SUPPORTING CONCEPTUAL DESIGN PHASE USING TRIZ

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Keywords: Conceptual design, TRIZ, creativity.

Abstract: The conceptual design phase, as it is presented in numerous works, is the most important phase present in product development because the design process's final results amd also the costs depend on it. In this paper is presented the use of an alghoritm for inventing based on TRIZ techniques that can support the conceptual design phase.

1. INTRODUCTION

The conceptual design phase is present in all design models and its important role is emphasiased because it is determinant in establishing the basic product's structure and features. Systematic design supposes to formulate the overall function of the product to be designed. Next, this function is decomposed into lower level subfunctions, seen as transformations between material energy and information [7]. A similar way to design is used in axiomatic design. Here, the difference is that the decomposition is made through zigzagging and the design itself is guided by the two design axioms independence axiom and information axiom [9]. In both approaches, for conceptual design phase, is mentioned that are useful creativity techniques because implies a creativity conceptual work conducted by the question of how can we respond to design requirements. Numerous approaches that use artificial intelligence in conceptual design phase are presented in literature in the last 15 years, aiming to automate the conceptual design phase or a part of the product design process. In [3], are conducted studies that use artificial intelligence during conceptual design phase aiming to obtain solutions to functions through the development of a conceptual design method based on a hierarchical co-evolutionary approach. In [4], is presented a research that aims to automate the systematic design process, the Pahl and Beitz design process. It is the result of the previous automated design research by developing a suite of computational design tools that transform a high-level, functional description of a nonexistent product into a set of embodied concept variants.

Creativity is not a controllable process.This creativity domain is hard to control because it is depending on how the designers think and the many different possible ways that designers can follow to reach the desired finality. To support the emergence of new ideas regarding the finding of new inventive solutions, it can be used a meta-alghoritm of inventing [6] that uses TRIZ technique. The use of the alghoritm and TRIZ technique leads to find redesign solution for a jigsaw' s main functionality - to be able to cut materials. The creation process has two phases the divergent and convergent phases. The paper presents the divergent creation phase and it presents an abstract of technical contradictions and a solution using Su-Field analysis. The TRIZ inventive principles were employed to establish the possible technical solutions for the jigsaw.

2. CONCEPTUAL DESIGN PHASE

The conceptual design phases presented in Pahl and Beitz approach [7] and axiomatic design approach [9] are briefly presented next.

In [7] conceptual design phase is seen as an iterative, evolutive and top down process that leads to a solution principle or a product concept. Its aim is to determine a set of

alternatives, general variants to design problem. These are accepted or rejected based on criterions and next weak spots are found and the principle solution is defined. This solution has to satisfy the fundamental requirements for the desired product.
The systematic work is supported by several general methods [7]: analysis, abstraction, synthesis, method of persistent questions, method of negation, method of forward steps, method of backward steps, method of factorization, method of systematic variation, division of labour and collaboration.
The methods regarding solution finding [7] are divided in *conventional methods* like Information gathering, analysis of natural systems, analysis of existing technical systems, analogies, measurements, model tests and *intuitive methods*: brainstorming, method 635, gallery method, Delphi method, synectics, combination of methods and discursive methods: systematic study of physical processes, systematic search with the help of classification schemes, use of design catalogues, methods for combining solutions, systematic combination, combining with the help of mathematical methods, selection and evaluation methods.
In axiomatic design [9] the design ideas emerge as we pass from functional domain to phisical domain and conceptual design is seen as a mapping from functional requirements to design parameters, an understanding of one conceptual domain în terms of another conceptual domain.
The passing from what to how implies the mapping –a creative conceptual work and during this process they have to think to all possible ways to realise the functional requirements identifying the proper corresponding physical parameter.
The instruments used to generate concepts are [9]: brainstorming, data bases, morphological tables, and as analyse instruments are used design axioms and, grupul de luare a deciziei, Pugh's concept selection and other.
To verify the possible coupling between the functional requirements is used the independence axiom. If there exists couplings, then it can be used the TRIZ technique to decouple them [9]. In both presented conceptual design approaches is emphasiased the importance of creativity techniques, instruments used to generate concepts.

