Development of Dynamic Assisted Tooling Using TRIZ Approach for Dimple Structure Fabrication in Milling Process

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ABSTRACT

Most processes used for dimple structure fabrication nowadays have side effects on environment and human, high consumption of energy and high costs of machine set up. In order to solve these problems, Theory of Inventive Problem Solving (TRIZ) approach has been used to identify the appropriate process and technique to fabricate dimple structure on a flat surface. This method is chosen due to its advantage in terms of time saving and cost reduction for selecting the appropriate technique for fabricating dimple structure. Result analysis on TRIZ approach proved that milling process is a suitable technique to fabricate dimple structure on a flat surface. An assisted tooling is required to assist the dimple structure fabrication using a milling process. Prototype Dynamic Assisted Tooling Milling (DATM) has been successful developed to fabricate dimple structure.

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Introduction

Now days, the development of manufacturing technology is very rapid due to product requirement and customer demand. Manufacturer must react with this environment in order to survive and competitive in the global market. In manufacturing industry, the demand from the customers will directly influence the production rate. New technology and latest production methods will improve the production rate and product's quality.

To fulfill the demand, a new and effective method is needed for making a new product. In industry, product data collection and various methods will be used and analyzed before development of new product or to improve the existing product. Data collection and method will be gathered with certain approaches then followed by producing a new product that meets the objectives [1]. Research and studies show that the implemented approach will affect the performance of the industry in terms of financial, corporate and brand identity [2, 3]. This approach has been used by Ford Motor Company, General Motors, Motorola, Digital Equipment Corp to fulfill market demand and produce a good quality product in a short time [4]. Product development has been completed in a short time, cheap and has good quality after using a certain approach in new-product development.

TRIZ approach has been used extensively in developing a product. This theory was developed in 1946 by Genrich Altshuller in Russia, and it has been applied widely to solve product design problems or system, etc. [5]. TRIZ is a method of identifying the problem and solving the problem in the early stages of the process up to the end product. The accuracy in problem solving generated by TRIZ depends wholly on customers' accuracy in identifying existing problems. Most customers use paradigmatic approach and not conceptualized in identifying problems faced [6]. All problems need to be identified before choosing the right TRIZ tool to solve them because a solution will be useless if a wrong tool is used. The principal characteristics of TRIZ approach are identifying and eliminating any issues that may arise from the solution by focusing clearly on the root cause in order to achieve the purpose of the subject [7]. The main advantage of adopting TRIZ approach as a problem solving tool is that it provides a systematic approach in addressing problems unlike conventional approaches that are often ad hoc and heavily dependent on luck.

TRIZ approach offers various tools to solve problems but the contradiction matrix, and the 40 inventive principles are the most commonly used because they provide guidelines to develop a useful concept of solutions for inventive situations [8].

Problem definitions play a vital role in the problem-solving and idea generation process since the quality of idea solutions depends highly on precise problem definitions. In other words, TRIZ approach is a methodology that is systematically compiled to solve arising problems [8]. This method provides a systematic and innovative approach for solving design problems compared to the existing conventional methods [7]. The aim of TRIZ approach is to provide users a strategy problem-solving process directly to the specify inventive solution to minimize trial-and-error iterations [6]. A lot of attention from researchers, when this method successfully achieves a target of production rates in a manufacturing process.

Fabrication of Dimple Structure

Before applying the TRIZ approach, preliminary researches on the effect upon dimple structure fabrication process were conducted in order to study the side effects that occurred before and after the process. Various fabrication processes were used to produce dimple structure. Among those selected by researchers were electro-chemical, laser and machining. However, most of the process will produce side effects on the environment and human health as well as to the quality to the dimple structure itself. Table 1 shows the pro and cons of various dimple structure fabrication process [9]

Table 1: Effect of dimple structure fabrication process [9]

