



TRIZ: A New Approach to Innovative Engineering & Problem Solving 1.

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1. Introduction

Problem solving is the heart of improving both product designs and the processes to make them. Continuous improvement is identifying and overcoming one problem after another, assisted by our own problem-solving methodologies selected from a huge palette of those that are known. Most of the time we make small improvements; once in a while we make a big one.

TRIZ (pronounced *trees*) is a Russian acronym that means Theory of Inventive Problem Solving. It is a systematic approach for breakthrough solutions to tough-nut problems based on finding a creative solution if one is possible. In industries that are compressing product and process development times, innovation cannot be a sometime thing. It has to occur regularly.

However, in engineering, as well as in much other human activity, the core process of creative problem solving remains trial-and-error, and when ideas are proposed without rules for generating them, the problem-solving process also remains stochastic. "Let's try this. Did it fail? Well, let's try another approach." We try different ideas until we either find a solution or give up.

Although idea generation seems chaotic, most steps to a problem solution follow a vector of psychological inertia, which is a pathway guided by the cumulative constraints of recognized perceptions, previous experience, knowledge, common sense, and cultural background. These lead the problem solver in traditional directions, while the solution may lie far from the path of inertia.

Trial-and-error has been enhanced by methods such as brainstorming, morphological analysis, Plan, Do, Check, Act (PDCA) storyboards, and synectics. These methods are quickly learned and easy to use, but when applied to challenging engineering and manufacturing problems, they remain too intuitive and stochastic to stimulate creativity.

2. Theory of Inventive Problem Solving

Genrikh Altshuller and his school started developing TRIZ in Russia in 1946. The main axiom is that evolution of technological systems is governed by objective laws, which Altshuller called Laws of Technological System Evolution. They can be used instead of blind search to consciously develop technological systems (or to solve problems). To formulate these laws, Altshuller analyzed some 400,000 invention descriptions from different fields of engineering gleaned from world-wide patent databases. He selected and examined the most effective solutions--the breakthroughs.

System Conflict

From this work, Altshuller developed the concept of System Conflict. A problem requires creativity when attempts to improve some system attributes lead to deterioration of other system attributes. Collisions, such as weight versus strength or power versus fuel consumption, lead to System Conflict. Creatively solving such a problem requires overcoming the conflict by satisfying all colliding requirements.

Ideality Principle

A second fundamental axiom of TRIZ is the Ideality Principle, which is that technological systems evolve toward increasing ideality. No system is a goal in itself, but only a "fee" for realizing the function desired of the system. The lower the fee, the more ideal the system.

At the ultimate, an Ideal System needs no energy to operate, costs nothing to produce, occupies no space, has no failure modes, etc. The Ideal System is no longer a physical entity, but the required functions are performed. In real systems, the "degree of ideality" can be characterized by costs measured in dollars, and by other means, compared with the aggregate of the useful functions performed by the system.

These laws are very helpful because they give designers a general direction for creative thinking. They are more frequently applied to practical problems using three principal sub-systems of TRIZ. (See **Figure 1**). One subsystem is the Algorithm for Inventive-Problem Solving (Russian acronym ARIZ), which

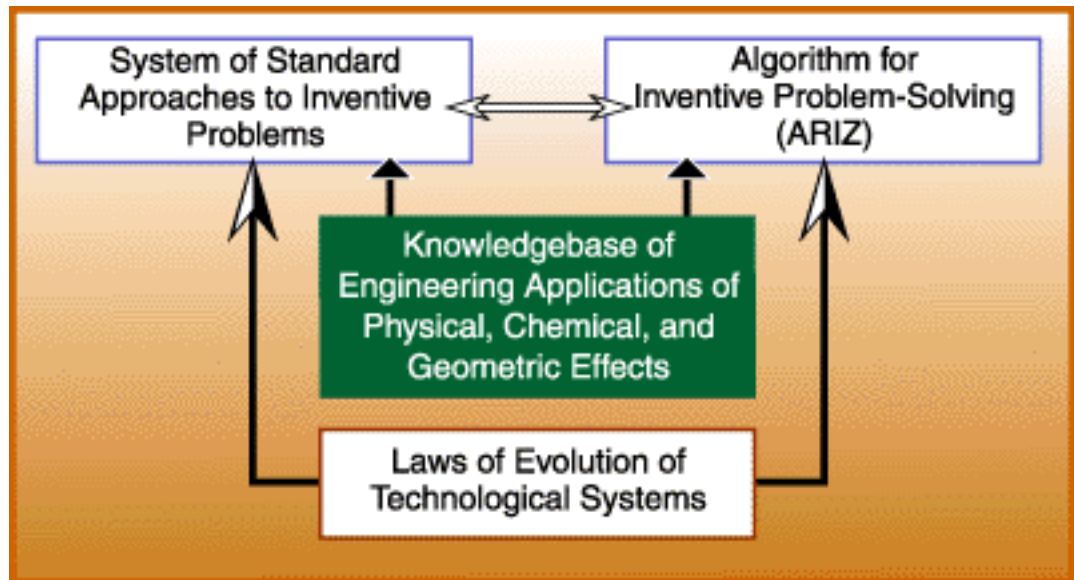


Figure 1

is a set of sequential, logical procedures aimed at eliminating the system conflict at the heart of the problem.

A second sub-system, Standard Approaches to Inventive Problems ("Standards" for short), is a set of rules for problem solving based on the laws established by Altshuller stating that many problems from different areas of technology can be solved by the same conceptual approaches.

The third sub-system, the Knowledgebase of Physical, Chemical, and Geometric Effects, greatly facilitates problem solving by suggesting analogies from prior creative solutions.