3. TRIZ AND META - ALGORITHM FOR INVENTION

Product creation process is composed from two very important phases. *The divergent creation phase* is when the team transforms the customer's requirements into an abstract creation. An extraction of all the essential elements is required, and using a divergent type of reasoning, the team comes up with a solution that takes into account the customer's requirements. This is the phase when all the psychological barriers of designers should be overcome and when deep, creative thinking should lead to the elaboration of bold product solutions. It is the phase when all design methods that contribute to the development of creative thinking are welcome. TRIZ plays a very important role in this phase. It is in this phase of creation, through breaking down the psychological barriers and imaginative thinking, that new products that cannot be obtained with the present technologies could be designed. Sometimes these bold products are not fully understood by people, and therefore they are not considered to be technological designs. It has been proven by the history that these "lonely wolves" of the human imaginative thinking have revolutionized technology and science.
The convergent creation phase is the phase when the team tries to select from the numerous solutions obtained in the divergent thinking phase those solutions that can be put into practice using existing technologies. Other choice criteria include maximizing the performance and efficiency of the solution and minimizing the product's cost.

Formalising the solving conflict process between design parameters and constraints was realised by TRIZ. Theory of inventive problem solving (TRIZ) is an alghoritmic approach to solve technical problems and generates ideas [2].
Also, is stated in [6] that TRIZ is a qualitative model that can provide recommendations, rules, instructions, suggestions, and examples. These types of qualitative models are all instruments for thinking – the achievement of practical results based on systematic and generalized experiences – and they correspond closely to the concepts of constructive mathematics. An algorithm is the entire set of rules that determine the development of the objects to be constructed. A generalized scheme of a meta-algorithm for invention is presented in figure 1 [6]. It comprises four stages:

- Diagnosis (statement of the problem),
- Reduction (reference to known models),
- Transformation (identification of ideas based on controllable rules of transformation), and
- Verification (check of the potential attainability of goals).

The diagnosis and reduction stages are in essence procedures for the analysis of the problem, while the transformations and verification stages synthesize the solution. This meta-algorithm for invention is the primary navigation system for solutions to any problem in inventing. The procedures from this scheme are supported by database shown clearly in the form of drawings whose basis is the A-navigators [6].We started to analyze the existent product, the jigsaw, (fig. 2). We know that the main functionality for our product is to be able to cut materials.

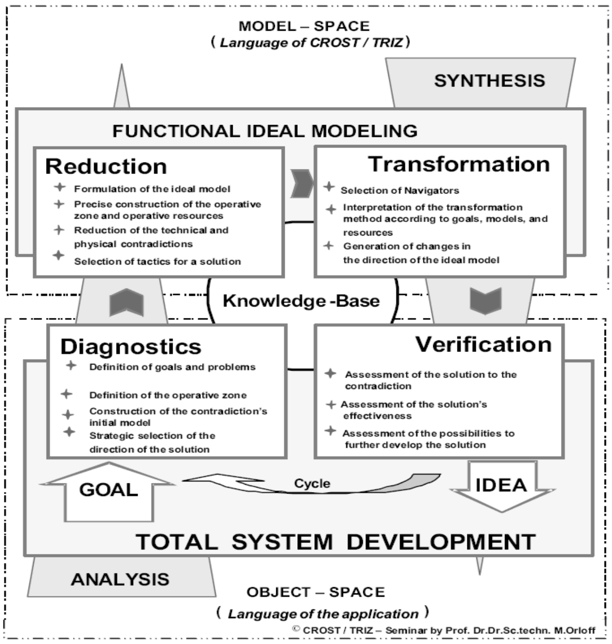

Figure 1. Generalized Scheme of a Meta-Algorithm of Inventing [6]

Figure 2. The Jigsaw

Taking into account these we searched a set of solutions for redesigning the jigsaw's main functionality. To reach this goal we tried in the divergent creation phase to solve technical contradictions and finding a solution using Su-Field analysis. The TRIZ inventive principles were employed to establish the possible technical solutions for the jigsaw.
During the divergent creation phase, an important step is to diagnose the problem [6]. In this step, the following measures have to be taken:

3.1. Defining goals and problems

The goal for the jigsaw is to cut a material in a very short time and make a cutout using small curvature radius.

3.2. Defining the operative zone and its elements

The operative zone (OZ) is the entire set of components of a system and its environment that are directly related to a contradiction.
Actors are the primary elements of the OZ that interact in the OZ and give rise to contradiction.
Inductor is an actor that influences another actor (receptor) with a transfer of energy, information, or material that then initiates a change or action in the receptor.
Receptor is an actor that receives the influence of the inductor and then changes itself or starts an action due to this influence.
The jigsaw can be abstracted, as presented in figure 3. The cutting tool is the inductor and the cutting material is the receptor. The inductor will receive the energy needed to realize the cutting from an energy source and by acting upon the receptor will realize the cut.

