TRIZ Approach for Designing a New Assisted Tooling for Dimple Structure Fabrication

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ABSTRACT

TRIZ is a systematic means or tool that provides a logical approach to solving problems through inventive and innovative manners. This research shows the TRIZ approach implemented in demonstrating the need and necessity for developing the design and concept of assisted tooling, which is relatively new, in fabricating a dimple structure for the turning process. Based on the analysis using TRIZ, a structural design and concept of linearly speed movement assisted tooling was developed by using low cost mechanical components that are readily available and easily purchased in the market. Movement of the tool holder was in the x direction with the help of a DC motor connected to a cam system to move the tool holder. The factors for selecting this concept of structural design in this research were based on low component cost, efficiency, performance, durability, minimum use of supportive components, and a simple design installation which can be mounted on a tool post and turret without redesigning the tool holder and, therefore, minimised the cost of fabrication.

Keywords: *TRIZ, Assisted Tooling, Dimple Structure, Turning Process*

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Introduction

Inventive and innovative approaches using the TRIZ method for solving issues and problems in various fields such as architecture and product development are widely used. TRIZ is an original concept that was successfully put forward by Genrich Altshuller, a Russian scientist and architect, along with his research partners by bringing out around 400,000 technological patterns in which each comes with a concept and specific rules for solving particular issues, the generation of new ideas as well as innovation of others, as stated by Ilevbare et al. [1]. Based on a few tools and techniques that were developed by Altshuller TRIZ, Souchkov [2] has provided a basic general picture and chronology of the TRIZ's development, along with its concepts, from 1946 up to 2008. Table 1 below presents the parts of the tool and TRIZ concepts that had been further simplified by Ilevbare et al. [1] has been favoured by many as their tool of choice in solving a particular issue or problem.

Table 1: 14 Main tools and concepts of TRIZ

Tools and Technique/Concept	Explanation
40 inventive principles	Solution concept for technical and physical contradictions
76 standard solutions	Rectify issues of a system without the need of identifying contradictions.
Database impact	Encompasses approximately 2500 concepts extracted from engineering and scientific knowledge for problem solving
Separation principle	Comprehending and solving physical contradictions through inventive principles in solving problems.
Contradiction Matrix	39 Matrix technical parameters are arranged vertically and horizontally which can be use in solving technical contradictions.
Technical system evo. pattern	Identify the direction of technological development.
IFR and ideality	an arbitrary system that has all its parts performing at the greatest possible capacity.
Fitting	a step returning to IFR wherein a concept or idea is not achieved.

Function Analysis	Understanding the functional analysis of the interactions between all the components in the particular system and sketching problems arising from the interactions.
Substance field	Drafting overall problem of a system without adding unnecessary information.
System resources analysis	Analysis of system resources externally to the advantage of the problematic situation.
Nine Windows	An inventive thinking system – for comprehending problems.
Creativity tools	A clear mind that is able to think creatively outside the box.
ARIZ	Series of arrayed steps using TRIZ tools to produce solutions and innovations

Referring to Table 1, it can be seen that there are various tools in the TRIZ concept that can be adopted in solving various problems in our daily life. An observation made by Ilevbare et al. [1] shows that as many as 61% of respondents apply TRIZ in problem solving during product innovation and technological queries and an even higher percentage of 85% apply the tools available in this concept when used for the solution of technical problems. These statistics prove the suitability of using the TRIZ tools in producing innovation with a particular product. As such, when looking at the effectiveness and success factors in the use of these methods to solve problems, including the development of new products, the focus of the author is using this approach to develop a new concept for an additional tool in manufacturing dimple structures is appropriate and significant. Chou [3], who also uses this method as a solution in the study of the development of new products by incorporating the concepts of mapping technique and fuzzy linguistic evaluation into a holistic methodology, claims that this method can help designers in generating new ideas - ideas of new product lines that suit the today's technology. Besides this, Chou also maintains there is an obvious comparison in the conventional ideation method when TRIZ is focused on the effectiveness of problem solving and generating ideas alone, but did not provide structural conceptualisation to formulate potential problems, avoid trial and error or identify product ideas [3].

