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TRIZ: A Perfect Tool for Process Innovation by Tackling Engineering contradictions

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Abstract: *For sustainability and meeting competitive requirements, firms usually perform product and process innovation. In fact the various contradictions like increase in strength naturally increase the amount and cost of material, are the major hurdles for innovation. Overcoming this contradiction headache needs to be a significant concern for all managers. There comes the Teoriya Resheniya Izobreatatelskikh Zadatch (TRIZ) technique which is scientifically proved to be an efficient tool for solving contradictions. Here in this work the concepts of TRIZ, overcoming technical contradictions are briefly described in a mechanical context with some illustrations.*
Keywords: *Contradiction Matrix, Engineering Contradictions, Inventive Principles, TRIZ.*

I. INTRODUCTION

There are numerous ways to solve industrial process problems during the developmental stages of products, processes, or services. Genrich Altshuler a Russian patent expert and navy consultant created the Theory of Inventive Problem Solving (generally known as TRIZ). The abbreviation TRIZ originated from the Russian phrase “Teorija Rezhenija Izobretatel’skisch Zadach” [1]. They also confirm that this work led Altshuler to research more on problem solving [2, 3]. As [4] noticed that these methods were based on the study of more than two million patents worldwide. Moreover these methods showed that the existing intuitive methods were obsolete for inventions of the century. [5, 6] indicate that TRIZ is a type of innovative theory that works by solving contradictions. According to [6] evolution of technical systems and the levels of invention by [7], the TRIZ methodology is composed of various types of methods, tools, and calculations for solving technical problems and providing innovative exploration .Also it is evident that TRIZ has been applied to various fields [8,9,6]

In addition, TRIZ uses concepts and tools that provide systematic approaches and general principles for analyzing and modeling problems, forming creative ideas, and forecasting evolution trends of a system or project. Classical TRIZ (developed by Altshuler and his colleagues) consists of methods to formulate and solve problems, a knowledge basis and the laws of evolution for technical systems [8]. In general, TRIZ is applied as follows: 1) an inventive problem is reformulated as a generic TRIZ problem, 2) The TRIZ tools are introduced to analyze and propose a general solution and 3) a generic solution (which should be interpreted to solve a specific inventive problem) is [10,11] . Large companies such as Procter & Gamble, Ford Motor Company, Boeing, Phillips, Samsung and LG have used TRIZ [12].

II. TRIZ

TRIZ is something beyond being merely a theory or a set of principle. It can be called as a collection of tools and techniques. TRIZ is a methodology for the effective development of new [technical] systems, besides it being a set of principles describing how technologies and systems evolve [13].Also, it has been described by as a toolkit consisting of methods which cover all aspects of problem understanding and solving. It can be regarded as a toolkit [14] and is the most comprehensive, systematically organized tool for invention and creative thinking methodology known to man [15]. It is a way of analytical logic and a systematic way of thinking. This systematic approach gives an overall structure for the TRIZ tools and techniques. Even though the TRIZ has been described in various ways–a methodology, a toolkit, a science [16], a philosophy [17], etc., and this creating an embracement on what it actually is, what it is said to be capable of achieving. It is a systematic approach for determining innovative solutions for technical problems and technical systems [10].

III. TRIZ WORKING

TRIZ possesses significant advantage over other methods applied to problem solving and innovation. Conventional methods like brainstorming, mind mapping, etc., have the ability to find or uncover a problem and its root cause, but lack the ability to give proper, innovative and quick solution. On the other hand, TRIZ determines the problems and offers direct solutions to them, along with confidence that most possible new solutions to the problem have been considered [14].

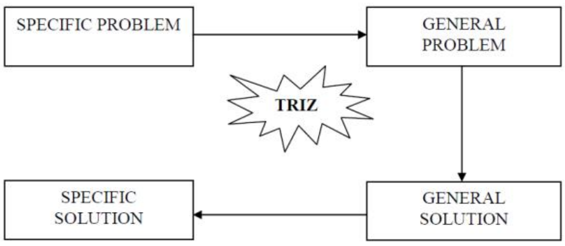

Figure 1 TRIZ Methodology

TRIZ solution consists of a set of conceptual solutions to technical problems. This set of solutions comprises of various inventive principles, trends of technical evolution and standard solutions [14].To apply any of these solutions the problem is reduced to its essentials and is defined in a conceptual format. Now, the problem can be matched with one or more of the conceptual solutions. The identified conceptual solution can afterwards be transformed into a specific, factual solution that answers to the original problem. This approach is the overview of the TRIZ problems solving process as shown in Fig. 1. It is a distinctive feature of TRIZ, distinguishing it from other conventional problem solving methods.

