The Application of LT-table in TRIZ Contradiction Resolving Process

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Abstract. TRIZ is used to resolve invention problems. ARIZ is the most powerful systematic method which integrates all of TRIZ heuristics. Definition of ideal final result (IFR), identification of contradictions and resource utilization are main lines of ARIZ. But resource searching of ARIZ has fault of blindness. Alexandr sets up mathematical model of transformation of the hereditary information in an invention problem using the theory of catastrophes, and provides method of resource searching using LT-table. The application of LT-table on contradiction resolving is introduced. Resource utilization using LT-table is joined into ARIZ step as an addition of TRIZ, apply this method in separator paper punching machine design.

Keywords: TRIZ; ARIZ; LT-table; Contradiction.

1 Contradiction resolving process in ARIZ

TRIZ has formed following instruments pass through several dozens years development [1].

- The Contradiction Matrix and 40 Inventive Principles;
- Separation Principles;
- Substance-Field (Su-Field) Analysis;
- The Standard Solutions;
- Evolution of Technique;
- Effect;
- Algorithm for Inventive Problem Solving (ARIZ is its Russian acronym);

Among these instruments ARIZ is used to resolve complex and difficulty problem. ARIZ is most recognized TRIZ instrument that includes many of TRIZ heuristics above. ARIZ is a multi-step program of actions that an inventor should make while resolving technical problems with a high degree of difficulty. The goal of ARIZ is to organize the thinking of an inventor with a method based on TRIZ[2]. Contradiction resolving is main content of ARIZ. ARIZ provides following multi-stages model for contradiction resolving.

In first stage (ARIZ1.1~ARIZ2.7), a fuzzy problem is expressed as explicit contradiction problem. Firstly, problem is defined as administrative contradiction.

Administrative contradiction is tried to resolve by analogy of similar problem in TRIZ case base. If problem is not resolved, technical contradiction is defined. Contradiction Matrix and Standard Solutions are used to resolve technical contradiction. In this stage cause of problem is not found.

In second stage (ARIZ3.1~ARIZ3.6), physical contradiction is identified by Ideal Final Result. Cause of contradiction is confirmed. X-resource which satisfies both sides of contradiction is the key of contradiction resolving. In this process free resources inside system are first attempted to server as X- resource.

In third stage (ARIZ4.1~ARIZ4.5), resource outside system is imported for contradiction resolving. The property of X-resource is identified by agent technique, then X-resource and domain solution is formed.

X-resource is the key of contradiction resolving in ARIZ step. But now X-resource is found by trail and error search method, this is difficulty to realize compare to Contradiction Matrix and Standard Solutions. Bartini's LT-table provides new method for the search of X-resource.

2 Search of X-resource from Su-field resources using L-T table

Physics studies set up the discrete interior of space-time, and also relationships between atomic quantities and cosmological quantities. However, no analytic relationship between fundamental physical quantities has been found. They are determined only by experimental means, Bartini[3] employs group theoretical methods and topological methods, gives an analytic relationship between physical constants, and also offered a L-T (Length-Time) kinematical system of physical values. In L-T kinematical system of units the dimension of a charge (both gravitational and electric) is

$$\dim m = \dim e = L^3T^{-2} \tag{1}$$

Bartini's system resulted in the LT- table (Table 1). In this table physical constants can be represented by product of L and T.

Table 1. Kinematical System of Physical Values (Length [L] vs. Time [T]) [3]

Values	L^{-2}	L^{-1}	……	L^4	L^5
T^{-6}		$L^{-1}T^{-6}$	……	L^4T^{-6}	L^5T^{-6}
T^{-5}		$L^{-1}T^{-5}$	……	L^4T^{-5}	Power
T^{-4}	$L^{-2}T^{-4}$	Specific gravity; Gradient of pressure	……	Force	Energy; Statistical temperature
T^{-3}		$L^{-1}T^{-3}$	……	Motion quantity; Impulse	Angular momentum; Action
……	……	……	……	……	……

T^1	Changing of magnetic permeability	Conductivity	……	L^4T^1	L^5T^1
T^2	Magnetic permeability	$L^{-1}T^2$	……	Distribution of volume along length	
T^3	$L^{-2}T^3$	$L^{-1}T^3$	……	$L^{-1}T^4$	

The vertical columns of the LT-table contain a series of integer degrees of length (from T^{-6} to T^3) and horizontal rows contain integer degrees of time (from L^{-2} to L^5). The crossing of each column and row gives the dimension of a certain physical quantity. Dimensions of all physical values are represented as a product of integer degrees, L^nT^m, where $|n+m| \leq 3$ for three-dimensional space. The LT-table expresses physical laws of conservation. Intuitively it is clear that the LT-table should have important practical value for inventor-related work. But Bartini did not provide data on its application in technical creation. Bartini's ideas have appeared in TRIZ literature. Alexandr[4] suggests using Bartini's LT-table together with TRIZ on a new mathematical basis.