3. Algorithm for Inventive-Problem Solving (ARIZ)

ARIZ is the main analytical and solution tool of TRIZ. It provides specific mechanisms for development of technological systems rather than the conventional approach to a creative problem. Traditional thinking tires to "leap" to a solution from the problem as given. The more difficult the problem, the more "leaps" before finding a solution.

On the other hand, TRIZ assumes that the degree of difficulty of a problem largely depends on the way it is formulated. The clearer the formulation, the easier to arrive at a solution. In the TRIZ approach, inventive-problem solving as a solution-seeking procedure is replaced by a process of problem reformulation. Through a chain of successive reformulations of the problem, it is transformed from ill-defined and frequently incorrectly-formulated mush into a lucid formulation of the root conflict. A solution either becomes obvious or it becomes clear that the problem cannot be resolved because we do not presently have the required technology or the scientific knowledge.

ARIZ is the set of successive logical procedures to reinterpret the initial problem through consecutive reformulations. Its structure consolidates two major ideas: System Conflict and the Ideality Principle. Since a technological problem becomes an inventive one when a System Conflict should be overcome, the problem for inventive-problem solving must include special

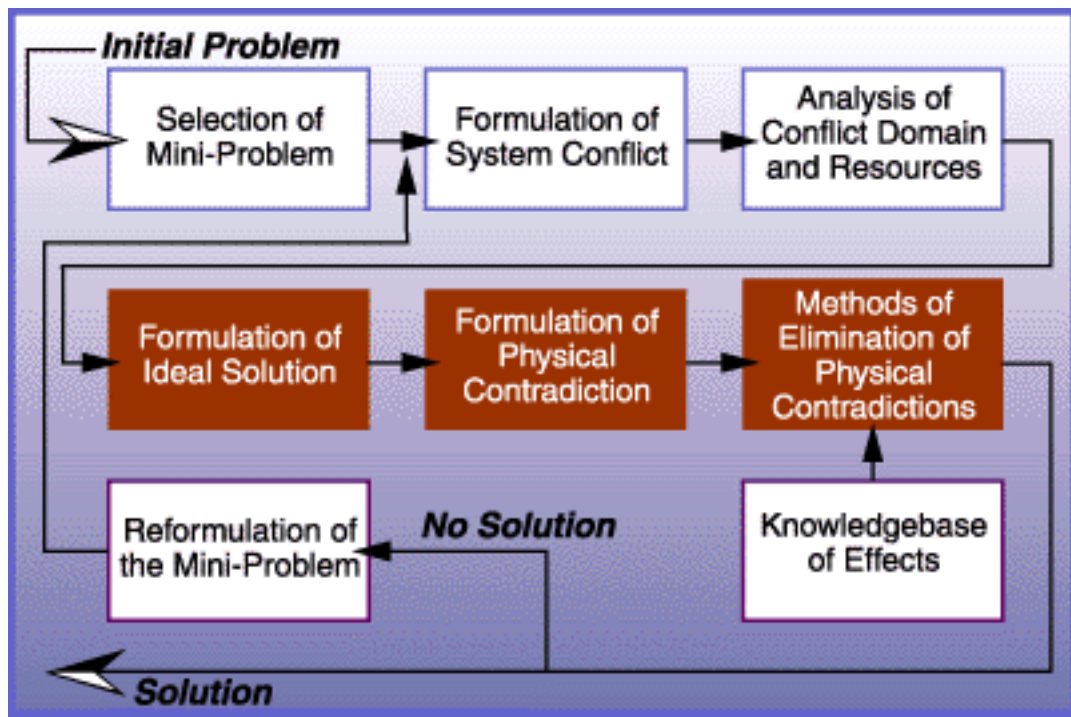


Figure 2

subroutines to reveal and clarify these conflicts. **Figure 2** shows the basic flow of problem reformulation using ARIZ.

Solving a problem using ARIZ starts with a transition from a vaguely (or even wrongly) defined initial problem into a mini-problem that is formulated by the

following rule, "Everything in the system remains unchanged, but the required function is realized."

The next step of formulation of the System Conflict, followed by a "Model of the Problem," which is a simplified scheme of the conflict. The Conflict Domain is specified to narrow the area of analysis.

The next step is assessment of the available material and energy resources. The problem is treated by selecting a critical system resource in the Conflict Domain and formulating an Ideal Final Result (IFR). Usually, to realize the IFR, this resource must possess contradictory physical properties, such as both cold and hot, opaque and transparent, electroconductive and electroinsulative, and so on. Such a condition, called a Physical Contradiction, is the cause of System Conflict.

ARIZ offers three generic methods for overcoming Physical Contradictions:

1. Separation of opposite properties in time: During one interval an object has property P; during another interval it has anti-property -P.
2. Separation of opposite properties in space: Part of the object is given property P while another part is given anti-property -P.
3. Separation of opposite properties between the system and its components: The whole system has property P while its components have the opposite property -P.

Elimination of the Physical Contradiction is provided by maximum use of material resources in the system and is supported by the Knowledgebase of Physical, Chemical, and Geometric Effects. As a rule, if a solution does not appear after an analysis has been thoroughly performed, the initial problem was wrongly formulated. In many cases a more general problem should be stated.

The key to success is to assume that you do not understand the nature of the problem. Instead, develop the discipline to forego thrashing for solutions and continue refining the problem definition down to the Conflict Domain and the basic Physical Contradiction using the ARIZ logic process. Software is available to prompt inventive problem solvers on the Standards and the Knowledgebase, but these are only aids. People solve inventive problems.

Three sample solutions using an abridged ARIZ process are provided:

- A. Spacecraft-Meteorite Collision Simulator**
- B. Toolholder-Spindle Interface Problem**
- C. Log Orientation Problem**

All three solutions have been implemented. Note how the steps of the process focus on the core of each problem and lead toward an Ideal System solution.

