TRIZ Analysis for Solving Problem in the Production of Aluminium Food Containers

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Abstract   On a daily basis, the concrete problems with researching solutions deal with the psychological inertia, the tendency to think and follow the same known mental schemes. The current work shows how the TRIZ can develop new and effective project solutions thanks to the examination of different prospective and points of view. In particular, the authors want to retrieve the analysis and the solutions for an anomaly found in an industry that designs and builds moulds and equipment for the production of aluminum food containers.

Keywords   TRIZ, Functional Analysis, Engineering Parameters, Contradiction Matrix, Inventive Principles

1. Introduction

Has somebody somewhere already solved a similar problem to mine? This question can summarize the main principle at the base of the TRIZ theory. TRIZ is the Russian acronym for Theory of Inventive Problem Solving which originates from an in depth study performed by Altshuller on technical and patent information. He observed that very few solutions are complete novel inventions, while ninety-nine per cent of them originates from previously known idea or concept applied in a new way. So, the TRIZ provides techniques and tools to be applied through its systematic perspective of technological world in order to reduce trails and error during the problem solving process [1,2]. The TRIZ theory is based on several important concepts including, but not limited to, the Inventive Principles (IP), the Technical Contradictions, and the Functional Analysis. The TRIZ approach has been applied in this work with the objective to develop a new and effective solution to remove an anomaly found in a factory near the city of Latina, Italy. The factory produces aluminum food containers and also designs and builds moulds and other equipment for the production of these containers. Although the factory's production cycle is divided and the products are for different markets, it can be said that the two processes of design and production are complementary and can be summarized as:

1. Designing container shape and stamp using CAD;
2. Building the stamp through techniques such as milling, vacuum hardening, wire EDM, smoothing, and polishing;
3. Assembling a complete line to produce the containers;
4. Production of the aluminum food containers with the shape of the designed stamp.

The anomaly in question is presented during the construction cycle, when some containers, just shaped and released from the press, instead to go in the stacker, they remained blocked under the light of press that harms them.

1.1. Design of Production Cycle

Figure 1.   Conveyor ribbon

The project manager, following the customer specifications, elaborates a CAD project to draw the stamps. The material used for the production of food containers is an aluminum alloy 8006H0 or 8088H22 with a thickness ketch between the 40 µm and 90 µm. This material is a very workable alloy that requires a precision in a range of one hundred millimeter in order to avoid dimensional errors during the production and waste in the finished products. The stamps set up on the press to give the shape of a coil of aluminum are generally in semi-sintered steel, the matrix and the punch in steel C45. The project of a complete line begins from the choice of the electro pneumatic press, then there is the conveyor system to stretch the aluminum coil and it ends

with the conveyor ribbon to drive the food containers to the automatic stacker through an electro pneumatic system composed by two tracks controlled by PLC. The production of the aluminum food container begins with the setting up of the aluminum coil in its holder where the ribbon is brought through the transporter in the press. Here the aluminum food container is shaped and released between stamp and counter with an air jet to late join the stacker (Fig. 1).

1.2. Description of the Anomaly and of its Causes

The anomaly in the production cycle appears when the aluminum food container, just shaped, is then ejected from the press and guided onto a conveyor ribbon. At the point of transition onto the conveyor ribbon the process can block itself and the container remains again under the press, as illustrated in Fig. 2.

This means that the aluminum canister that remains blocked is unavoidably rejected from the production. As this situation repeats itself after 150-200 times the finish of the

stamp is consumed and the counter becomes lightly scratched. The consequences are:

1. The rejection of about 3500 food containers out of 120-130 million produced per year;
2. An average of ten times per day the production chain is stopped in order to reset operations;
3. The stamps need to be dressed about 20 times per year due to the consumption of their surface finish.