The approach of this concept in solving a particular problem has been proven countless times in various research studies by previous researchers. Cempel [4] used the TRIZ approach in solving problems in his observation of the vibrations in machinery by creating a TRIZ mind map of the structure that can be referred to in Figure 1 which shows the parts of the

TRIZ structure shown by Cempel [4]. A TRIZ approach and the same structure were also adopted by Vinodh et al. [5] in the study and development of his products.

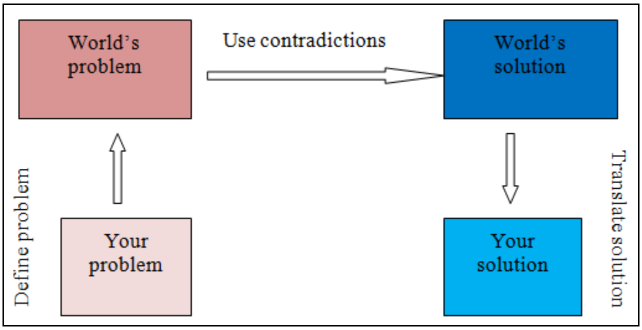


Figure 1: Parts of the Mind Map of the TRIZ Structural Approach [4]

The use of mind maps and collaboration with the TRIZ structure is perceived as creativity in the field of engineering because, according to Cempel [4], agrees with a Chinese proverb that states a picture provides more than a thousand words. The incorporation of a mind map in the TRIZ structure encompasses contradictions, innovative problems as well as the solution to the previous problem. All of these are visually elaborated into a clear graphic.

The relationship between the applications of TRIZ in developing product concepts that assisted tooling for the turning process to produce a dimple structure is also closely related to the surface texturing of a component. A dimple structure is applied to the surface of a component to be able to act as a booster for the characteristics of good texture on the surface, and thus enhance the tribology attributes. Tribology maintains a significant relation with wearing and friction which are elements that need to be set at a minimum level, or minimised, to ensure the specific function of a mechanical component that moves in contact between surfaces may function efficiently and effectively. According to Farhanah & Bahak (2015) [6], High friction will cause wear and defects on the surface components, due to friction and wear which have a very close connection between them. The fact was also supported by Syahirah et al. 2015 [7], which revealed that, if the friction process is continuously acting at a certain points, thus it will cause in increasing the temperature as well as developing the surface wear at that point. Bruzzone et al. [8] have widely discussed the relevance of characteristics and functions of a surface, in addition to that they also made inferences regarding the function of the use of surfaces bearing micro dimples on the surface distribution of the shaft will act as a lubricant and reduce friction by 30%. This fact was also supported by Xiaolei et al. [9] who found a textured surface such as micro dimples or grooves will be able to keep lubrication. According to Basnyat et al. [10] and Voevodin et al. [11], enhancing the tribology characteristics of a particular surface is through the presence of a micro reservoir which acts as a lubricant. There are several mechanisms that contribute to the friction and minimise wear on the mechanical seal or the bearing in which every dimple acts as a small oil reservoir that could supply lubrication to a surface that goes through friction such as stated by Etsion [12]. In order to produce a high quality dimple from a machining process for the purpose of increasing these tribology characteristics, the production of assisted tooling needs to be developed through the TRIZ methods to solve problems in developing the concept of new products such as stated by Chou [3]. There are multiple means or methods for fabricating dimple structures such as the use of lasers, engraving machines, photochemical, stamping and several other processes that are suitable for the application of structure dimple on a specific surface or component. However, based on certain justifications, the selection process required using the turning process for the production of this dimple structure. A turning machine, or lathe, requires assisted tooling for movement of the tool in producing a dimple structure. The movement concept of the tool's movement and assisted tooling were developed by various researchers who conducted research in relation to fabricating this dimple structure. However, it transpires that there are a few constraints based on existing assisted tooling which are associated with the high cost of components, the lack of an appropriate design to suit the tool post and CNC turret, high consumption of electronic components and hindering the maintenance, storage and preparation processes. Other than that, the accessibility of the components is also very limited which, consequently, requires international purchase. As such, the author feels the need to develop a concept of assisted tooling that uses a mechanical system that is cost-saving, easily fabricated as well as being suitable for use.