A. Spacecraft-Meteorite Collision Simulator

Problem Statement

To simulate a meteorite hitting a spacecraft, a 3-5 mm diameter steel ball is injected into a high-speed jet and accelerated to collide with a fragment of the spacecraft's shell (see **Figure A-1**). Dropped into an 8 km/sec jet stream, the balls remained intact but this speed inadequately represented a collision. At the desired speed of 16 km/sec, the balls disintegrated from acceleration stress upon entering the jet stream. Attempts to use a stronger material for the balls failed.

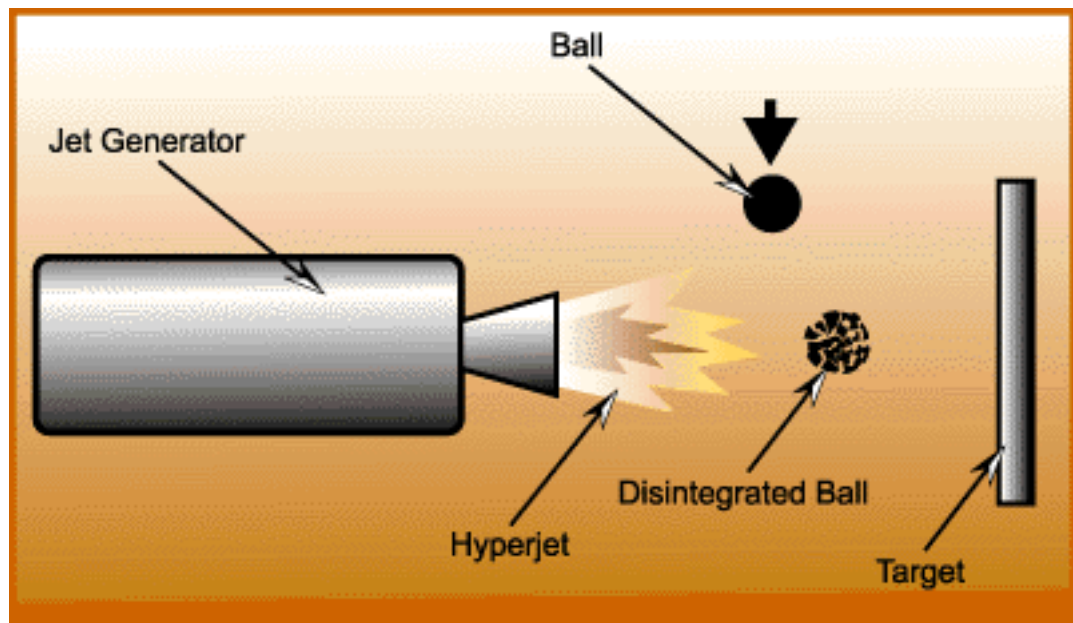


Figure A-1

Mini-Problem

It is necessary, without major changes in the system, to accelerate the ball.

System Conflict

The 16 km/sec jet accelerates the ball, but destroys it. 8 km/sec is too slow.
Reformulated Problem: Since no material can survive this environment, the destroyed ball must somehow be reassembled.

Model of the Problem

The 16 km/sec jet accelerates the ball well, but disintegrates it. Something is needed to reassemble the fragments and retain the effectiveness of the ball hitting the target.

Analysis of the Conflict Domain and Resources

The Conflict Domain is a layer of the jet in the vicinity of the "cloud" of fragments. The only resource available in the Conflict Domain is the gas itself.

IFR

The gas in the Conflict Domain should develop compressive forces acting toward the center of the cloud.

Physical Contradiction

To develop compressive forces, the gas particles should move toward the center of the "cloud."

Elimination of the Physical Contradiction

Separation of opposite demands in time: Develop compression only at the moment of disintegration of the ball.

Engineering Solution

Cover the ball with an explosive. When the ball enters the jet, the resulting implosion prevents the fragments from flying away. They behave as a concentrated mass impacting the target (see **Figure A-2**).