Methods	Remarks
Electrochemical Micromachining	Costly disposable of waste, high-cost process due to long fabrication time, small size of dimple
Milling	Cheaper process, big size of dimple
Ultrasonic Nan crystalline Surface Modification (UNSM)	Expensive process, very small size of dimple, limited shape of dimple.
YAG laser	costly process, hazardous (has to follow strict precaution), various shapes of dimple, big size of dimple
Electrox Laser Marking Machine	Expensive process, hazardous (has to follow strict precaution), various shape of dimple
Micro Tooling	Intermediate process cost, various shapes of dimple
Photochemical Machining	Costly disposable of waste, high-cost process due to long fabrication time, medium size of dimple, various shapes of dimple
Miniature Engraving Machine	Cheaper process, big size of dimple, restricted shape of dimple
Laser Textured Surface	Expensive process, hazardous (has to

	follow strict precaution), various shapes of dimple, big size of dimple
Femtosecond laser	expensive process, hazardous (has to follow strict precaution), restricted shape of dimple, intermediate to big size of dimple.

One specific solution for dimple structure fabrication process is needed to overcome the side effects that occur while the fabrication process is in progress. Any fabrication process that contributes/causes side effects should be avoided, and the machining process is the best process to produce dimple structure on the material surface. This is because it does not contribute towards chemical wastage disposal, and it does not use high energy. However, it has its own weaknesses in fabricating dimple. Among them are longer rate of dimple production and cutting effect like burr occurs after the process.

TRIZ Problem Solving

From the previous researches, [10][11][12] general model for TRIZ problem solving, Figure 1 was formulated to find solution and specific problems in fabricating dimple structure.

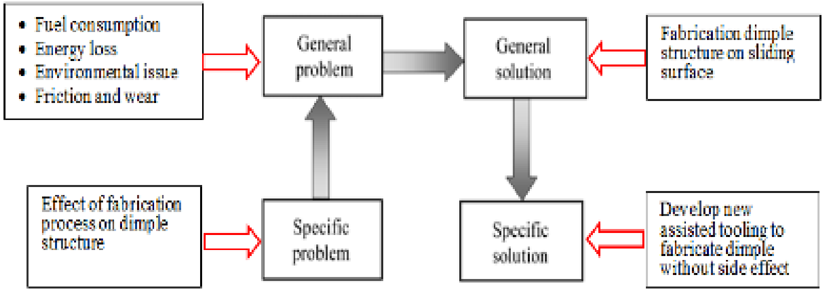

Figure 1: The general model for TRIZ problem solving to develop new assisted tooling

Figure 2 shows the flow of TRIZ process that is applied as a solution to the arising problems that occur/exist during the machining process. There are two tools used, cause and effect chain analysis and engineering contradiction followed by engineering formulation contradiction statement and finalized with 40 inventive principles as solution references to these problems.

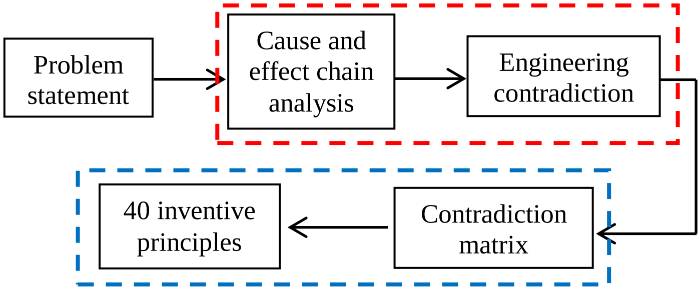

Figure 2: TRIZ process flow

Figure 3 shows a flowchart of dynamic assisted tooling for milling (DATM) development where technical contradiction was referred based on DATM development impact on the operation during the process. In other words, deteriorations on DATM developed characteristics may occur in the effort to upgrade these DATM technical attributes. The change on the machining process has the effect of dimple structure fabrication process [5].