The high volume of aluminum containers rejected in the production has been almost "accepted". However the interruption of production and time needed in order to allow the worker to remove food canister to be thrown out, represents a delay in the production cycle of about an hour, needed to do this operation. The biggest delay on production time is when the machines need to be stopped for applying a new dressing; an operation that needs two hours. Stopping cycle for two hours means that two hours of energy used for production are instead being used elsewhere.
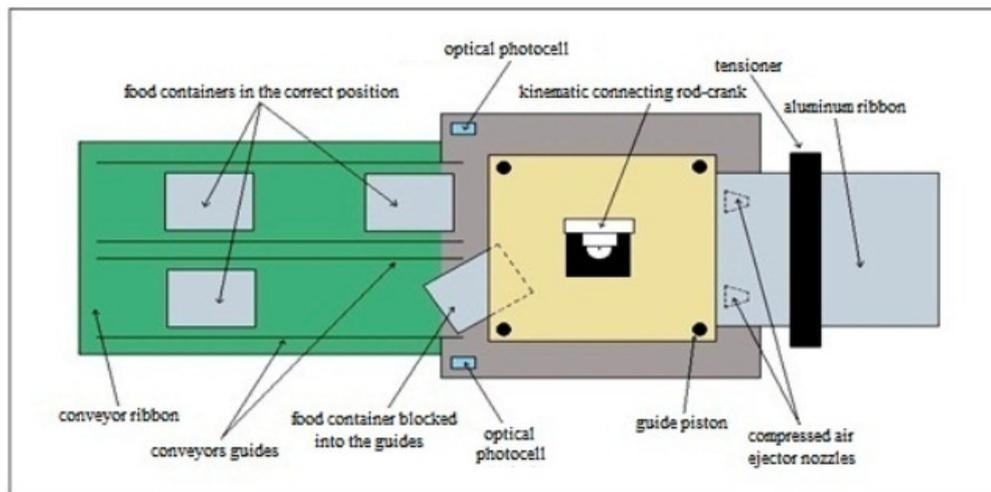

Figure. 2.   Schematic representation of the anomaly

In below Fig. 3 is shown the matrix and the punch that compose the stamp that forms the containers.

Figure. 3.   Matrix and punch of a stamp for aluminum food containers

The machine is isolated from:

- Eventual air flow that could be created internally (in fact the isolated cabin containing the press is opened only for ordinary maintenance when the machine is fully turned off);
- Vibrations, because the floor on which the press stands is made of rubber and this stops the increase of eventual residual tensions.

These causes should exclude themselves.

After a careful analysis have emerged the following potential causes:

1. The speed of the press (120 beats for minute) doesn't allow the punch to fully stop when the optical photocell catches the aluminum food container blocked. As a result it wastes them;
2. The guides, which are of the exact dimensions of the food container, with their grip could be the cause of the blockage.

It is so defined, the Ideal Final Result [3,4]: the food container ejected from the press must reach the stacker avoiding staying under the stamp, and food containers do not remain blocked between the guides.

2. Methods

In a problem solving process it is important to take in account the two main components: the problem itself and the context/system in which the problem resides. Problem analysis and transformation of systems have been highlighted as essential for problem resolution in successful innovative experiences [5,6]. The theoretical basis on which TRIZ tools are founded is the pattern for the evolution of technological system [2,7]. To face and solve the anomaly reported in this case, the TRIZ approach has been used. This method is applied here through the following phases:

1. Patent Research;
2. Functional Analysis;
3. Trimming;
4. Engineering Parameters;
5. Contradiction Matrix.

The first phase consists in a careful analysis of the state of art [8], the second one is a problem analysis, and the remaining phases are related to the creation of solutions.

2.1. Patent Research

This research is done throughout the various sectors of technology with the scope of finding an already existing solution to this anomaly, or for a similar one. This research has the goal of using what is already known and to apply it anew. In this case the research was executed firstly in similar sectors dealing with the production lines of aluminum food containers; then other sectors were examined such as that of the rubber-plastic and that one of the electro pneumatic press for printing; and in particular the press electro pneumatic that belongs to the class of patents B30 and saves with patent US AIDA.

Unfortunately the research of already existing patents did not yield any useful results.

2.2. Functional Analysis

It needs to understand and to control the problems and so to correctly formulate and analyze the functions that reduce the Ideality [2,9]. Creating a functional model is very useful because by mapping all of the interactions, positive and negative, within a system and its elements the area in which the anomaly is located can be identified. This is achieved primarily due to:

- Identifying and mapping of all system elements;
- Understanding the functions and the role of elements.

The functional model of Fig. 4 represents the system's elements, the relationship between them, their environment. In this model has been schemed the production's anomaly that through the blocks represents the production's system with at the center the final product.