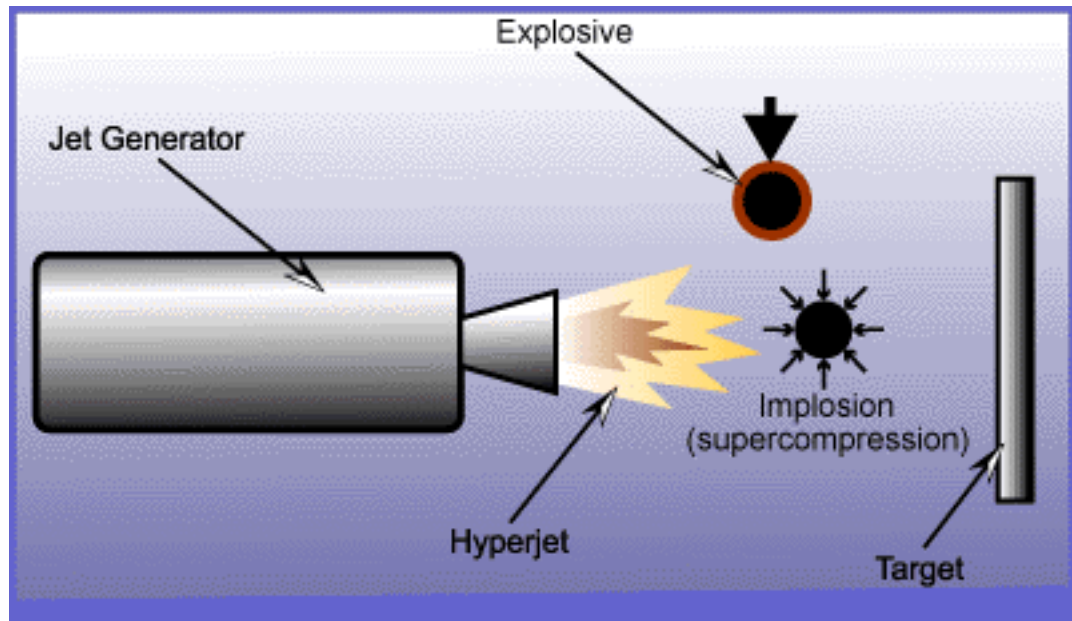


Figure A-2

B. Toolholder-Spindel Interface Problem

Problem Statement

7/24 tapered toolholders are used in the majority of CNC machining centers. They are impossible to machine perfectly; the tolerances for the male and female tapers assure contact at the front part (close to the flange) to obtain higher stiffness, and the large diameter of the taper is dimensioned to guarantee a large clearance between the flange of the toolholder and the spindle face (see **Figure B-1**). As a result, a small clearance at the back causes radial runout, and the flange-face gap reduces stiffness at the end of the tool.

Mini-Problem

To improve the stiffness of the toolholder-spindle interface without major changes in the system.

System Conflict

Toolholder taper positions the tool, but does not allow flange-face contact.

Model of the Problem

Some element of the existing system should permit flange-face contact without hindering the positioning ability of the toolholder.

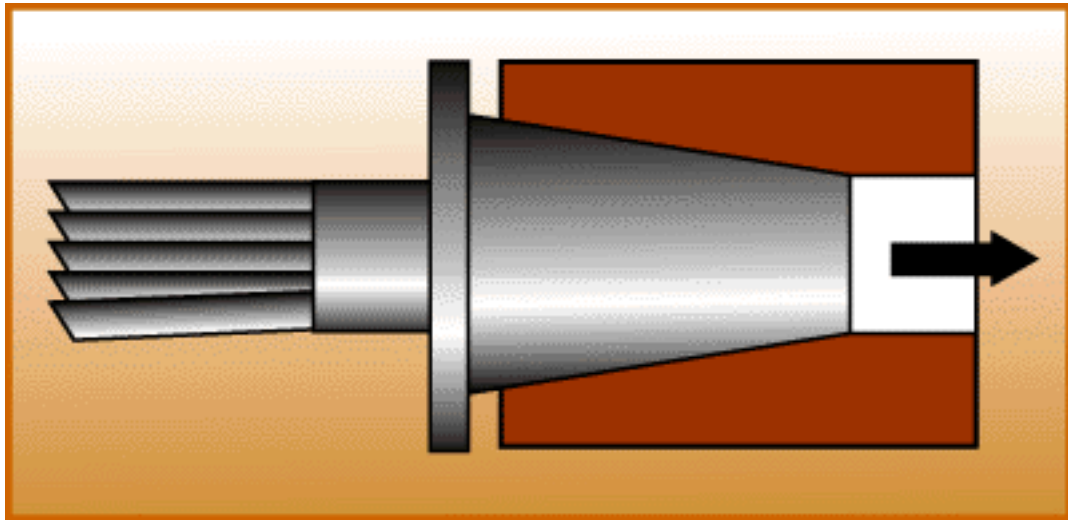


Figure B-1

Analysis of the Conflict Domain and Resources

The Conflict Domain is the contact area between the male and female tapers. The only resource is the surface of the male taper.

IFR

The surface of the male taper should both position the toolholder and provide the flange-face contact.

Physical Contradiction

To position the toolholder, there should be solid contact between the male and female tapers. but to provide the flange-face contact, there should be no contact between male and female tapers.

Elimination of the Physical Contradiction

Separate the opposite demands between the system and its components. This can be done if the entire surface of the male taper has no solid contact with the female taper, but some points of that surface do.

Engineering Solution

The male taper is covered with precision balls and managed stiffness. These "springing" balls compose a virtual tapered surface that allows for the flange-face contact (see **Figure B-2**).

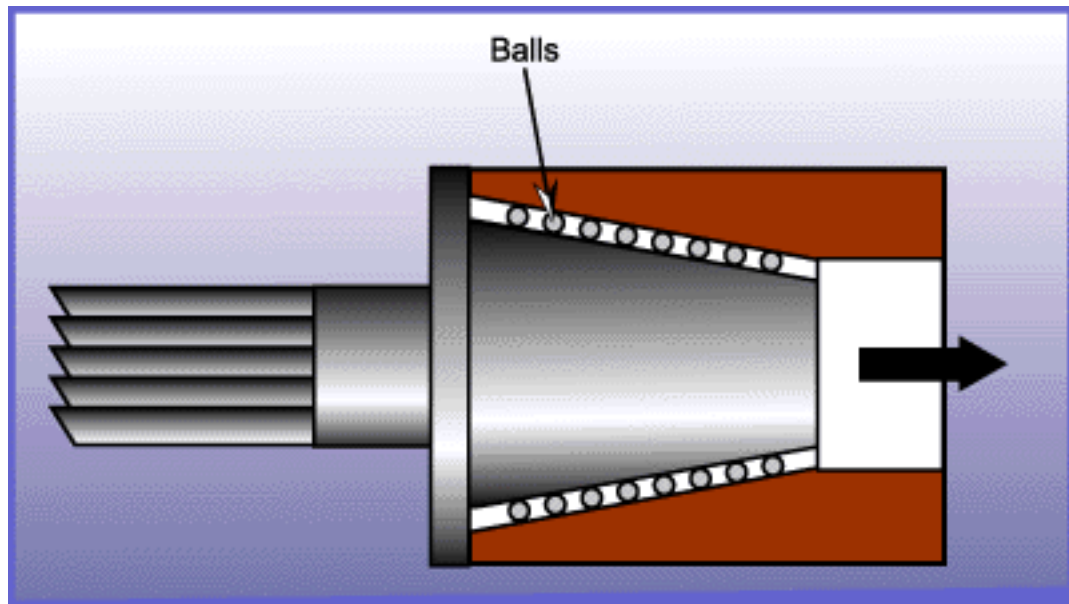


Figure B-2

C. Log Orientation Problem

Problem Statement

After debarking in a chip mill, logs drop chaotically onto a conveyor and must be longitudinally oriented. Robot-like aligning devices are complex, occupy a large floor area, and are not reliable untangling jams (see **Figure C-1**). Needed was a simple, reliable, cost-effective method to align logs.