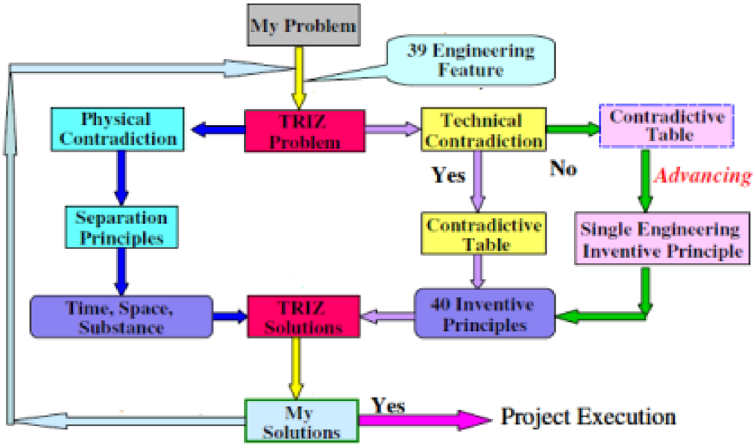

Figure 3: TRIZ resolving flowchart for DATM development

In Figure 4, Cause and Effect chain analysis was developed to study the main problems in dimple structure fabrication. The effects like hazards to the environment and human are the dominating effects in dimple structure fabrication at the moment. The side effects generated during, and after the fabrication process has become the main cause for developing DATM. The DATM developed could increase a production rate of dimple as compared to the existing machining with better quality and consistent dimple structure array.

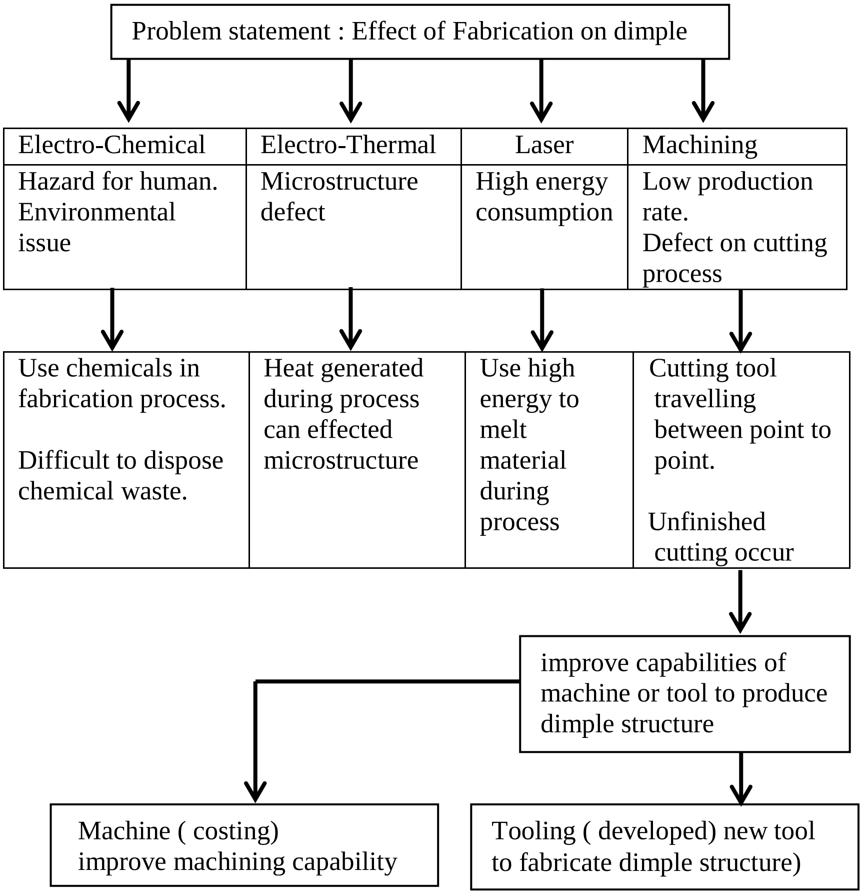

Figure 4: Root Cause and chain effect analysis for development of DATM

Based on the cause and chain analysis, machining process is a suitable process for fabricating dimple structure without side effects. However, from the financial point of view, improving machine capabilities is not the best choice as compared to develop assisted tooling to fabricate dimple structure. In developing this assisted tooling, its production and operation have become the main parameters being referred to in 39 Engineering parameters of TRIZ, Table 2.

