An integrated process for designing around existing patents through TRIZ

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Abstract

Patent infringements have become an important issue for industries when developing products. Designing around existing patents of competitors is a task constantly faced by designers. New design problems, which are often a "local innovation" of an existing patent, are generated during the design around process. Innovative design methodologies are needed to solve these new design problems, while the rules of patent infringement judgment present the major constraints to such design problems.

This paper proposes an integrated process for designing around existing patents through TRIZ. This process integrates patent design around strategies, innovative design methods in TRIZ and rules of patent infringement judgment to systematically design around existing patents and increase the patentability of results of innovation. Redesign of a portable magnetic impact tool to design around an existing patent is used to illustrate the integrated process.

Keywords: design around, TRIZ, patent infringement, magnetic impact tool

1. Introduction

Patent infringements have become an important issue for industries when developing products. Product-related patents are often the major barriers in the development of new products. On the other hand, the direct and less time-consuming way to develop identical or similar products with competitors' products is to counterfeit, imitate, copy or add functions to existing ones.

Designing around existing patents of competitors is a task constantly faced by designers [1, 2]. Designing around is based on the process and rule of the patent infringement judgment to develop the required techniques that have the substantial difference with the scope of claims of existing patents. Nydegger and Richards [3] proposed three possible methods for designing around an existing patent:

(1) Reduce the number of elements in the claims to satisfy the full elements rule.
(2) Use the method of substitution to make the accused subject matter different from the techniques disclosed in the claims to prevent literal infringements.
(3) Substantially change one of the constitutive requirements of way/function/result to prevent infringements according to the doctrine of equivalents.

Note that each of the methods described above presents a new design problem to be solved. Such design problems are often a "local innovation" of an existing patent. For example, in the second method described above, how to find an alternative design so that the results of innovation are not equivalent to any existing patents is a new design problem which may require innovative design methodologies. One very special characteristic of such a design problem is that, the rules of patent infringement judgment present the major constraints. Designers may have to sacrifice the performance of the product in order not to infringe with existing patents.

TRIZ is the Russian acronym for the "Theory of inventive problem-solving" developed by Genrich Altshuller in Russia in 1946 [4]. It is a series of tools, methods and strategies developed through over 1500 person years of research and the study of over two million of the world's most successful patents [5].

There are two important concepts and problem-solving techniques in TRIZ, namely "ideality" and "contradiction solving" [4]. The "ideality" of a system is the measure of how close it is to the perfect system. The perfect system has all the expected benefits by the customer with no cost and harmful effects. The application of the concept of "ideality" can reduce the number of elements in the system to lower product cost and enhance product benefits. Meanwhile, designing around the existing patents hopes to reduce the elements that constitute the claims or to replace the existing elements with different ones, which share the same idea of "ideality".

However, when a design engineer tries to reduce the elements that constitute the claims or to replace the existing elements with different ones, it usually creates a system incompatibility or conflict design problem. That is, as the designer changes certain parameters of the system in his/her design problem, it might make other parameters bad. In TRIZ, these are called the "tradeoff contradictions". The "tradeoff" means that the design engineer "trades" the improvement of one feature against declining of another feature in hope of finding a compromising solution to the problem.

In TRIZ, the concept of "contradiction solving", which seeks to identify and eliminate contradictions, is almost the complete opposite of traditional problem solving strategies, in which the emphasis is very firmly placed on the importance of achieving "optimum" compromises between the conflicting problem parameters. If the conflicting components involve "inherent contradiction" or "physical contradictions", separation of action, space or time is recommended. If the contradictions are "tradeoff contradictions", TRIZ introduces 40 principles with the contradiction matrix to solve about 1500 problems involving technical contradictions.

This paper proposes an integrated process for designing around existing patents through TRIZ. This process integrates patent design around strategies, innovative design methods in TRIZ and rules of patent infringement judgment to systematically design around existing patents and increase the patentability of results of innovation.