Mini-Problem

The logs are to be oriented without major alterations of the system.

System Conflict

Orientation of logs requires an aligning device, but this complicates the system.

Model of the Problem

Some element of the existing system should be responsible for the orientation.

Analysis of the Conflict Domain and Resources

The Conflict Domain is the surface of the conveyor. The only resource is the conveyor.

IFR

The conveyor itself orients the logs.

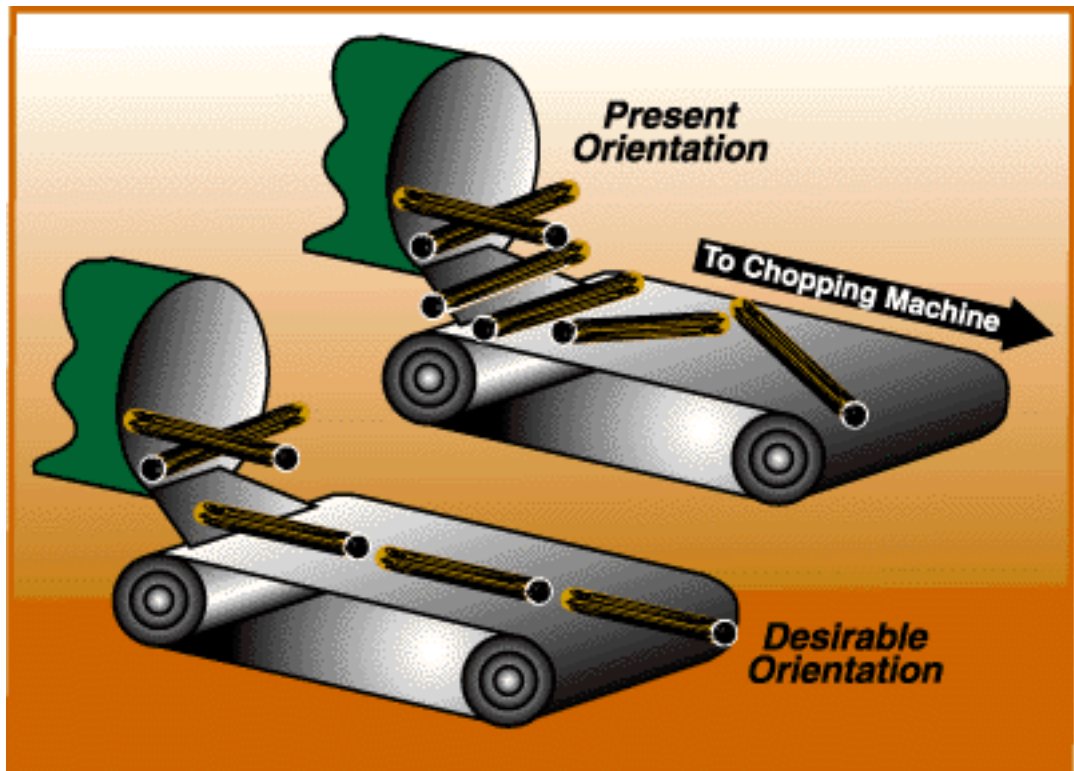


Figure C-1

Physical Contradiction

To orient, different parts of the conveyor should have different speeds, but to convey, the surface should move at one speed.

Elimination of the Physical Contradiction

Separate opposite demands between the system and its components. Let the whole conveyor move at one production speed, but its components move at a different speed.

Engineering Solution

Side belts move in opposite directions to align the logs. The central belt conveys the logs aligned in the longitudinal direction (see **Figure C-2**).

Note: Alignment problems are common, and many are solved by similar mechanisms. However, the solution developed using TRIZ is closer to ideal than most.

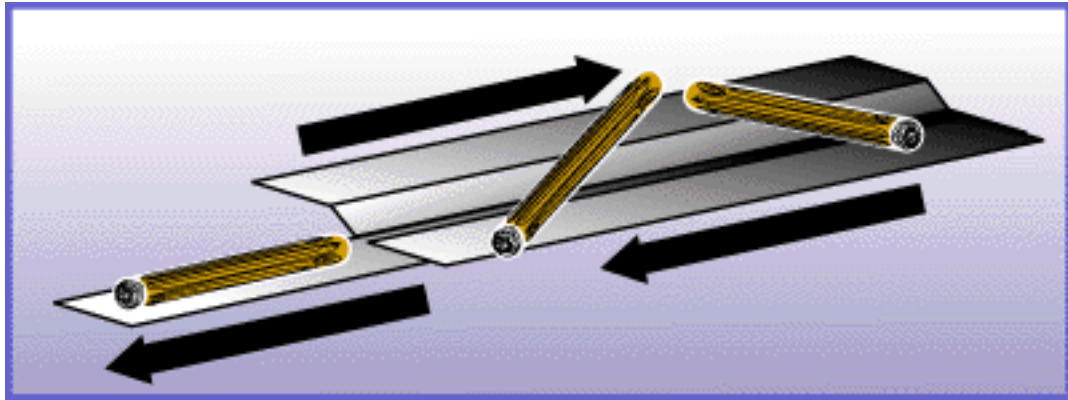


Figure C-2

4. Standard Approaches to Inventive Problems

Altshuller noted that approaches to solving problems were similar in different fields of technology. That led him to classify typical system transformations regardless of technology. These transformations are recorded in the Standards sub-system using a special symbolic language based on the substance-field modeling concept.