Table 2: 39 Engineering parameter of TRIZ [11]

39 Engineering parameters of TRIZ	
1. Weight of moving object.	21. Power.
2. Weight of stationary object.	22. Loss of energy.
3. Length of moving object.	23. Loss of substance
4. Length of stationary object	24. Loss of information.
5. Area of stationary object.	25. Loss of time.
6. Area of stationary object	26. Quantity of substance.
7. Volume of moving object	27. Reliability.
8. Volume of stationary object	28. Measurement accuracy.
9. Speed	29. Manufacturing precision.
10. Force (Intensity)	30. Object affected harmful.
11. Stress of pressure	31. Harmful side effect.
12. Shape.	32. Ease of manufacture.
13. Stability of the object.	33. Ease of operation.
14. Strength.	34. Ease of repair.
15. Durability of moving object	35. Adaptability of versatility.
16. Durability of non-moving object	36. Complexity of device.
17. Temperature.	37. Complexity of control.
18. Illumination intensity.	38. Level of automation
19. Use of energy by moving object	39. Productivity
20. Use of energy by stationary	

Table 3 showed parameter #32 Ease of Manufacture has become the positive parameter that needs to be upgraded from the production point, while # 33 Ease of Operation has become a negative parameter from its operation point in fabricating dimple structure.

Table 3: TRIZ Contradiction matrix for developments DATM

Improving (positive) \ Worsening (negative)		#33 Ease of operation
32	Ease of Manufacture	2, 5, 13, 16

Via contradiction matrix table, inventive principles proposed are as shown on Table 3. These principles have become problem solving guidelines in DATM development. Among the proposed principles are:

#2. Taking out
#5. Merging
#13. The other way round
#16. Partial or excessive action

Brainstorming concept was used to determine a suitable principle that has been potential in developing this assisted tooling. Table 4 showed inventive parameters selected based on reasoning and proposed actions plus solutions to problems that exist in developing this assisted tooling.

Table 4: Proposed action and reasoning using selected inventive principles of TRIZ

Principles	Proposed Actions	Reasoning	Figure
#2. Taking out	Cutting parts and main structure needed to move freely without any constraints during the machining process.	Cutting tool needs to spin freely and move on Z-axis during the cutting process. This movement is to produce the dimple structure array	
#5. M	Cutts o become one unit to DATM while the machining process is in progress.	DATM can operate as a complete unit without other support during dimple fabrication process	

Prototype DATM has been developed and tested to produce the dimple structure as shown in Figure 5a and 5b. Prototype has been developed to assist the fabricating of dimple structures on a flat surface using milling machine.

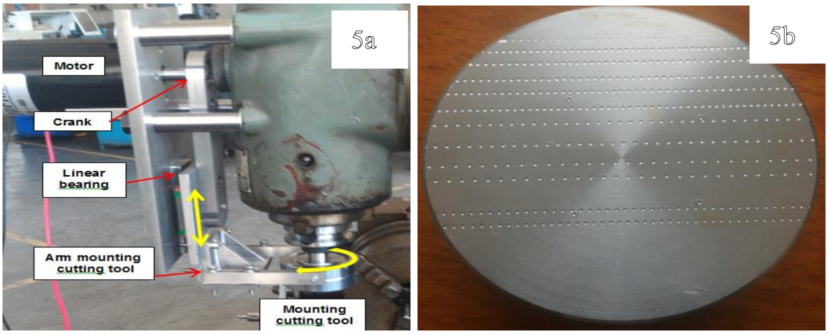

Figure 5: Dynamic Assisted Tooling; (a) attachment on machine and (b) dimple structure produced with DATM on milling machine

Taking out and merging principles are chosen to develop DATM as a one complete assisted tooling and moves freely on Z axis during fabrication process. Dimple structure as shown in Figure 5 (b) are successfully fabricated using DATM. Although the detailed study on the quality of the dimple produced is still at the early stage, but DATM is environmental friendly, easy and simple to use for dimple fabrication on flat surface.

Conclusion

DATM was successfully developed using effective inventive principles of TRIZ. This proves that systematic TRIZ approach is suitable for developing DATM, which covers problem identification, idea generation and conceptual solution development. This newly developed DATM is used along with the milling machine to fabricate dimple structure on a flat surface.

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