The model is built of:

- Electro pneumatic press system;
- Conveyor guidance system;
- System that ejects compressed air.

It has shown the interactions, positive and negative, among the different elements. Analysis of these shows that the causes of the anomaly are:

1. The excessive speed at which the press operates,
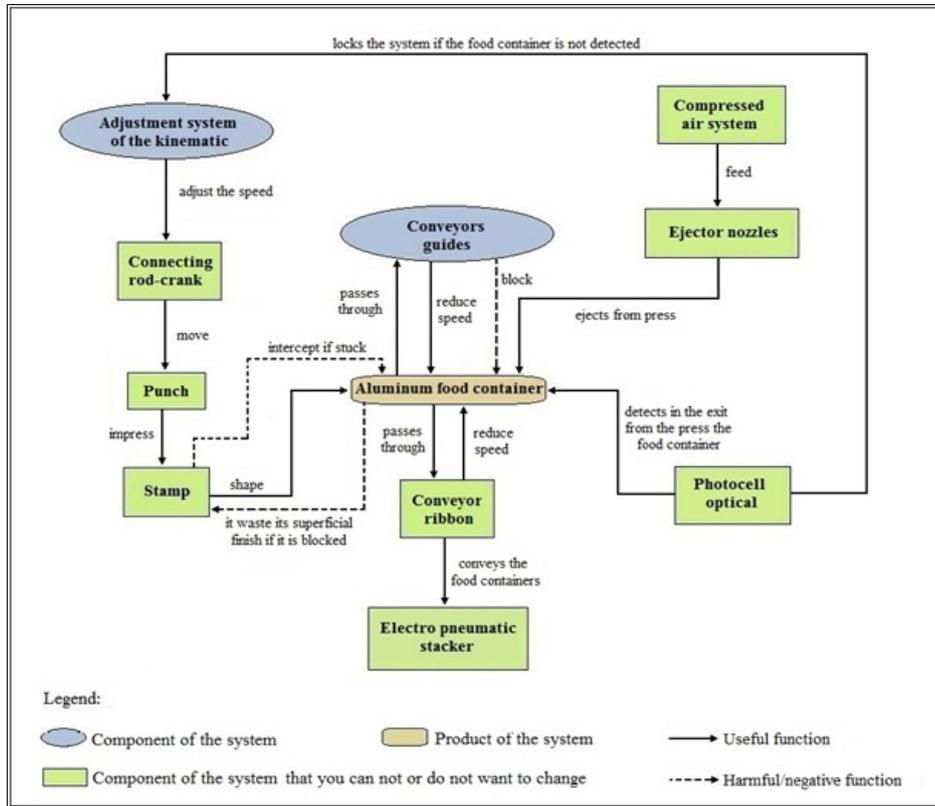2. The grip with the conveyors' guides.