Altshuller suggested considering all technological systems as composed of substances and fields. Then a transition from system A to system B can be described as changes in the substance-field (sufield for short) structure of system A.

Sufield is a model of a problem that reflects the critical feature of the subject "system A" which embodies the physical contradiction. It usually contains three components:

1. Substance (S_1): An article, material, or object to be controlled, processed, etc.
2. Substance (S_2): A tool, or an object to control or process the article, S_1 .
3. Field (F): The energy used for interaction between S_1 and S_2 .

For example, the basic sufield diagram (see **Figure 3**) shows "energy" (F) acting on a "tool" (S_2) to modify an "article" (S_1).

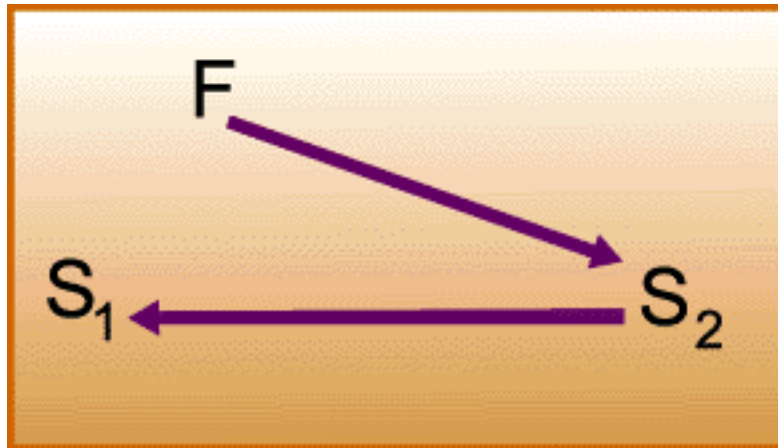


Figure 3

The most frequently encountered fields are mechanical (pressure, inertia forces, vibrations, etc.), thermal, magnetic, and electric. The problem may be clarified by the absence of some components from the sufield. In that case, one should complete the sufield.

5. Example: Molding Bristles

Molding of bristled plastic mats required custom-made dies for each design. These needed to be frequently cleaned, and cleaning was not easy. **Figure 4** illustrates this original method.

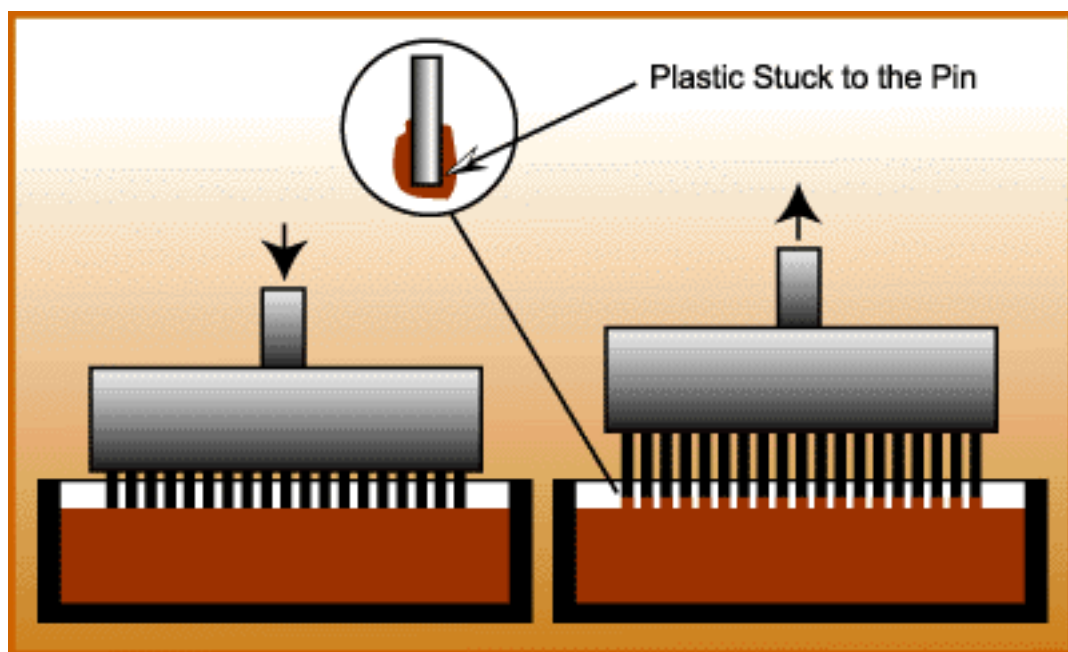


Figure 4

A different method was needed, but it was not obvious how to apply sufficient molding force to melted plastic (S_1) without a conventional die. Modeling the heart of this problem using the sufield concept, a pair (F, S_2) must be introduced into the system such that S_2 will transform F into a mechanical force acting at the correct points on the plastic. Soon it was seen that if F were a magnetic field and S_2 were a ferromagnetic material, a solution might be possible. **Figure 5** shows the sufield diagram for this idea.