3.3. Constructing the initial model of contradiction

Useful functions (positive) include:
- obtaining a cutout using small curvature radius, and
- removing rapidly the material which is in the front of the tool

Negative functions include:
- wearing down of tool, followed by its failure,
- creating increased vibrations generated by cutting, which decreases the quality of the cut, and
- productiveness of the cutting's work out

Operative zone is represented by the contact (connection) between inductor and receptor.
A Su-Field analysis, according to [8] and [1], is presented in figure 4.

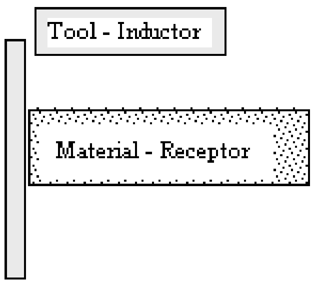

Figure 3. Tool's abstraction

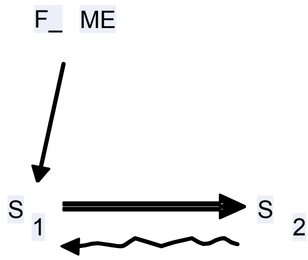

Figure 4. Operative Zone Su-Field Model

It can be observed that a mechanical field, a pressure that acts upon the cutting tool (S1) will help to transform the material ahead of it – the material is then removed, thus realizing the cutting of the material. In turn, the material to be cut (S2) acts upon the tool and wears it down.
The following directions to solve the problem are noted:
- intensifying the inductor's motive power upon the receptor,
- Intensifying the inductor cutting speed, and
- designing a cutting tool with increased wear resistance.

The greater the inductor's motive power, the greater the yield from cutting; however, the tool is also worn down more so and it loses from its ability to provide a quality cut, hence giving rise to vibrations. To cut along small curvature radii, it is important to have a tool that creates a narrow cut. The contradictions that arise are presented in figure 5.

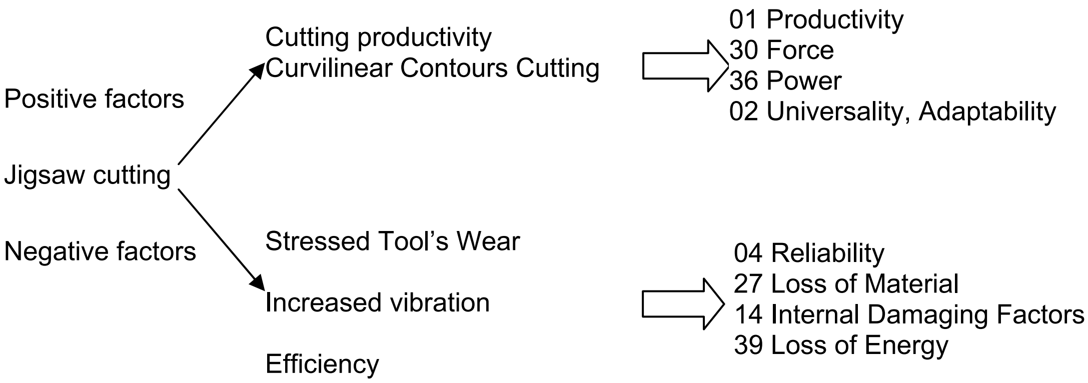

Figure 5. Technical contradictions

3.4 Identifying a strategic selection of the direction of the solutions

Using contraction matrix [11] specialized solution directions can be identified, such as:

1. Employing the mechanical oscillation

According to this solution direction, the cutting tool will undergo an oscillating movement in order to discard parts from the material to be processed to prepare it for cutting. The cutting blade (see figure 6) has an oscillating movement with an active stroke. This solution exists and the blade teeth are oriented upwards so that the cutting force is taken over by the portable saw (as seen in figure 6).