In table 1, the fragment L^0T^0, L^1T^0, L^2T^0, L^3T^0 in first horizontal row is known as physical sequence "point-line-surface-volume". These fragments form an evolution trend defined by physical dimension. Dimension L^nT^0 of the new essence is product $(L^{n-1}T^0)\cdot(L^1T^0)$, the multiplier L^1T^0 enters into dimensions of all elements of a spatial trend, defining the general property of a spatial trend in the mathematical image. Multiplier L^1T^0 is a gene of a spatial trend or genetic length, too, as $L^1T^0 = L^1$.

In same way vertical lines of the LT-table construct trends of the temporal development of resources. Each cell of a temporal trend differs from the next cell of the same trend on a multiplier T.

Diagonal lines of the LT-table are the Su-field trends of all resources. Each cell of a Su-field trend differs from the next cell of the same trend on a multiplier L^1T^{-1}, velocity $V = L^1T^{-1}$ is gene of trends.

It is important significance that a social-biological analogy can be used in invention problem. Alexandr sets up a mathematical model to describe the hereditary information in an invention problem using theory of catastrophes. Transfer of the hereditary information is the transfer of physical properties from the technical contradiction to the new solution (or X-resource). There is a biological analogy: opposite properties of the technical contradiction are "parents" and the -resource is their "baby".

The mathematical model of the conflict pair and X-resource is set by cusp catastrophe with potential function [4]:

$$E(x) = 0.25x^4+0.5\lambda x^2+ux \qquad (2)$$

where x = coordinate of state of object, λ = tool control parameter, u = X-resource control parameter.

The minimum of potential function $E(x)$ is the purpose of invention solving, therefore the size of potential function is equal to the undesirable effect. Every item should have the physical dimension, x^4 in equation (2). So λ has the physical dimension of x^2, u has the dimension of x^3. Further detailed conclusions are obtained [4].

- The object defines the linear extent of the conflict, the tool defines the superficial area and the X-element defines the volume of the conflict.
- In a geometrical sense, the trend "object-tool-X-element" is part of TRIZ's trend "point-line-surface-volume."

In addition on the base of studying and simulation of transient process from the technical contradiction to the Substance-Field. Following equations are get in literature [5,6].

$$Kdx / dt = -3xy + az \tag{2}$$

$$Kdy / dt = 3xy - az \tag{3}$$

$$Kdz / dt = 3xy - az \tag{4}$$

where x and y = the coordinates describing a change of competing properties of the technical contradiction, z = the coordinate describing a change of property of an X-resource, K and a = factors.

The reduction of equations (2-4) is

$$z = q^* xy, \quad q = 3/a \tag{5}$$

Equation (5) is fair for dimensions, $x = L^{n1}T^{m1}$, $y = L^{n2}T^{m2}$, $z = L^{n3}T^{m3}$, $n3=n1+n2$, $m3=m1+m2$. Useful and harmful properties of the technical contradiction are entrance parameters. The resource of the X-resource will be an output of the LT-table. If useful and harmful properties of the technical contradiction are established, suitable physical dimension of these properties should be found in LT table.

Then the dimensions are multiplied. The product gives a cell of a new physical dimension in the LT-table. Diagonal lines of the LT-table are the Su-field trends of all resources, so suitable physical properties of the X-resource may be located in diagonal line of this physical dimension. This method of resource search using LT-table has follow steps [4]:

- Logic multiplication "and-and" of dimensions of useful action and harmful action in contradiction situation.
- Finding the cell of product of two dimensions of contradiction in LT-table. Diagonal lines of the product cell in LT-Table is potential range of X-resource.
- Choosing a suitable resource of an X-resource on the resource trend.

The method of resource search by LT-table does not replace TRIZ, but a good addition for TRIZ. LT-table method is joined into ARIZ step 4 in this paper, and this method is validated in separator punching machine design.