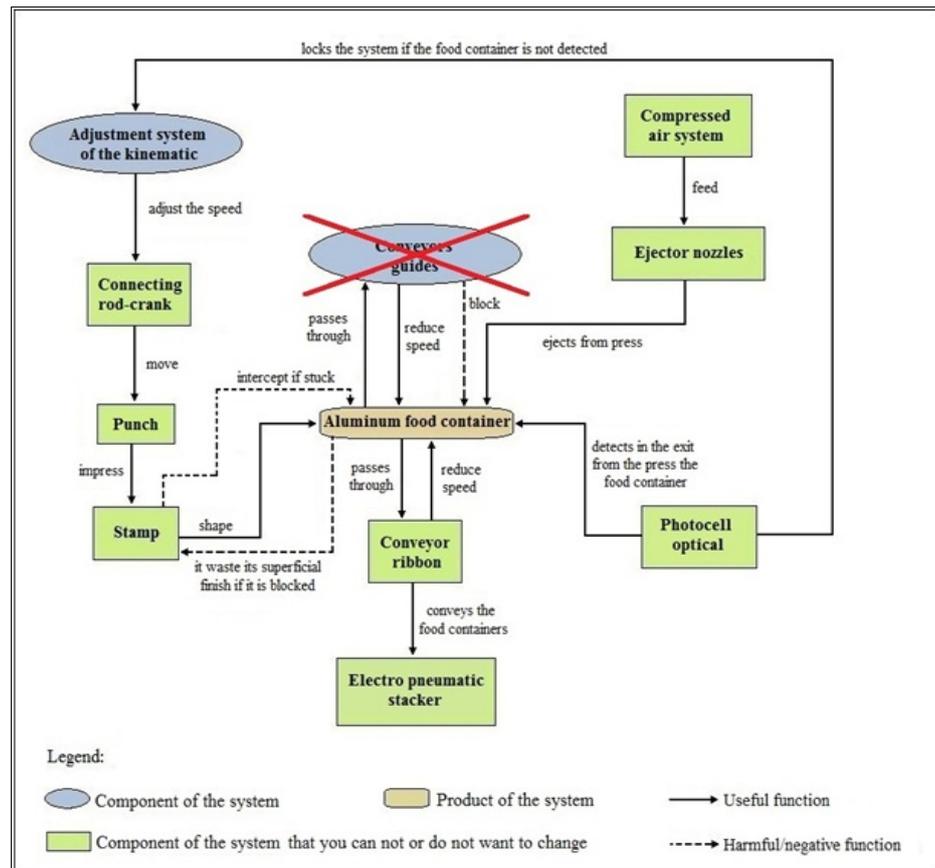**Figure. 4**.   System functional model

Figure 5.   Examination of the system functional model without the conveyors guides

2.3. Trimming

The Trimming [10], together with Substance–Field analysis, is adopted from Altshuller in the TRIZ analysis and it is used, in particular, in: solving Technical Contradictions. It is an analytical tool that simplifies systems, removing one or more critical elements highlighting the evidence of functional models. It is mainly used in this industry for the analysis of the production process, because it is divided in two phases:

1. The removal of the elements associated with the harmful functions, including the costs and the other possible sources of problems;
2. The distribution of the useful functions that these elements grant to new components compatible with the system.

In this project Trimming has suggested the new functional model represented in Fig. 5, where the conveyor guides, identified as contradictory elements in the production process, have been removed.

2.4. Engineering Parameters

For a clear understanding, the TRIZ analysis done on the system has been divided according to the causes caught on the functional model and shown here below in the Fig. 6:

Following the functional model [11,12], it is important to detect the Engineering Parameters (EP) involved on the 39 found from Altshuller. In this case, on the subsystem of regulation of the kinetics, the Parameters detected are the EP9 "speed" of the stamp punch and EP15 "time of the action of a mobile object", the time necessary for the printing of a food container. In the subsystem of the conveyor guides, the Parameters detected are the EP38 "level of automation" transport from the guides related to the entire productive system. EP12 "shape" tubular of the guides installed and finally the EP33 "usability" with which the guides installed are used. The following step was been to find before and the resolution later, of the contradictions. For this scope trials are made in the functional model of the system and through the using of the Trimming with the Contradiction Matrix, these Technical Conflicts have been solved and it has been detected that the guides can be considered an element of conflict and thus the goal is their substitution or removing.
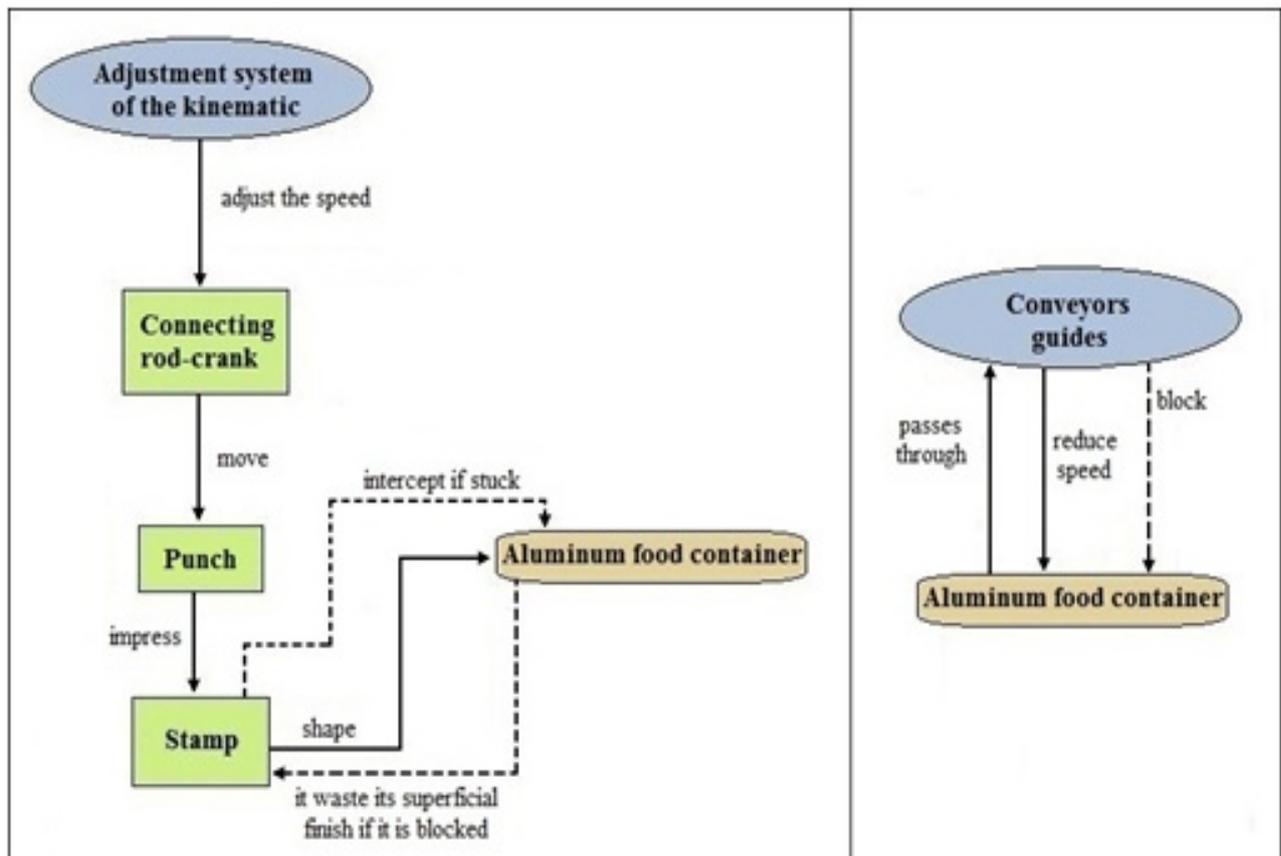

Figure 6. Problems emerging from functional models

2.5. Contradiction Matrix

The Contradiction Matrix is the most important resolving tool used by Altshuller in the TRIZ analysis. It is a matrix, which presents on the rows the Engineering Parameters to be improved while on the columns those that simultaneously become worst. In the cell intersection between a row and a column there are the numbers of corresponding Inventive Principles suitable to solving the contradiction examined, written in decreasing order of frequency of use. The principal diagonal is created from the intersection of a parameter with itself and it is represented by an empty cell. In Fig. 7 here below, it is represented an extract of the Contradiction Matrix of Altshuller, where there have been put in evidence the Inventive Principles suggested from TRIZ analysis for the solving of the anomaly found in the production.

Figure 7. Extract of Contradiction Matrix of Altshuller

3. Analysis of the Results

Thanks to the Contradiction Matrix by Altshuller, Inventive Principles (IP) were found, that in similar cases resulted in successful solutions. The Inventive Principles found by Altshuller are 40 and they are the mainly applied in the 40,000 patents analyzed in his studies.

It has examined firstly, the problem related to the excessive speed of the Kinetics that moves the punch and the stamp. The press has a speed of 120 beats for minute, which allows the six production lines to realize 120-130 million food containers per year and in these operating conditions, even though the signal sent to the photocell is immediate, when the machine does not notice the passage of the food container the brake system composed of two linings is not able to block clearly the punch going down and causes the stamp to crush the food container blocked it into the guides. The situation shown brings us to the definition of the problem that can be summarized as the following: the speed of the press influences the time necessary to brake the punch. The TRIZ tools aims to break the relationship among the parameters in conflict to solve the anomaly in question through its planning and the resolution of the contradictions that are announced through a couple of Engineering Parameters. Parameters related to Technical or Engineering Parameters and the consequent Technical Contradictions described by the following:

1. "Speed" (EP9) or rather the rhythm at which an action or a process has been finished on the time;

2. "Time of action of a moving object" (EP15) or rather the time during which an object changes position in space and it is able to execute its functions in the correct manner.