Figure 1 shows the flowchart of this integrated process. To start with, the designer conducts standard patent search and analysis to identify the related patents to be designed around. The abstract list for each concerned patent is developed to record the scope of claims and core techniques (or functions). Then the independent claims of each concerned patent are checked to see whether each element of a concerned independent claim is necessary, to find out the limitations of the claim terms of each element, and to examine if there are potential disadvantages or other characteristics existing in the core techniques. In the mean time, the TRIZ process is also initiated in this step. A "functional model" of each concerned patent is built to help the designer understand the relationship (useful function, harmful function, insufficient function, etc.) between elements of the core techniques.

Next, the approaches of designing around are applied. If one or more elements in the concerned patent are found to be redundant in the previous step, they can be eliminated directly to generate a solution with simplified components/functions. In the infringement analysis, the designing around is successful according to the "all elements rule".

If all elements are necessary, the designer has to make at least one substantially different condition on the way/function/result to prevent "doctrine of equivalents" infringement. In this branch, a new design problem is generated. The new design problem is then solved by the standard TRIZ process: to formulate the design problem, to construct a new functional model for the design model, to examine for contradiction and to apply the inventive principle to obtain new solutions, or to perform the so-called "Substance-Field Analysis".

The feasibilities of the new solutions are then evaluated. Finally, the infringement analysis is performed to make sure that the new design concepts do not infringe on the original patent.

