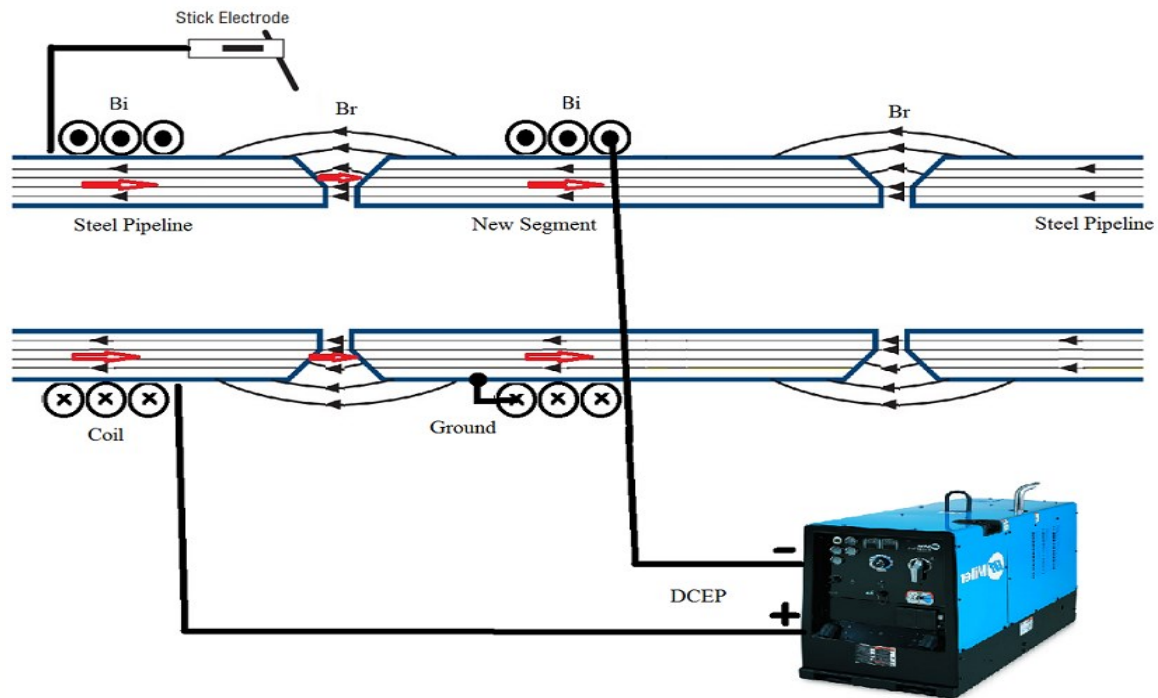


Fig. 14. Potential solution

5. Discussion

The case study above shows that even the complex problem like the low quality arc welding problem during pipeline maintenance can be easily solved at the first part of ARIZ in the proposed algorithm. The Contradiction Matrix Table and 40 Inventive Principles, though maybe simple, are still useful in idea generation for resolving technical contradiction in Step 1.4. Moreover, the proposed MAR Operator in Step 1.7 is also very effective in manipulating components of the substance field system and its environment in order to improve the useful function or eliminating the harmful interaction without the burden of going into the details of System of Standard Solution.

As for the general problems from the general problem solvers, especially from TRIZ beginners, the proposed algorithm is sufficiently effective enough to solve general problems with Part 1 of ARIZ after which Part 7 can be reached for evaluating the solution concepts attained in Part 1. This help make ARIZ more user-friendly and can be more popular among problem solver. ARIZ will be adopted more widely in industries and the academic world as well. This new version of ARIZ proposed here is easy to understand and applied by the general problem solvers, especially from TRIZ beginners. In this aspect, the new method solves the problem addressed in this paper. Besides, when people are encouraged to learn and get more acquainted with ARIZ, it will be easy for them to start solving complex problem ideally by exploring system resources and formulating Ideal Final Result and Physical Contradiction in the latter parts of ARIZ process.

And when compared with other variants of ARIZ, in general, this new method required shorter learning curve from problem solvers. More importantly, with minimum changes to the system, this new method preserves the essence and originality of ARIZ-85C which is the last version developed by Altshuller while facilitating the problem solvers to solve technical problem with less burden.

6. Conclusions

A new version of ARIZ is proposed to facilitate the understanding and usage of problem solvers by integrating the 40 Inventive Principles and the MAR Operator into Part 1 of ARIZ without lessening the essence and originality of ARIZ-85C. A case study of industrial pipeline maintenance problem is used to test the effectiveness of the proposed version and comes out with satisfactory result. The new version is expected to be used widely and can be easily extended to cover the problem in the business and management area.

In addition, a computer software called "ARIZ-85C+" which supports this version of ARIZ, is under development. More rigorous testing and quantitative evaluation of the proposed version can be conducted with more cases in the near future.

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