Once identified the Engineering Parameters, from Contradiction Matrix we can obtain the Inventive Principles most used in the past by Altshuller to solve the same type of technical conflicts. From the Contradiction Matrix therefore emerges, the following Inventive Principles IP3, IP5, IP19, and IP35:

IP3: "Local quality" (when an object or a system is uniformed or homogeneous, to make it not uniform);

IP5: "Consolidation" (merges or join objects, operations or functions so that they act all together in the same moment);

IP19: "Periodic action" (if an action is periodic, changes the amplitude of the period or of the frequency in order to satisfy the external requirements);

IP35: "Transformation of Properties" (change the physical state, concentration, level of flexibility and others parameters of an object).

Among these Inventive Principles one apply to a specific case, because most suitable to the observed anomaly, the Inventive Principle 19 suggested the following solution: reducing at 40 beats for minute the speed of the press in order to allow the stop of the punch.

This solution cannot be adopted because of the insuperable high volume of production requested by the corporate bond. At 40 beats per minute only 40 million food containers per year can be produced, and for the industry in question it is not convenient.

Secondly it has been examined the problem related to the passage of an aluminum food container in a wrong position between the guides. The guides have the double task of reducing the speed acquired due to the ejecting jet and to bring the aluminum food container under ribbon. The metallic guides are tubular and according to the type of food containers they are to produce they are sometimes coated sometime with rubber (see Fig. 8):

Figure 8. Conveyor guides

In addition, the guides, depending on the variety of the food containers made, are installed in the productive lines according to the exact dimension of the food container. Similarly, in the previous case, the problem can be summarized in: the conveyor guides, even by reducing the ejecting speed from the press cause the blocking of the food containers. As a consequence the conveyor guides are the cause of the anomaly. In light of the above, by applying the Trimming to the two following steps:

1. Removal of the conveyor guides from the system;
2. Distribution of useful functions and new compatibles components to the guides.

By removing the guides, the resulting functional system is not balanced. It has been suggested in order to rebalance the system, the introduction of a tool able to do the same positive tasks of the guides. This tool was suggested by TRIZ analysis in solving the Technical Contradictions due to Engineering Parameters:

- "Shape" (EP12) Vs. "Level of automation" (EP38),
- "Convenience of use" (EP33) Vs. "Level of automation" (EP38),

where:

- Shape means that one tubular of guides is already set up;
- Level of automation means the degree of automation carried by the system (guides) in the transporting automatically the containers to under ribbon;
- Easy use, means the comfort and usability of the guides.

As with the first problem, identified with Engineering Parameters, with the Contradiction Matrix, are obtained more Inventive Principles mostly used by Altshuller to resolve similar types of technical conflicts. With the Contradiction Matrix, emerge, the following Inventive Principles (IP1, IP3, IP12. IP15, IP32 and IP34):

- IP1: "Segmentation" (divide the system in sections or more separated parts);
- IP3: "Local quality" (when an object or a system is uniformed or homogeneous, to make it not uniform);

- IP12: "Equipotentiality" (if an object requires or is exposed to tension or compression forces, redraws the environment so that the forces are balanced or eliminated);
- IP15: "Dynamicity" (if an object or a system is rigid or static, to make it mobile);
- IP32: "Changing the Color" (to change the visibility of things by using colorants additives);
- IP34: "Rejecting and Regenerating Parts" (restore consumables parts of a system during an operation);

The Inventive Principles that has been applied to the specific case are the IP3 and the IP15 suggesting the following common solutions:

- IP3: "Local quality" (to let each part of the system working at best: to improve the press/conveyor ribbon in ejecting the aluminum food containers);
- IP15: "Dynamicity" (if an object or a system is rigid or static to make it mobile by moving the guides).