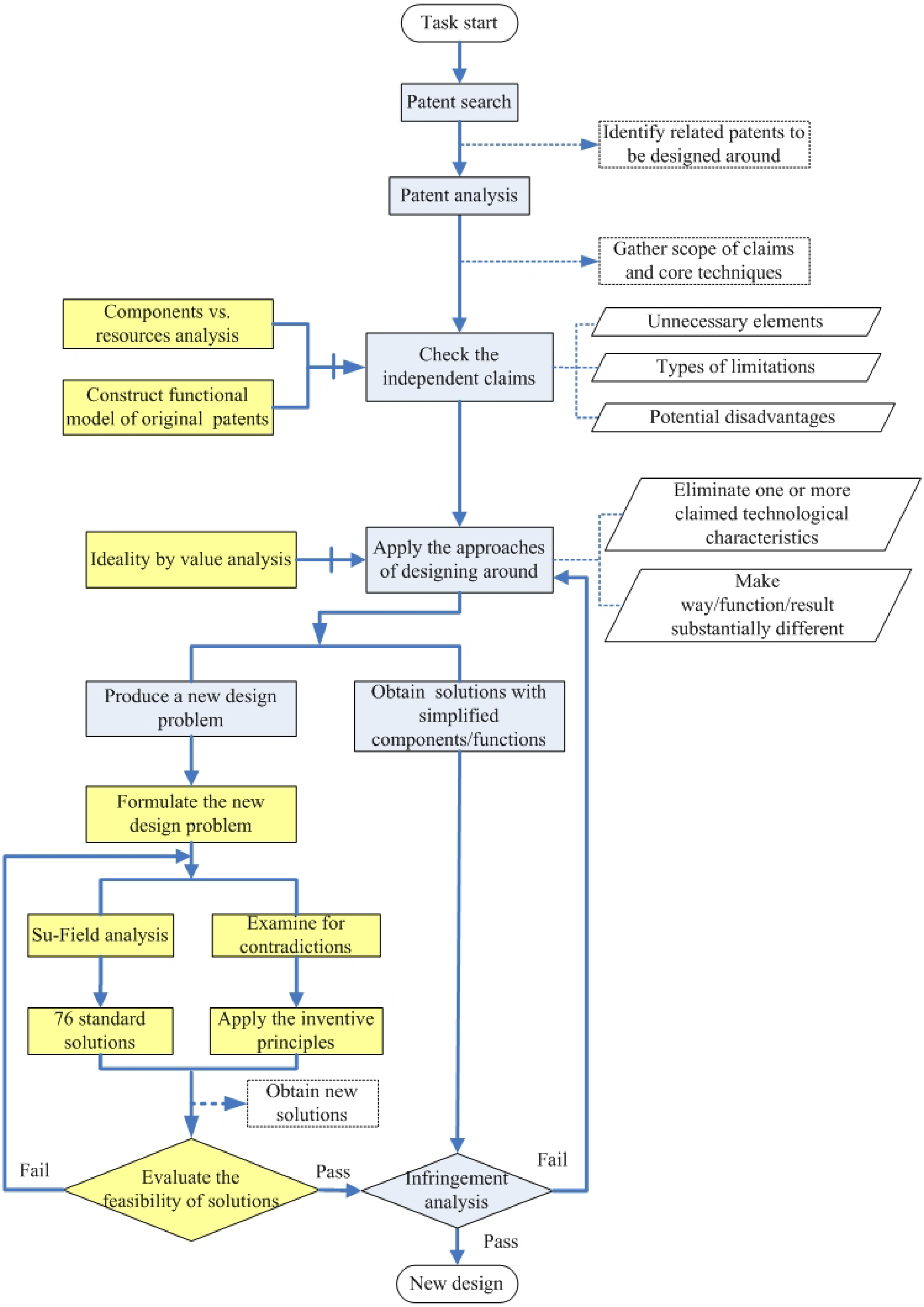

Figure 1. Flowchart for integrating design around with TRIZ

An example of redesigning a portable magnetic impact tool is used to illustrate the integrating process of patent design around. In the next sections, two new design concepts of the magnetic impact tool are generated to design around U.S. Patent 6,918,449 using this process.

The rest of this paper is organized as follows. Section 2 describes the impact tool design problem and the process of “design around”, and Sections 3 and 4 describe two new design concepts generated using the integrant process. Section 5 describes the infringement analysis of the two new design concepts. Finally, Section 6 concludes this paper.

2. Designing around U.S. Patent 6,918,449

Portable power tools used for drilling and fastening are expected to be relatively small and light, yet providing high power to perform the desired functions. Figure 2 shows the major components of a portable power tool driven by an electric motor. The rotational motion of the motor is transmitted to a chuck that holds a tool output shaft by means of a hammer. The motor is generally small due to restrictions imposed on the overall size and weight of the portable power tools. Limited power of the small motor might not be enough to drive the intended load. A hammer type of mechanism is used to generate high output torque from a small drive.

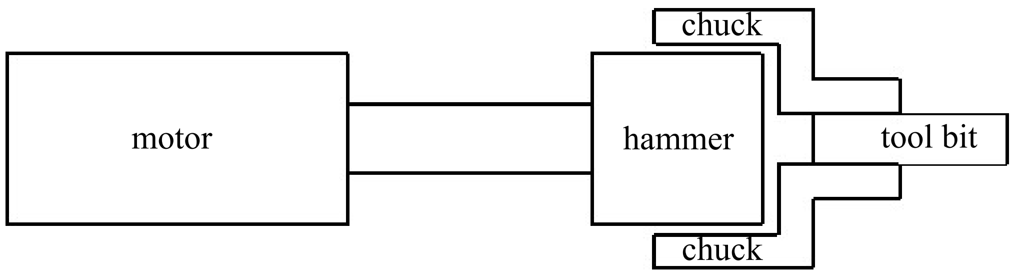

Figure 2. Components of a portable power tool

As shown in Figure 3, the hammer stores the rotational energy of the motor over a large angle of rotation, for example, a half turn. Then the hammer hits the chuck to create an impact torque over a small angle (for example 10 degrees) of rotation of the chuck. In this type of portable power tool, loud noise is generated when the hammer hits the chucks.