3 Button battery separator paper punching machine design

The interior of button battery is composed of electrodes and separator paper. The function of separator paper is to separate positive and negative electrode. Circular separator paper needs to be punched out from the separator paper tape. The automation of existing punching machine is low, this resulted in low product efficiency and low material utilization of separator paper. Separator paper is very

expensive, so the battery enterprises urgent need a kind of automatic punching machine for separator paper. Institute of Design for Innovation is entrusted to develop a kind of automatic separator paper punching machine. The machine must satisfy following demands:

1. Increasing the material utilization as much as possible;
2. The machine can produce different diameter separator paper;
3. High automation, reduce the labor intensity;
4. Increasing product efficiency;

In the design process of separator paper punching machine, difficulty function and contradiction are indentified. ARIZ is used to resolve these problems and LT-table method above mentioned is used to resolve contradiction of separator paper punching machine.

1. Determine work principles and design problem

In concept design stage preliminary work principles of separator paper punching machine are confirmed. As show in figure 1, feeding mechanism transfers separator paper intermittently, winging mechanism pulls and collects separator paper. To increase productivity multi-punch model is adopted. But there is a problem about winging function.

Tension of paper tape should be invariable, this requires that linear speed of winging shaft equals to linear speed of feeding. Winging shaft should make alternating rotate consistent with feeding movement. Meanwhile, angular speed of winding shaft should decline dynamically with increasing of paper coil diameter. These are difficulty to realize by current technique.

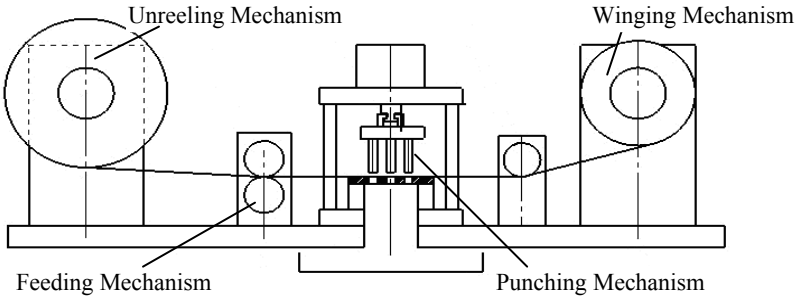

Fig.1. Design draft of separator paper punching machine

2. Resolve design problem by ARIZ integrated with LT-table.

1.1 According to the following text form, state winging mechanism.

The main purpose of winging mechanism is to pull and collect the waste paper tape. Its main subsystem includes winging shaft, driving motor. Useful function includes winging separator paper tape、keeping tension by pulling separator paper tape, the harmful function is abruption of separator paper tape.

1.2 Answer the following question to judge whether the problem includes contradictions. The regular problem does not need to employ ARIZ.

(1) Employ the known method to improve the useful function, is the harmful function improved at the same time?

Method 1: Winging shaft rotates with feeding action simultaneously. Paper tape is transported intermittently for punching action, so linear velocity of winging shaft should be intermittent also. In addition angular velocity of winging shaft should decline with increasing of cycle number of winging paper core. But these lead to complexity of the control system violently.

Method 2: Winging shaft rotates with a uniform speed, but the paper tape could be broken in the intermittence of feeding.

(2) Dispel or weaken the harmful function, whether the useful function weakened at the same time?

Method 1: Winging shaft does not rotate，the paper tape would not be broken. Harmful function is eliminated, but useful function of winging the paper tape is lost. So this question is not regular problem but a contradiction problem.

1.3 Adopt "mini-problem" to state the original problem.

How to realize winging function and not to break the paper tape?

1.6 TRIZ case library application, whether solutions of similar problem can be used here.

Search the similar case in the TRIZ case base, but there are not cases similar to this problem.

1.7 The question was not solved, turn to step 2.

Step 2：Analysis of the problem's model.

2.3 Define at least two Technique Contradiction (TC1 and TC2) between products and tool, according to two kinds of technical contradiction, construct the following technical contradiction (TC1, TC2).

TC1: Winging shaft rotates at the uniform velocity, the paper tape is broken soon;

TC2: Do not make the paper tape broken, the useful function of pulling the paper tape can't be realized;

2.4 Choose Technical Contradiction TC1 as the problem model.

2.5 Confirms the contradiction, try to solve the Technical Contradiction with 40 Invention Principles and Contradiction Matrix.