The TRIZ analysis done suggests removing from the current system the guides presently used. In fact, it is evident that the current conveyor guides are static and do not favor the movement of the food containers to the conveyor ribbon. This system of guides can be replaced with an ensemble of dynamics guides to favor the passage of the containers despite their wrong position and avoid them to lay under the stamp with the result of been caught by the moving punch. A research among the patents in the different sectors, oriented toward this type of solution has not created any positive result because a similar system does not exist yet. The Inventive Principle of the dynamics, suggests to adopt a system of guides made of transmission toothed, belts and activated by an electric engine. These belts are present on the market and already used in the paper industry [13]. In Fig. 9 a scheme of a suitable belt for the examined case.

These belts, made of polyurethane are produced by MEGADYNE®. Their application have this advantages:

- Resistance to wet, fats, oils;
- Resistance to hydrolysis, UV rays and ozone;
- Resistance to abrasion;
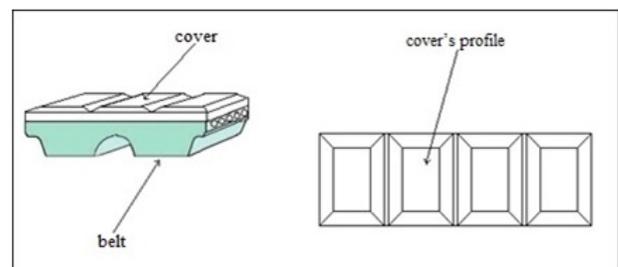- They will not create any dust and therefore will be suitable for food industry.

Figure 9.   Selected belt and related cover's profile

The belt's cover is made of an atoxic material used to over many transmission belts in several industries. This material, thanks to its molecular structure, is able to reduce the impact

of the containers ejected from the press without ruining it. The belt dynamics in addition to the particular geometric profile avoid the blockage that was priorly happening. The belts will be rightly installed with a speed synchronized with the conveyor ribbon. They will have function of reducing the speed in bringing the food containers from the press through the static guides.

By executing the Trimming through the TRIZ analysis, it evidently appears that in the productive system the current conveyor guides are the contradictory elements. In fact also the Engineering Parameters:

- "Shape" (EP12) Vs. "Level of automation" (EP38);
- "Convenience of use" (EP33) Vs. "Level of automation" (EP38).

Confirm that the conveyors guides reduce the ejecting speed of the food containers from the press, but because of their grip, they are the cause of the blockage. Also in this case, by identifying the Engineering Parameters with the Contradiction Matrix, the same Inventive Principles found in the previous case are obtained:

- IP1: "Segmentation";
- IP3: "Local quality";
- IP12: "Equipotentiality;
- IP15: "Dynamicity";
- IP32: "Changing the Color";
- IP34: "Rejecting and Regenerating Parts".

Among these Inventive Principles ones apply to the specific case, the more suitable for the examined anomaly is the IP3: "Local quality"(to let to each part of the system work at best; to let every part of the system executing different useful functions).

The current guides improve the level of automation of the productive system, but due to the grip, they are not suitable for the moving of the containers. The Trimming suggests removing the current guides from the system and distribute the useful functions of the new compatible components. A research of patents among the different technological sectors, has suggested the use of conveyor ribbon already in use to move little glass food containers and aluminum boxes in the glass and aluminum industry. The Figure 10 represents the vibrating ribbon.