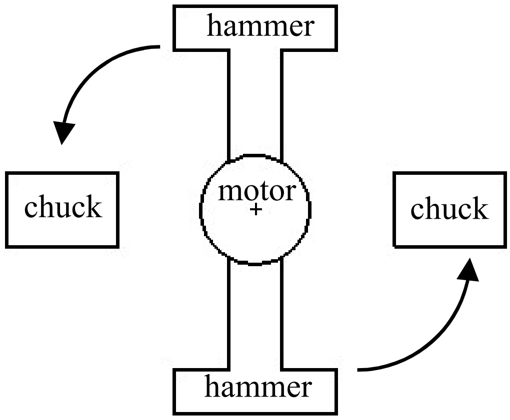

Figure 3. Top plan view of a hammer type impact generator

To eliminate the hammering noise, some patents have proposed the concept of a magnetic impact tool with which screws are tightened using magnetic coupling to deliver a strike without any contact. A tightening rotational impact force is obtained without a collision sound. The successful example of a magnetic impact tool is disclosed in U.S. Patent 6,918,449 [6], granted to Shinagawa et al. As shown in Figure 4, the magnetic impact tool comprises a magnetic hammer driven by a motor, a magnetic anvil disposed so as to face the magnetic hammer, and an output shaft that rotates together with the magnetic anvil. The magnetic hammer is movable with respect to the magnetic anvil without contact.

A rotational impact force is magnetically generated in a non-contact manner for the magnetic anvil in conjunction with the rotation of the magnetic hammer. During the screw-tightening work for example, when the load torque is initially low, the magnetic hammer and magnetic anvil begin to rotate together without any impact action. When the load torque exceeds the magnetic attraction torque, the magnetic hammer and magnetic anvil are not synchronized anymore. Impact action can be generated, and screw tightening and loosening work can be carried out even if a low-torque motor is used.