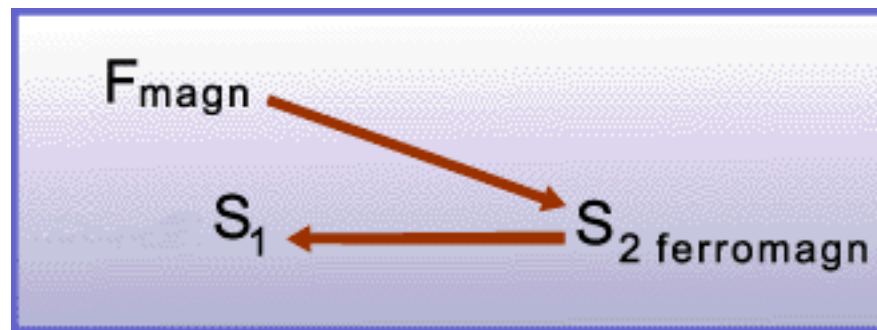


Figure 5

Solution

Ferromagnetic powder was added to the molten plastic according to the required bristle pattern. A magnetic field pulls out the powder, thus forming the bristles. An additional benefit is that bristle patterns are quickly developed and altered. **Figure 6** illustrates the engineering solution for this problem.

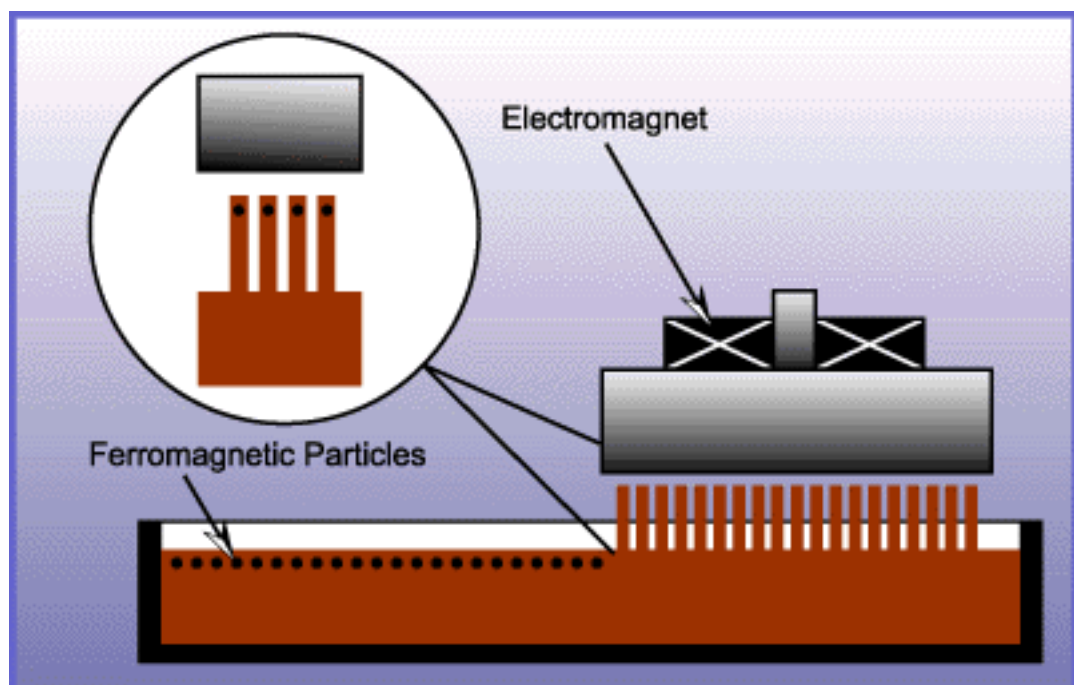


Figure 6

6. Example: Shot Blasting

Curved sections of pipe in steel shot blasting machines wear almost as if they were workpieces. Various protective coatings only improve the situation marginally. **Figure 7** illustrates this original method.

One can formulate a Physical Contradiction. To protect the pipes, there should be a coating. On the other hand there should be no coating, since it cannot survive. The sufield model of the problem (see **Figure 8**) is stated, where S_3 in this case is an intervening agent to protect the pipe.