Figure 10.   Vibrating ribbon

This ribbon will be placed at the exit of the press. The food containers, ejected by compressed air will reach the vibrating ribbon in a wrong position and not laying to follow the stacking. The vibrating ribbon through vibration pulses will let to the aluminum food container trough a guide with the suitable profile, in order to get in the correct position to fulfill the next operation of stacking. In the Fig. 11 is shown a scheme the solution proposed.
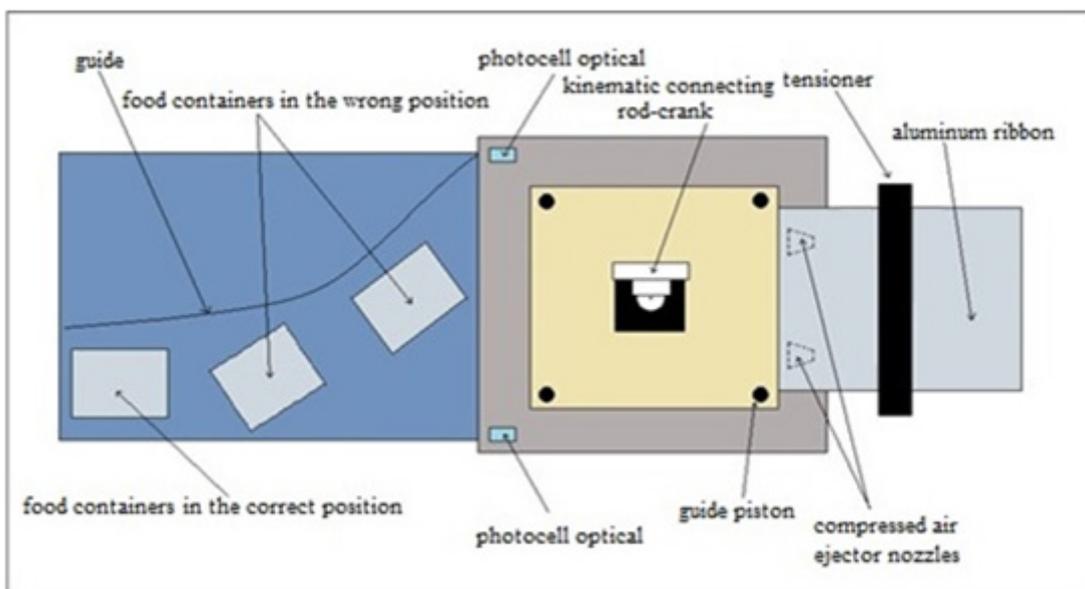

Figure 11.   Proposed solution with the vibrating ribbon

4. Conclusions

This work aims to investigate on the TRIZ utilization as a design tool for innovative application. In this past few years TRIZ has been used more often in the design field, both as a single design tool as well as complementary to other models. For example, in literature is easy to find examples of TRIZ use in conjunction with the Axiomatic Design, either using the TRIZ from the perspective of Axiomatic Design as well as adapting the Axiomatic Design to the TRIZ frameworks [14,15]. The decomposition of issues in order to analyze the problems in their context and in relation to other factors is adopted in may areas of industrial production as well as in the more general problem solving matters [16].

A deep knowledge of TRIZ theory could be very useful for the project manager, when he needs to solve Technical Contradictions by using a creative process to conceptualize and resolve them [17].

In particular this paper shows the innovative solution of the toothed belts, instead of the static guides of the previous system, has been examined by the industry's technical staff who are now evaluating an eventual economical awareness and the application of this solution to future production lines. The analysis of productive processes, through the TRIZ methodology, has evidenced how a careful analysis can detect the causes of anomalies laying in the final production stages. The resolution of the Technical Contradictions, thanks to the Contradiction Matrix as brought to Inventive Principles and suggested the solutions proposed. This experience in the industry has put in evidence how the TRIZ theory could be considered a technique of innovative as well as preventative projecting. In fact, if it is suddenly and exactly applied through the TRIZ, findings of problems in industrial process can be improved and cycle of the productions can be optimized. The TRIZ represents at the moment a change of mindset and a powerful tool to serve the project managers and the industries. It improves the performances of the productive cycles by correcting the present contradictions and projecting new effective and efficient productive systems. On a daily basis, the concrete problems with researching solutions deal with the psychological inertia, the tendency to think and follow the same known mental schemes. Despite the research of primary sources and other example of innovation in manufacturing process regarding food container, no significant results of were found. It is to note that there are developments of new materials such as plasma which might be used for food packaging especially due to its suitably adaptation to shapes and bio responsive properties [18]. The current work shows how the TRIZ can develop new and effective project solutions thanks to the examination of different prospective and points of view. In particular, the authors want to retrieve the analysis and the solutions for an anomaly found in an industry that designs and builds moulds and equipment for the production of aluminum food containers. The analysis of the anomaly has put in evidence two critical issues: the first one is linked to the excessive speed of the press while the second to the grip of conveyor guides. With the TRIZ, thanks to the Contradiction Matrix, it has been possible to detect the Inventive Principles necessary to solve the emerged Technical Contradictions. Smart solutions have been proposed in particular for the transmission belts that after examination from the technical staff, now is in the economical evaluation phase and will be now proposed in an experimental way to another organizations for whom the found anomaly happens more frequently.

Acknowledgements

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