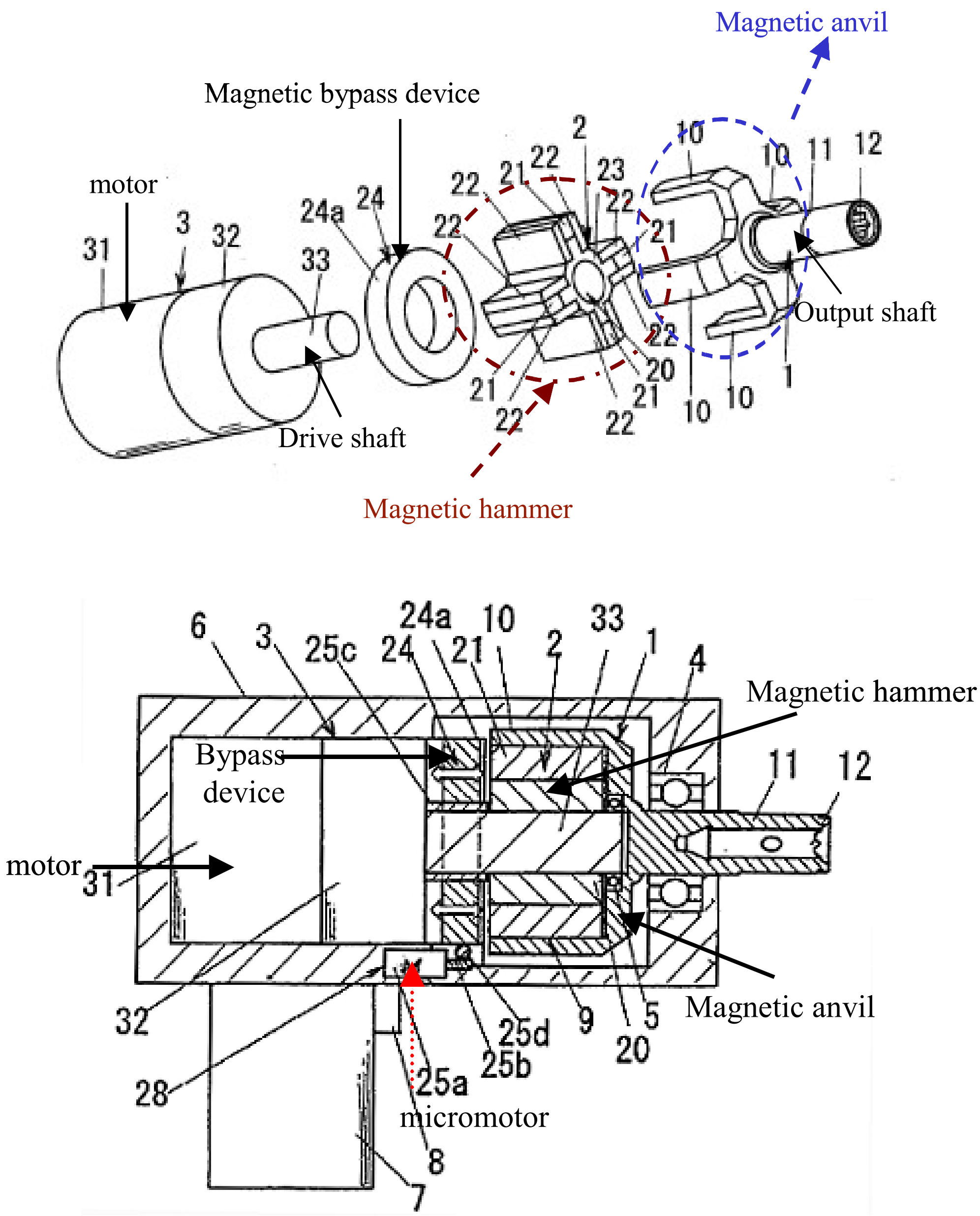

Figure 4. U.S. Patent 6,918,449

The torque generated between the magnetic hammer and magnetic anvil can be changed by the changing device to vary the distribution ratio of the magnetic flux from the magnetic hammer to the magnetic anvil. As shown in Figure 4, there is a magnetic bypass device for distributing magnetic flux between the magnetic anvil and the magnetic hammer. There is also a changing device for changing the distribution of magnetic flux. The changing device comprises a micromotor (25a), a worm gear (25b) and pinion gear (25d). The pinion gear is mounted on the external peripheral surface of the bypass device (24a). The bypass device can be moved in a reciprocating manner in the axial direction of the drive shaft by driving the micromotor. Thus, the distribution of magnetic flux between the magnetic hammer and magnetic anvil can be changed. A switch for controlling the operation of the micromotor may be provided separately.

A standard design around approach is first applied to U.S. Patent 6,918,449. Nydegger and Richards [3] summarized the process of designing around patents as follows:

Step 1. To search related patents.
Step 2. To develop the abstract list for each concerned patent.
Step 3. To check whether each element of a claim of the selected patent in the second step is necessary or not.
Step 4. To inspect whether the limitations of terms exist in the elements.
Step 5. To examine if there are potential disadvantages or other characteristics existing in the core techniques due to the generation of some function or specific effects in the patented invention.
Step 6. Try to use various approaches of implementation to have substantially different functions.
Step 7. To compare the results from designing around and the objective patent.

In this research, U.S. Patent 6,918,449 is the target for designing around (Step 1). There are 7 technological characteristics in the independent claim of this patent (Step 2):

- A motor for generating rotational force.
- A drive shaft rotatably driven by the motor.
- A magnetic hammer rotatably moved in a coupled state with the drive shaft.
- A magnetic anvil which faces the magnetic hammer and to which the rotational force is transmitted by magnetic coupling, with one of the opposing surfaces of the magnetic hammer and magnetic anvil having a magnetic pole, and the other having a magnetic pole or magnetic body.
- An output shaft rotated by the magnetic anvil.
- A magnetic bypass device that bypasses the magnetic flux between the magnetic anvil and the magnetic hammer, and changes the state of magnetic coupling there between.
- A changing device that changes the bypass quantity of the magnetic flux with the magnetic bypass device, with the torque transmitted from the magnetic hammer to the magnetic anvil being changed in accordance with the change in bypass quantity of the magnetic flux varied by the changing device.

For Steps 3~5, the technology/function matrix of U.S. Patent 6,918,449 is constructed as in Table 1, in order to investigate the techniques which can produce the specific functions. For example, in the third column in Table 1, the assembly of magnetic bypass device and changing device makes the magnetic flux vary.