Solutions Using ARIZ Tools

ARIZ is an abbreviation which stands for Algorithm for Inventive Problem Solving. This tool is a systematic procedure in identifying solutions, without glaring contradictions, to a much more complex problems. There are several analysis steps in this tool which are namely:

Problem statement

In this research the problem is identified as existing assisted tooling that requires components that are not available locally, is of high cost, is challenging in its fabrication, and requires expert workforces in its handling.

The difficulty in adjusting a tool holder that has been modified to fit the tool post as well as CNC turret, the use of high level electric components will hinder the maintenance, storage and preparation processes. The need and significance in developing an assisted tooling design with low cost components which are easily accessible in the local market, easy to maintain, more flexible and can be easily handled are issues that need to be looked into. Other than that, obtaining the appropriate shape and size of dimple also needs to be seen in the cutting tool geometry itself.

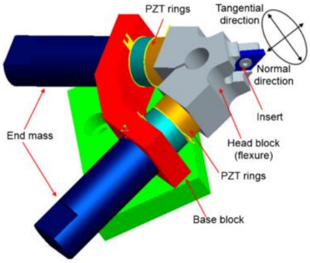
Mini-Problem

It is crucial for us to research the ability, durability and performance of the existing assisted tooling as well as those that will be developed in the future. These characteristics are also important because the ability and performance of assisted tooling that will be developed in the future should live up to the standards of the pre-existing ones and be able to produce dimple structures such as those of existing assisted tooling.

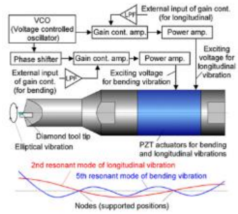
System Conflict

Comparisons of the existing assisted tooling concept and design in table 2 show the various designs wherein the majority use a high electrical component. The cutting tool holder is designed to suit the use of a piezo actuator and other components. Preferably, the use of the actual tool holder is necessary considering that the tool post, as well as the CNC turret, is designed to hold the actual tool holder by taking into account vibration factors and the durability of the tool holder.

Table 2: Comparison of Assisted Tooling

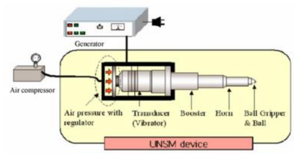
Supported Components	Assisted Tooling Design and Researcher
• National Instrument data acquisition card (NI DAQ PCIe-6361) • piezo amplifier (TREK PZD 350) • two Langevin transducers • MicoSense capacitance sensor	 The elliptical vibration texturini Process – Guo and Ehmann (2013)

- Langevin type transducer (BLT)
- PZT actuators



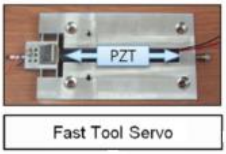
a vibration control system of a two-degree-of-freedom (2-DOF) – Suzuki et al. (2011)

- A generator and piezoelectric transducer
- acoustic booster
- ultrasonic transducer



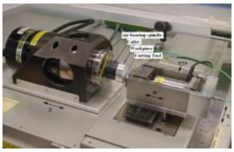
Ultrasonic nanocrystal surface modification - Amanov et al. (2012)

- PI high voltage amplifier
- piezoelectric actuator
- Lab View software - generate the input signals



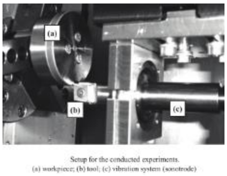
Fast-tool servo (FTS).based diamond Machining - Lu et al. (2014)

- encoder resolution of 1024 line/revolution
- customized piezoelectric type FTS
- AC servo motors



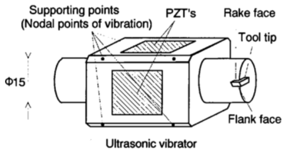
Fast tool servo (FTS) diamond turning - Yu et al.(2012)

- ultrasonic frequency generator UIP250
- ultrasonic vibration system (DEVAD GmbH, Germany)



vibration-assisted turning process - Zhang et al. (2014)

- two piezoelectric plates
- piezoelectric-type dynamometer
- Optical sensor
- Amplifier



ultrasonic elliptical vibration cutting - Moriwaki and Shamoto (1995)

Reformulated Problem

The pre-existing designs all require the use of components that are not readily available and need costly supportive components such as a piezo actuator, transducer or amplifier. Looking into each design individually, none uses the actual tool holder and this causes difficulties regarding suitability in assembling the conventional or CNC turret turning machine tool post.