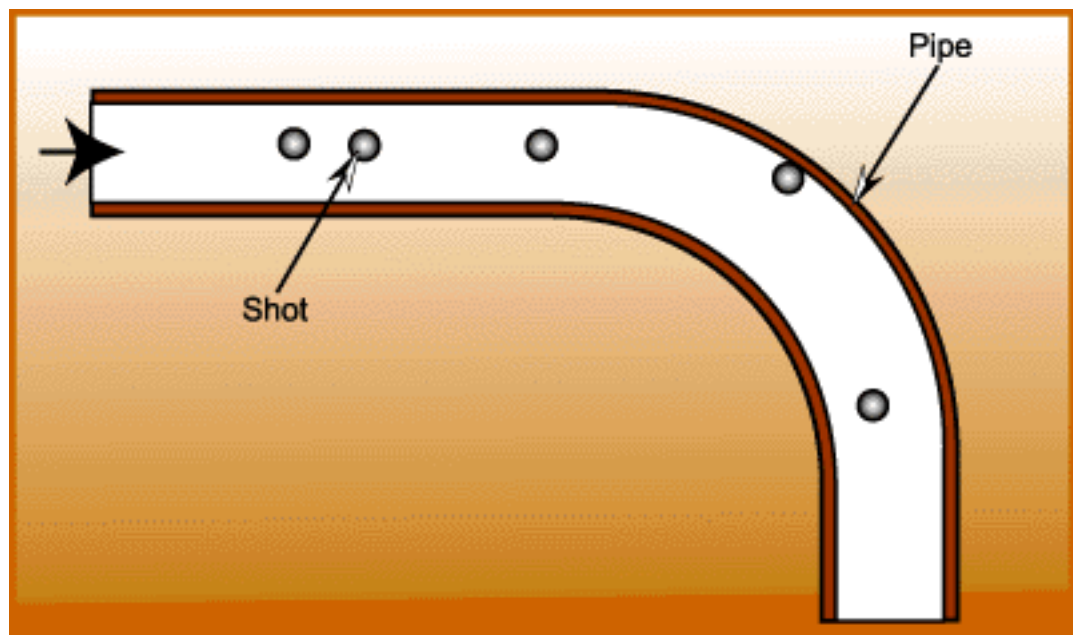


Figure 7

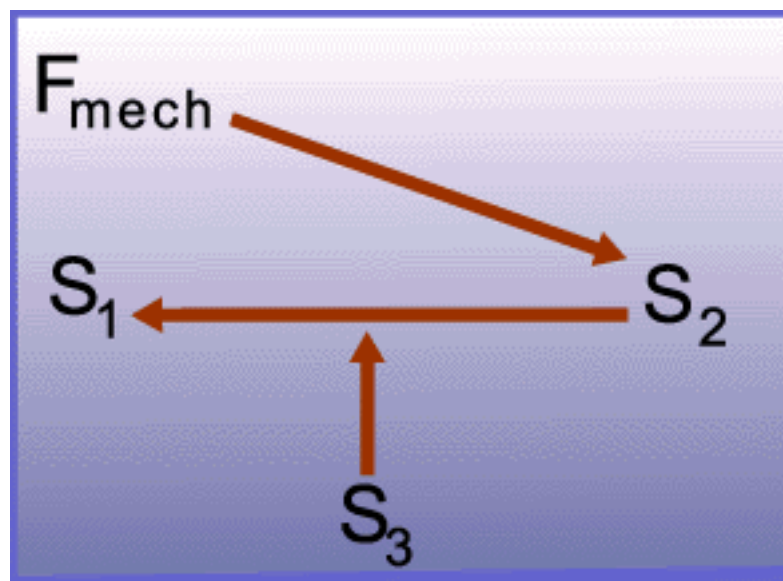


Figure 8

Solution

The shot particles themselves serve as a coating. A magnet placed on the outside of the flying shot particles to form a protective layer inside the bend.

Figure 9 illustrates the engineering solution for this problem.

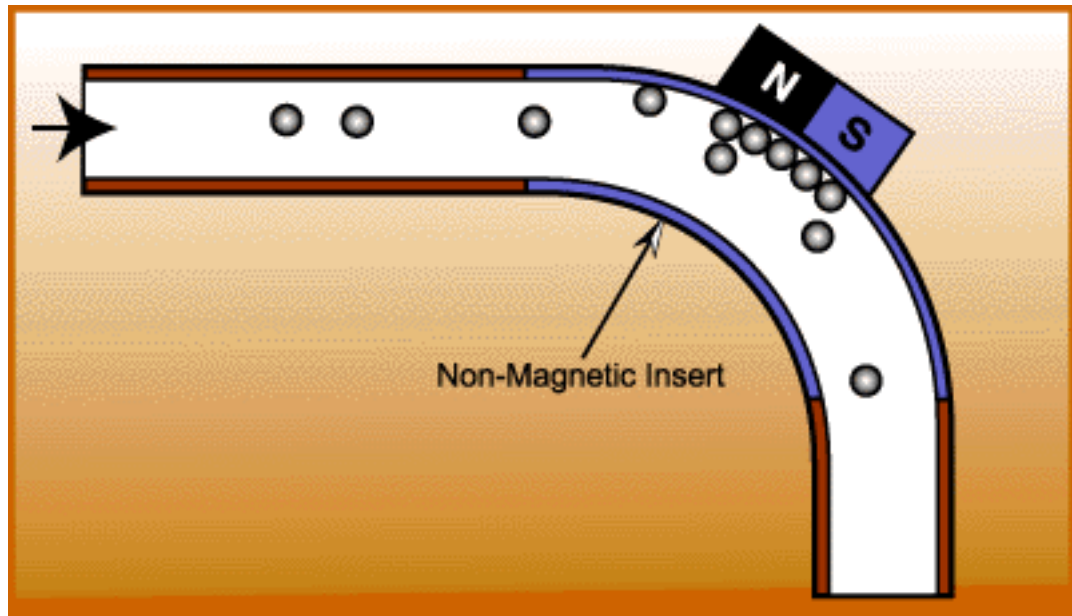


Figure 9

This solution was suggested by one of the standards in the Standards package, which recommends, "if a useful interaction between S_1 and S_2 is accompanied by a harmful interaction, and the latter can be eliminated by introducing S_3 between S_1 and S_2 , then S_3 should be made either out of S_1 or S_2 , or else out of modifications of S_1 or S_2 ." This standard promotes the Ideality Principle because S_3 is not a foreign object, but made out of in-system resources.

A symbolic summary of the preferences from the Standards would be $S_3 = S_1, S_2, S_2', S_3', (S_1' + S_2')$. Analysis showed that $S_3 = S_2$ was the most effective transformation. The ARIZ and Standards packages work together to form one system. They have special "input" and "output" blocks to interact with each other.

7. Conclusion

TRIZ is a unique, systematic approach to develop globally competitive products and processes. Simple solutions to many problems are obvious after the fact, but are not so obvious beforehand. Some problems do not have an elegant solution based on the current state of science and technology, but we can do better with what is known.

Now engineers may rely on a structured, algorithmic methodology when looking for creative, breakthrough solutions to complex technological problems. All the examples given are mechanical because they are easy to present, but the same principles apply to chemical, electronic, and thermal processes. These examples were taken from participants in numerous workshops and courses on TRIZ.

In practice, organizations are using TRIZ coupled with many other techniques such as QFD, FMEA, simulations, and so on. Among all the techniques, TRIZ is the "rock buster." It enhances analytical and solution skills used to solve product design and manufacturing problems, so that people can be better engineers after mastering only its basics.

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Footnote:

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