Table 1. Technology/function matrix

Technologies \ Functions	Tighten/ loosen screw	Generate impact torque	Change magnetic flux
Motor	●	●	
Magnetic hammer	●	●	
Magnetic anvil	●	●	
Drive shaft	●	●	
Output shaft	●		
Magnetic bypass device			●
Changing device			●

In Table 1, "tighten/ loosen screw" and "generate impact torque" are two fundamental functions for the magnetic impact tool, and the 5 related components (the motor, the drive shaft, the output shaft, the magnetic hammer, and the magnetic anvil) are hard to be reduced or replaced. Therefore, the magnetic bypass device and the changing device are selected as the target for designing around.

Steps 1 to 5 of the process of designing around patents are more operational types of tasks. Note that these 5 steps are already reflected in the upper half of the flowchart for integrating design around with TRIZ in Figure 1. The actual implementation in Step 6 involves an engineering design work.

In the following sections, two new design concepts of the magnetic impact tool are generated to design around U.S. Patent 6,918,449 using the integrated process for designing around existing patents through TRIZ, following the bottom half of the flow chart in Figure 1 with two different approaches.

3. Generating a new concept of the portable magnetic impact tool

- **Check the independent claim of U.S. Patent 6,918,449**

The scope of claim and core techniques of U.S. Patent 6,918,449 has been described in Section 2 (Step 2). In this step, constructing a functional model can further help the designer understand the relationship between the elements of the core techniques. Figure 5 shows the functional model of U.S. Patent 6918449. A rectangle in Figure 5 represents a "system component", which is the basic element which constitutes a system or a product.

A hexagon represents a "super system", which is an essential factor that will influence components of the system. An ellipse represents a "target", which is the acceptor of the major function in the engineering system. A solid line represents relational actions linking the various components.

In the original design, the motor, the drive shaft, the output shaft, the magnetic hammer, and the magnetic anvil are the 5 important system components to generate impact torque, which is the major function (or primary useful function) of the magnetic impact tool. The output shaft is also necessary to tighten or loosen screws. The other two components, the magnetic bypass device and the changing device, are the auxiliary elements to provide function of adjusting the value of impact torque.