According to TC1, the improved parameter is the degree of automation, the worsened parameter is that the tension of paper tape becomes greater and greater. Consult the Contradiction Matrix, we can adopt the second invention principle(separate principle) and the 35th invention principle (parameter changed). But these two invention principles can't solve the problem.

Step 3: Ideal Final Result and Physical Contradiction Determination

3.1 Define operating area in design draft (Figure 2).

3.2 Define the IFR1:

IFR1: In the zone and time of winging，the useful function of winging paper tape is realized, the system doesn't become complicated, and eliminate the harmful function of breaking paper tape.

3.4 State the microscopic physical contradiction.

The linear velocity of winging shaft must be same as speed of feeding. Winging shaft must stop rotating at the time of blanking, so as not to break the paper tape.

3.6 Define IFR 2:

Ideal solution 2: X-resources selected make winging shaft rotate at a high speed when feeding the paper tape, but also make the winging shaft stop rotating when feeding action stops.

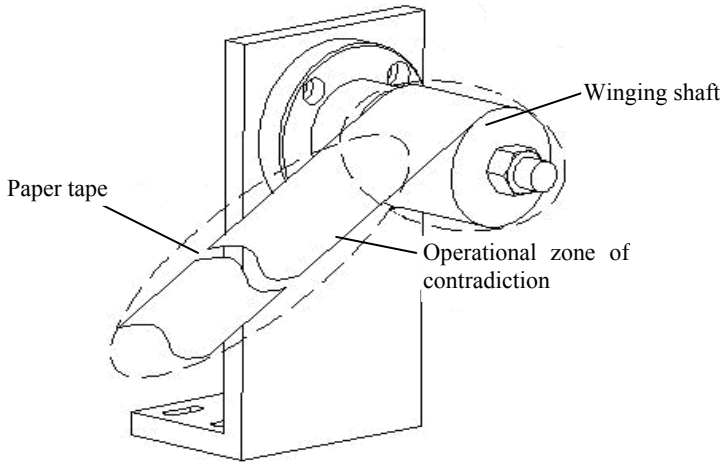

Fig.2. Contradiction zone of winging mechanism

3.7 Try to apply Standard Solution to solve the problem which IFR2 pointed out；

Consult the Standard Solution, we do not find the solution which can be used, turn to step 4.

Step 4: Substance-field resources applications

4.6 Analyze the physical dimension of problem model, Confirm physical dimensions of useful and harmful function in technique contradiction situation, the dimension of technique contradiction carries on logic multiply, inquire about LT-table to confirm X-resource.

In the process of winging shaft function, the winging shaft is tool, the paper tape is products. The tool acts on the products, decisive action result is pulling force on the paper tape.

Useful function process: winding shaft rotate to pull and wing paper tape. The physical dimension of function is the velocity;

Harmful function process: the force imposed on paper tape is difficulty to control, the force break the paper tape. The physical dimension of function is force;

According to LT-table, the velocity has dimension of L^1T^{-1}, force has dimension of L^4T^{-4}, carry on logic multiply of two dimension, we get $(L^1T^{-1})*(L^4T^{-4}) = L^5T^{-5}$. Corresponding dimension of L^5T^{-5} in LT- table is the power/motive force, so we can determine the resource trend of the unknown X-resource. The X-resource physical dimension trend is ‘none dimensional constant--velocity -- potential difference -- current / mass loss--force-- Power’ as showed in table 2.

In this physical dimension trend, the velocity, potential difference, electric current, mass loss can't be used to solve the problem, only the physical dimension ‘force’ can serve as X-resource.

Table 2. Fragment of LT-table for design problem of separator paper punching machine

Dimension	L^1	L^2	L^3	L^4	L^5
T^{-5}	L^1T^{-5}	L^2T^{-5}	L^3T^{-5}	L^4T^{-5}	power
T^{-4}	……	……		force	……
T^3	……		electricity mass loss		……
T^{-2}	……	potential difference		……	……
T^{-1}	velocity	……	……	L^4T^{-1}	L^5T^{-1}

Firstly, separate principle in step2.5 is applied, winging shaft and winging core are separated on structure as showed in figure 3. Winging core is driven by friction force imposed by fraction disk, friction disk rotates consistent with winging shaft and is free on axial direction. Frictional force drives winging core to pull paper tape when feeding mechanism transports paper tape. When punch acts and feeding mechanism stops, frictional force take-up paper tape. If maximum frictional force is less than the force that breaks the paper tape, winging core will stop and paper tape can not be ruptured. The friction force can be controlled by the spring in figure 3.