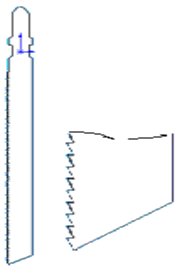

Figure 6. Cutting blade

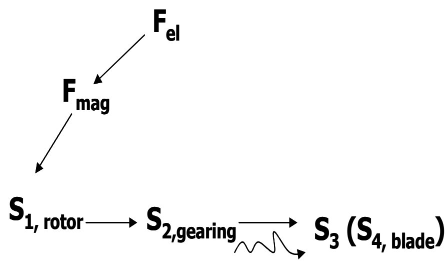

Figure 7. Fields transforming in oscillatory movement

In the present solution, presented before, the following transformation of certain used fields is included. One can see how the electrical field is transformed in a magnetic field that spins the rotor of an electric motor S1, rotor, obtaining a high rotation motion. This in turn is transformed in another slower rotation motion, through a gear reduction unit S2, and the crank and connecting-rod assembly S3 transform the rotation motion into an oscillating parallel displacement motion. The cutting blade (S4) forms a unit with S3, and through its upward stoke produces the cut (see figure 7).
This transformation implies the existence of a revolution reduction unit, which with a relatively high revolution transfer rate can lead to vibrations that are not desirable.
Thus, a new operative zone appears, corresponding to the transformation of the electric field into an oscillating parallel displacement motion through a shorter chain, as shown in figure 8. According to this scheme, the electric field is transformed into a magnetic field, which operates on S3, with which the cutting blade S4 is forming a unit; the oscillating parallel displacement motion needed for cutting is thus created. A viable solution that creates the needed motion is based on Tutelea's research [10] and is presented in figures 9 and 10. The linear permanent magnet oscillatory machines have gained momentum in the last decade and could play an important role in the direct driving of piston pumps,

compressors, etc. A flat surface mover allows for permanent magnet flux concentration, and the machine core is easy to manufacture from laminations.The sketch of the permanent oscillatory machine with buried permanent magnet flux concentration is show in figure 9:

- the mover is sliding on linear bearings,
- the kinetic energy is recovered by two mechanical springs, and
- the blade will be joint with mover.

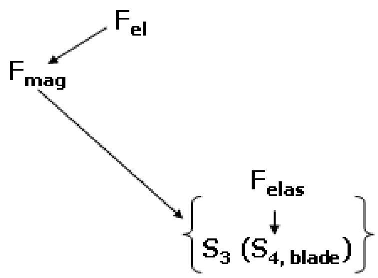

Figure 8. Decreasing the transformation chain

The sketch of the permanent oscillatory machine with surface permanent magnets is present in figure 10. The disadvantages of this solution are: the frequency of the mover has to be equal with the resonance frequency of the mechanical spring, the cutting speed has to be constant, and the maximum stroke is 30-40 mm.

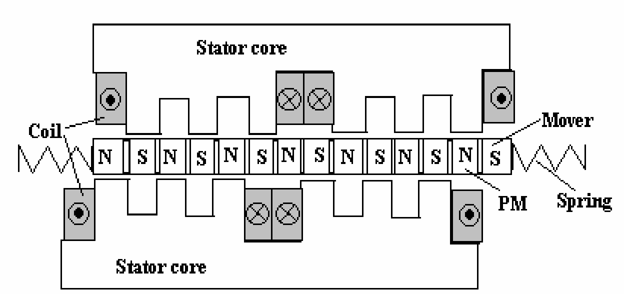

Figure 9. Solution with buried permanent magnet

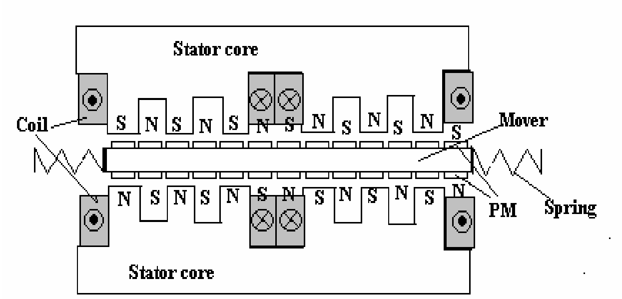

Figure10. Solution with surface permanent magnets

2. Replacement of mechanical matter

Replacement of mechanical matter- according to this direction, the replacement of the solid body of the cutting blade with other materials leads to other types of material cutting.

If the solid body of the cutting blade is replaced with a liquid under pressure, which engages abrasive particles, then we have fluid cutting. This type of cutting requires a high-pressure liquid that engages the abrasive particles, which will in turn cut the processed material. The solution has the advantage of curvilinear cutting, following small curvature radii, due to the fluid's reduced intensity resulting in a very high quality of the cutting. It is difficult to apply this solution to a manual saw because the transfer of the fluid at a high pressure from the fixed part of the saw to its mobile part would create some problems and also the protection of the operator and environment would be difficult to achieve.

The use of air under pressure, which would engage abrasive particles to cut materials, raises even bigger problems regarding operator and environment protection.