IV. MAIN CONCEPTS IN TRIZ

To understand the TRIZ methodology, it is important to have a clear understanding of its fundamental concepts. Contradiction, Ideality and Patterns of evolution are the main concepts of TRIZ which were introduced by Altshuller and at least one of these concepts is applied in any TRIZ problem solving process.

Table 1 39 Engineering Parameters [2, 3]

1. Weight of moving object	2 .Weight of nonmoving object	3. Length of moving object
4. Length of nonmoving object	5. Area of moving object	6. Area of nonmoving object
7. Volume of moving object	8. Volume of nonmoving object	9. Speed
10. Force	11. Tension, pressure	12. Shape
13. Stability of object	14. Strength	15. Durability of moving object
16. Durability of nonmoving object	17. Temperature	18. Brightness
19. Energy spent by moving object	20. Energy spent by nonmoving object	21. Power
22. Waste of energy	23. Waste of substance	24. Loss of information
25. Waste of time	26. Amount of substance	27. Reliability
28. Accuracy of measurement	29. Accuracy of manufacturing	30. Harmful factors acting on object
31. Harmful side effects	32. Manufacturability	33. Convenience of use
34. Repairability	35. Adaptability	36. Complexity of device
37. Complexity of control	38. Level of automation	39. Productivity

4.1 Contradictions

Contradictions are mutually contradicting requirements apparent in compatibility of desired features within a system. Resolving the contradictions solves the problems. There are two major types of contradictions: *technical contradictions and physical contradictions*. Technical contradiction: This arises when an attempt to improve certain attributes or functions of a system leads to the deterioration of other attributes of that system. For example, a bigger and powerful engine for an aircraft increases its speed but it would contribute more weight to the aircraft, which in turn limits the speed, therefore negating the desired benefit of increased speed. Physical contradiction: This arises when there are in consistent requirements to the physical condition of the same system. A feature must be present and it should not be present at the same time. For instance, a system might have a function (or be in a state) which is both beneficial and adverse or unpleasant. For example, helmet's big size helps with protection from dust, but may make it too cumbersome to carry around, and therefore, its size requirements (big helmet for protection and small helmet for convenience) present a physical contradiction.

After noticing the significance of contradictions Altshuller went on to classify them into 39 parameters and in a similar way he identified 40 common principles that he found had been frequently and repeatedly used in patented solutions. To illustrate all these possible technical contradiction combinations he produced a 39 × 39 matrix and identified which of the 40 inventive principles were more commonly associated with specific combinations of contradiction parameters. This matrix is called the Technical Contradiction Matrix.

4.2 Contradiction Matrix

This matrix is a road-map between the technical contradiction and the possible solutions given in the 40 inventive principles. The 39 Engineering parameters are present in both an x and y axis, giving a 39×39 matrix. The Contradiction Matrix is, in principle, applicable to all contradictions, regardless of the problem at hand. The 'improving feature' of the problem (e.g. improved reliability) is given on one axis, while the other axis represents 'worsening features' that may be secondary problems; thus a contradiction. At the intersection of each improving feature and worsening feature, applicable inventive principles are given by reference number.

	Worsening Feature → / Improving Feature ↓	Weight of moving object	Weight of stationary object	Length of moving object	Length of stationary object	Area of moving object	Area of stationary object
		1	**2**	**3**	**4**	**5**	**6**
1	**Weight of moving object**	+	-	15, 8, 29,34	-	29, 17, 38, 34	-
2	**Weight of stationary object**	-	+	-	10, 1, 29, 35	-	35, 30, 13, 2
3	**Length of moving object**	8, 15, 29, 34	-	+	-	15, 17, 4	-
4	**Length of stationary object**		35, 28, 40, 29	-	+	-	17, 7, 10, 40
5	**Area of moving object**	2, 17, 29, 4	-	14, 15, 18, 4	-	+	-
6	**Area of stationary object**	-	30, 2, 14, 18	-	26, 7, 9, 39	-	+

Figure 2 Contradiction Matrix

4.3 Ideality

Ideality derives from ''the ideal machine'', an arbitrary system which has all its parts performing at the greatest possible capacity, introduced by Altshuller [2]. Ideality is a measure of how close a system is to the ideal system of its kind i.e. the ideal machine (or the ideal final result (IFR)). Ideality of a system can be expressed in mathematically as

$$Ideality = \frac{\sum Benefits}{\sum cost + \sum harms}$$

The benefits are the useful functions by the system and harms are its unwanted outputs, waste products (also regarded as harmful functions) of the system. One of the primary objectives of TRIZ is to increase ideality (or move a system toward the IFR).As the above equation indicates, this can be achieved by one or a combination of finding a means of increasing the benefits provided by the system, reducing the costs of resource inputs towards providing those benefits, or reducing the harmful functions (or unwanted outputs) that come with the benefits. In innovation, defining the IFR is important since it points at the direction in which the search for new and better systems should be carried out [2, 3].