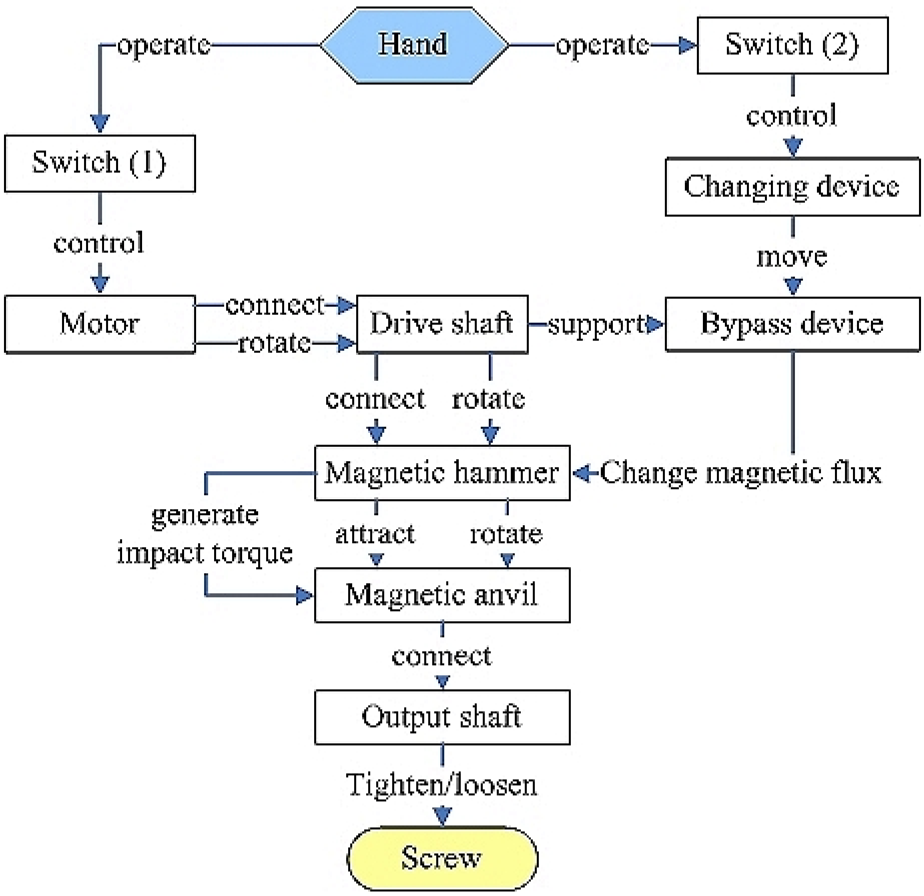

Figure 5. Functional model for U.S. Patent 6,918,449

- **Apply the approaches of designing around**

Referring to Figure 1, there are two possible approaches of designing around. In this section, the approach of "eliminating one or more elements of a claimed system" is used.

As discussed earlier, the application of the concept of "ideality" in TRIZ can reduce the number of elements in the system to lower product cost and enhance product benefits. Commercial software TechOptimizer 4.0 from Invention Machine Corporation [7] was used to "trim" the original function model and generate a new design concept to achieve the goal of "ideality".

Trimming is a method for improving systems based upon the elimination of components that are problematic, costly or unessential in the system. In this research, after value analysis on the functional model for U.S. Patent 6,918,449, the changing device was chosen to be eliminated. Without the changing device, the bypass device cannot work by itself, and should also be eliminated. The simplified functional model is shown in Figure 6. The dotted squares and dotted lines are the components and the relational actions to be trimmed, respectively. In addition, some relational actions from the original design may be eliminated or transferred as a result of reconfiguring the system.