Model of the Problem

The existing assisted tooling uses a lot of supportive electronic components that need specific maintenance and handling during the operation and storage period. Minimising the use of electronic components in developing assisted tooling with a mechanical concept without compromising its durability, performance and ability in producing high quality dimple structures is therefore highly important.

Analysis of the Conflict Domain and resources

The use of a piezo actuator as the main component in the movement tool for the existing assisted tooling also depends on the positioning of the PZT ring to transmit electrical current. PZT rings will vibrate according to the current received and most often is located near the tool of the designed assisted tooling. Connection of wires supplying current to PZT rings are very complex and space consuming which narrows the area in the assisted tooling. Besides that, the electrical component needs proper and delicate care requiring experts for handling which, in turn, increases the cost.

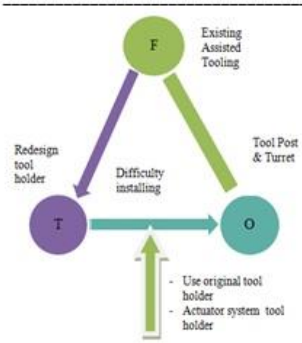
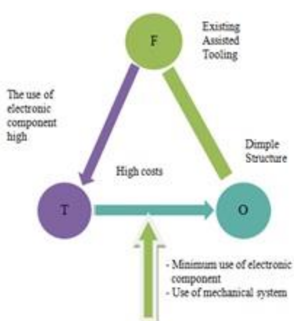
Ideal Final Result (IFR)

The solution requires a movement concept that is connected to a cam system which moves the tool holder with a fast movement. Minimal use of supportive mechanical components such as bearings or linear bearings. Needs to be easily handled and stored, as well as without wire connections as a power source near the cutting tool to prevent complex connections that are space consuming and narrowing. As such, assisted tooling utilising the concept of cam system supported movement is proposed.

Physical Contradictions

Physical contradictions here are the use of multiple electrical components which are costly and require delicate and proper handling as well as maintenance. The suitability of the assisted tooling design with the existing tool post and CNC turret is a physical factor that needs to be investigated and analysed. Table 3 shows the analysis using S-field in developing the concept for new assisted tooling.

Table 3: Analysis using S-field model in developing a new assisted tooling

S-Field Model	Solution	Description
	Using existing tool holder without modification	Intends for easy assembly that can be suited with the tool post and turret for CNC. Overall assisted tooling not requiring the use of the actual tool holder
	Designing a movement system on the tool holder	Consistent movement that does not require much maintenance
	Minimising the use of expensive electrical components	Use of piezo, transducer, amplifier, sensor and other costly components not available locally.
	Using a mechanical system	Designing a mechanical system that moves the tool holder at high speed. A suggestion would be the use of a cam system that will move the DC motor. Besides that, this system is also easily designed and fabricated which allows low fabricating cost.

Elimination of the Physical Contradictions

The use of a cam system is proposed for minimising the electrical components in the existing assisted tooling. A new design needs to be developed without modification of the tool holder in order to suit the CNC and conventional machines.

Engineering Solution

The development of assisted tooling of a suitable size compatible with the CNC as well as conventional machines which is easily assembled. Overall movement mechanism that uses a mechanical system. The cam system proposed is also examined in detail from the cam lobe structural or design aspect to determine the ability of the frequency that can be produced to move the tool holder. Besides that, developing a tool that is suitable in achieving a dimple structure of various shapes and sizes.

Conclusion

Overall, the use of TRIZ in developing either a particular new product or making modifications based on problems is one of the methods that are simple and easy, as well as having a huge impact by acquiring precise solutions that are quick and effective. As a result, development of assisted tooling with a new design and concept can be carried out through several analyses that are incorporated in this ARIZ tool.

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