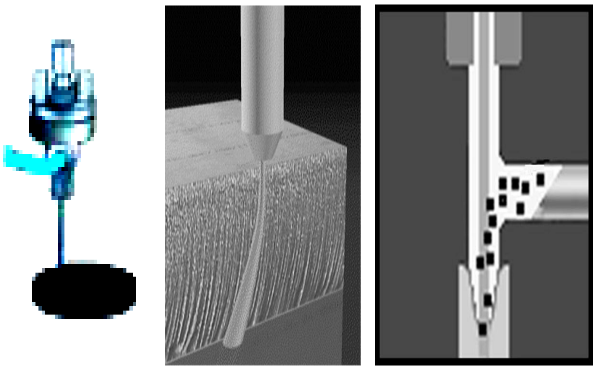

Figure 11. Cutting with liquid jet

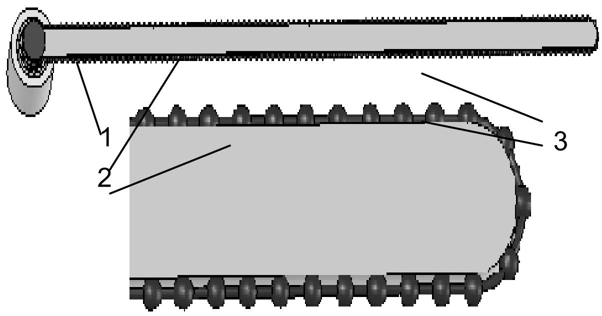

Figure 12. The tool with continuous movement

3. Inverse action

According to this solution direction, the following solution can be developed: In mechanical cutting, due to the interaction between the cutting blade and the material to be processed, apart from the abrasive wear, heat results, which contributes to the tool damaging. Solutions which make use of heat in cutting materials are:

Laser beam cutting. In this case the heat from the laser beam is used to evaporate the material touched by the beam and thus the materials are cut. Using the laser beam with a manual saw creates other problems, thus making it a solution not likely to be used.

Another solution is *the use of the heat emitted by electrical energy*, which melts the material and cuts it. It is the case of the wire electro erosion processing. This solution is difficult to implement with a manual saw because the material to be cut has to be immersed in a dielectric.

In order to use the abrasion as a proper solution, a cutting using the electrical contact was developed in [5] In this method the tool interacts electrically with the material to be processed. The heat resulting from the electric contact melts the material in front of the tool, which is then removed by the movement of the tool. Notice that by adjusting the electrical and mechanical parameters of the cutting equipment, there is little to no wear of the tool. This depends in a large part on the characteristics of the material to be processed and on the working parameters of the cutting equipment. In addition, the cutting tool needs to be properly cooled.

Although the electrical cutting would be tempting when making a portable saw, presently there are some technical problems which would be difficult to surmount. The small dimensions of the tool (which is intend to be a line) makes the proper cooling of the tool difficult to achieve), and moreover, the portable saw is used when cutting a wide range of materials with different mechanical characteristics, case in which the tool wear would be greater, so the tool would damage rapidly. Perhaps the future technologies would solve this debate and this solution could be adapted to a portable saw.

4. Dynamization, segmentation

According to this solution direction applied to jigsaw, the tool constructive design should be changed so that continuous rotating movement can be used at high speed (rpm). The disadvantages of constructive solutions that use straight reciprocating motion are: the existence of a return stroke that leads to the decrease of the cutting efficiency, inertia forces that are generated when the tool's movement sense of direction is changed (because of the oscillatory movement), and the insertion of a supplementary device that will interrupt the tool's contact with the working material in the return stroke. These disadvantages can be removed using a continuous tool movement, but it has to ensure that the tool's return stroke will be through the previously made cut.

The cutting tool with continuous movement (fig. 12) is made from a resistant and flexible wire, 3, that has attached spheres. The upper side of these spheres is made from abrasive material - diamond milling- and the inferior side of the spheres is used to drive the cutting wire, meaning to guide this on a guiding plate, 2. This wire meant for abrasion cutting is driven into the rotation movement by a driving roller, 1. Also, in this case, the wire's rotating sense of direction is chosen so that the jigsaw will take over the cutting force. This design can be easily transformed by using arc cutting, case where the wire will be without spheres; however, the problems of excessive wear and cooling would have to be solved.

5. CONCLUSIONS

Nowadays the products requierements and functions are increasingly complex. This complexity creates the need to employ TRIZ creative thinking methods and to work in teams with experts from different fields. In this way, all expertise are pooled, thus leading to the creation of products with new, exciting functions and features. This paper's aim was to present a set of solutions for redesigning the jigsaw in the context linked to conceptual design phase. The used method to generate solutions is TRIZ and provides us with good results. It was used the Su-Field analysis to abstract and solve the technical contradictions. Using the TRIZ contradiction matrix and TRIZ inventive principles it was established the possible technical solutions for the jigsaw.

ACKNOWLEDGMENTS

The research for this paper has been done in the 6th Framwork Program - Virtual Research Lab for a Knowledge Community in Production (VRL-KCiP) project, FP6-507487 contract and Excellence Research Program - National Research Network for Integrated Product and Process Engineering (INPRO) project, 243/2006 contract.

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