4.4. Patterns of evolution of systems

Altshuller noticed that technical systems usually follow certain regularities in their development. These regularities were transformed into patterns of evolution and for developing good solutions to problems they were used and it can be used for predicting how systems would evolve [24].It was found that there are eight distinct trends that guide development, and each trend further divides into lines of evolution [12].It is possible to express the idea of technical evolution through the concept of ideality [25]. Understanding the patterns of evolution can help in forecasting technology development and determining features that are likely to be successful in newly launched products.

Table 2 TRIZ 40 Design Principles [2, 3]

1 Segmentation	2 Taking out	3 Local quality
4 Asymmetry	5 Merging	6 Universality
7 Russian dolls	8 Anti-weight	9 Preliminary anti-action
10 Preliminary action	11 Beforehand cushioning	12 Equipotentiality
13 The other way round	14 Spheroidality – Curvature	15 Dynamics
16 Partial or excessive actions	17 Another dimension	18 Mechanical vibration
19 Periodic action	20 Continuity of useful action	21 Skipping
22 Blessing in disguise	23 Feedback	24 Intermediaries
25 Self-service	26 Copying	27 Cheap short-lived objects
28 Mechanics substitution	29 Pneumatics and ydraulics	30 Flexible shells and thin films
31 Porous materials	32 Colour changes	33 Homogeneity
34 Discarding and recovering	35 Parameter changes	36 Phase transitions
37 Thermal expansion	38 Strong oxidants	39 Inert atmosphere
40 Composite materials		

V. CASE STUDY

(*Ref: Alla Zusman and Boris Zlotin, Ideation International Inc.)*

Eventhough the TRIZ can be used for a number of applications in the field of mechanical engineering such as automobile engineering, industrial engineering, facility planning and design, supply chain management etc.. Here a case study from manufacturing is selected for explaining the solution procedure for TRIZ .

Problem: To make a vice that can grip work pieces of complex shape. It is expensive to produce a unique tool for every work piece. Also it is very difficult and time consuming for every machining the holding device change. Let us see how this problem is solved.

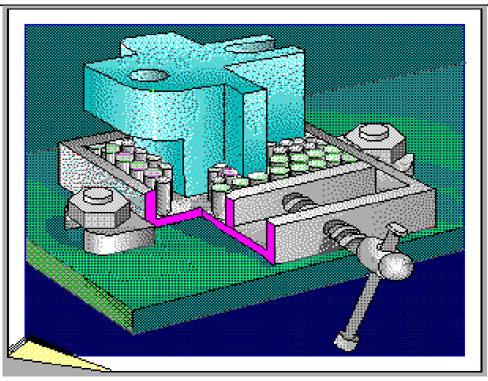

Figure 3 Flexible Jaw vice

Define the problem and identify the contradictions:

- Parameter to be improved / worsened:
  –Stability of an object (with a better grip) ⇨ 13

- Worsening/improving parameter:
  –Shape (cannot accommodate different or complex shapes) ⇨12
  –Adaptability ⇨35

From TRIZ Contradiction table

– (13, 12) ⇨1 (segmentation), 4 (asymmetry), 18, 22
– (13, 35) ⇨2, 30, 34, 35
– (35, 13) ⇨1, 8, 15, 37
– (12, 13) ⇨1, 4, 18, 33

According to the values obtained from the table identify the necessary inventive principles for arriving at the ideal final result. Solution for the considered case is to make a vise with ordinary jaws and add multiple hard bushings around the work piece that move horizontally according to the work piece's shape. Placing multiple hard bushings around the work piece can conform to the necessary shape thus eliminating the case of separate vice or jaws for various materials of different shapes. Hence time for setting and money for separate device has been saved. Likewise there are other solutions are also possible by using other inventive principles.

VI. DISCUSSIONS

Firms are eagerly waiting for innovative and advanced technologies to respond to market trends and customer needs. They will try to make it indigenously but these contradictions drastically affect the speed and quality of their Research and Development. That is why TRIZ (the theory of inventive problem solving) has been promoted by several corporates as a systematic methodology or toolkit that tackle these contradictions which give rise to proper and innovative solutions as per demand . The methodology originated in U.S.S.R in the 1960s, has spread to over almost all countries across the world. It is now being taught in several universities and it has been applied by a number of global organizations for new product development.

VII. CONCLUSION

From this study it is inferred that TRIZ is a wonderful tool for overcoming the technical contradictions. It does not avoid the contradictions but find out and intensify it. The problem is first defined and then the contradictions are identified. Then classify them to improving and worsening feature. Using the contradiction matrix and other tools a number of innovative solutions are obtained and the most effective solution for the particular context is being selected. If the problem definitions are somewhat different then obtained solutions would also be different. That is using other inventive principles it is possible to obtain some other innovative solutions.

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