The IFR1 is realized. Winging shaft rotates continuously, so control of drive motor is simple. The paper tape do not be ruptured also. Problem is solved, turn to step 7.

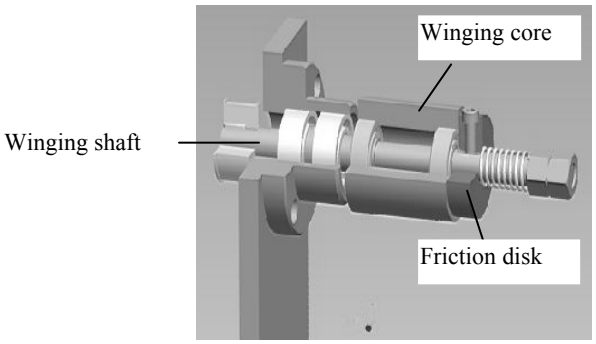

Fig.3. Three dimension graph of winging mechanism

Step 7: Analyzing the method of resolving the physical contradiction

7.1 Checks every kind of material or field introduced newly, if these materials or fields are not necessary?

The solution introduces a kind of material spring and friction disk, which are used to produce new driving force-- friction force. So it is essential to introduce these materials.

7.2 Principle solution appraisal:

This scheme has realized the main goal of IFR1, has realized the useful function-- the paper tape winding, meanwhile dispels the harmful function-- paper tape breaking. The scheme includes a resource easy to be controlled, the friction force can be controlled by regulate the length of spring.

Step 8: Applying the obtained solution; Analyze the implementation of solution. appraises if this solution has the universal significance principles, if the principles can be applied in other problem.

The principle of this solution can be stated as following. static friction is used to pull paper tape, when tension of paper tape exceeds static friction, winging coil begin to skid. Static friction can be controlled by the length of spring. Paper tape would not be ruptured when static friction can be controlled,

Unwind mechanism also need keep the tension of paper tape, this principle can be also used in unwind mechanism to keep tension.

3. Prototype machine and production test

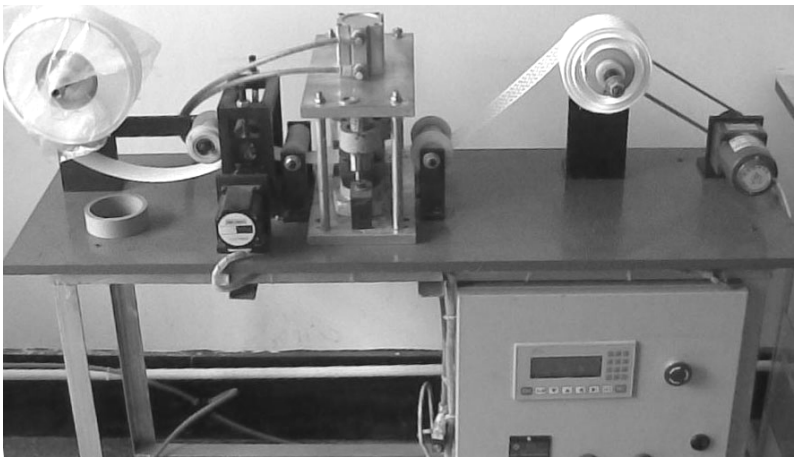

Fig.4. Photo of prototype machine

On the base of above work principles and invention solution, prototype machine is made as showed in figure 4. After production test, this machine is proved to satisfy the demand of enterprise. This machine has following advantages:

(1) High automation, this machine does not need labor except for feeding of paper tape at first time;

(2) Material utilization ratio enhances 15%;

(3) Low cost of machine.

This machine has been applied in enterprise. An invention patent application is submitting now.

4. Conclusion

Resource utilization is important part of ARIZ. To increase effectiveness of resource search in ARIZ, LT-table method is introduced and joined into problem resolving flow of ARIZ. The ARIZ flow integrated with LT-table is used in separator paper punching machine design. Effectiveness of LT-table is validated.

In addition the method of resource search using LT-table can serve as the physical and mathematical body for TRIZ, LT-table opens a new field of invention research.

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