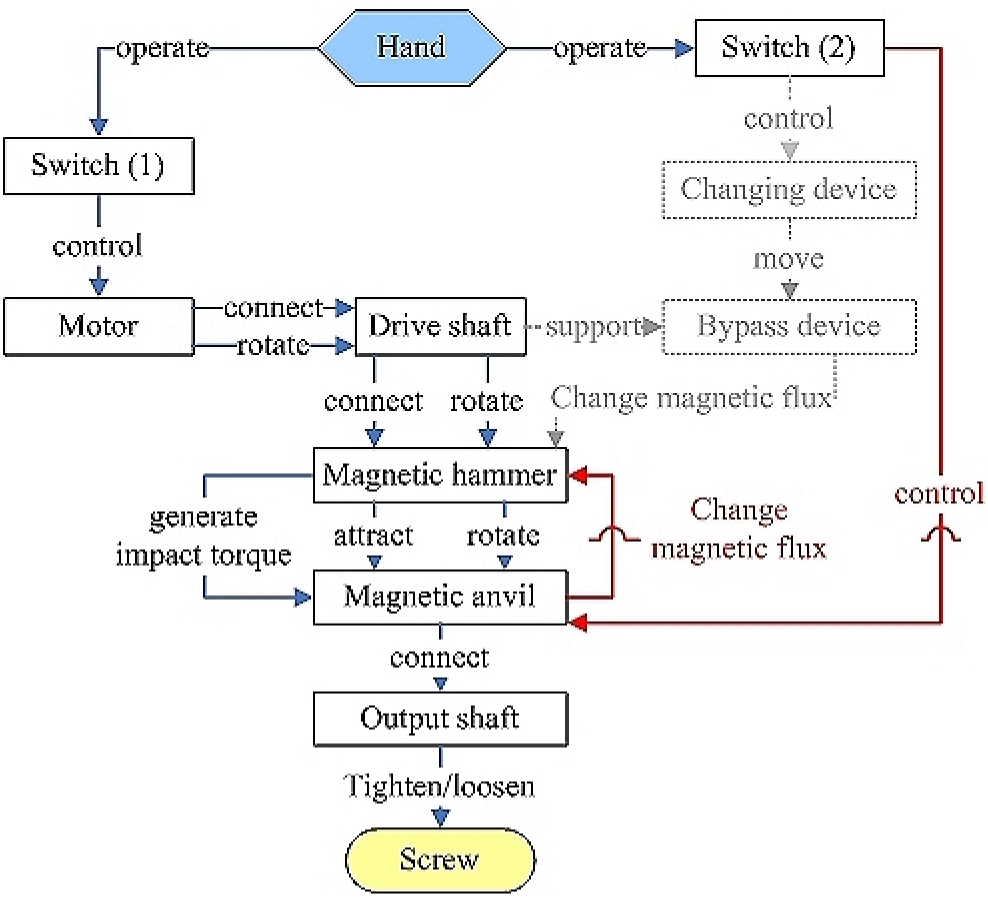

Figure 6. Simplified functional model for U.S. Patent 6,918,449

- **Formulate the new design problem**

Without the changing device and the bypass device, the impact torque cannot be adjusted and the whole function of the magnetic impact tool deteriorates. Therefore the useful functions of the eliminated components have to be redistributed. As shown in Figure 6, the function "change magnetic flux" originally provided by the changing device and the bypass device will be provided by the magnetic anvil. Two new design problems occur during the trimming process:

a. How to add the function of "*changing magnet flux*" in the magnetic anvil?
b. How to "*adjust the magnet flux*" by the magnetic anvil?

Note that the two new design problems are not independent and have to be solved simultaneously.

- **Examine for contradictions and apply the inventive principles**

In this section, the contradiction matrix (Table 3) and the inventive principles from TRIZ are used to solve these two new design problems. In TRIZ, force is defined as any interaction that is intended to change an object's condition. Therefore parameter 10 (force) is selected as the feature to change for adding the function of "*changing magnet flux*" in the magnetic anvil, as shown in Table 3. In the mean time, we still hope to be able to "*adjust the magnet flux*" by the magnetic anvil. Therefore parameter 33 (ease of operation) is selected as the feature not to be deteriorated in Table 3. In TRIZ, ease of operation means that convenience and facility with which an object or system is operated.

As shown in Table 3, four inventive principles can be obtained. They are Principles 1 (segmentation), Principles 28 (Mechanical interaction substitution), Principles 3 (local quality), and Principles 25 (self-service).

Table 3. The contradiction matrix

Undesired result / Feature to change		1 Weight of moving object	…	33 Ease of operation	…	39 Productivity
1	Weight of moving object					
…	…					
10	Force			1, 28, 3, 25		
…	…					
39	Productivity					

After reviewing the four principles, Principle 28 was utilized to generate the new concept in the portable magnetic impact tool. In TRIZ, Principle 28 has four explanations:

a. Replace a mechanical system with an optical, acoustical, thermal or olfactory system.
b. Use an electric, magnetic or electromagnetic field to interact with an object.
c. Replace fields that are: stationary with mobile, fixed with changing in time, random with structured.
d. Use fields in conjunction with ferromagnetic particles.

In particular, we decided to apply “use an electric, magnetic or electromagnetic field to interact with an object” to solve the new design problems.

- **New concept of the portable magnetic impact tool**

In the original design of U.S. Patent 6,918,449, the adjustment device of magnet flux consists of the changing device and the bypass device, as shown in Figure 7(a). The changing device comprises a micromotor, a worm gear and a pinion gear. The pinion gear is mounted on the external peripheral surface of the bypass device. The bypass device can be moved in a reciprocating manner in the axial direction of the drive shaft by driving the micromotor. Thus, the distribution of magnetic flux between the magnetic hammer and magnetic anvil can be changed.

Figure 7(b) shows the derivation of the solution using Principle 28 in TRIZ. Electromagnets are used in the magnetic anvil, and the impact torque can be changed by varying the distribution ratio of the magnetic flux by operating a switch for setting the output of the electric current value. In this concept, the electromagnet anvil has already replaced the function of the changing device and the bypass device.

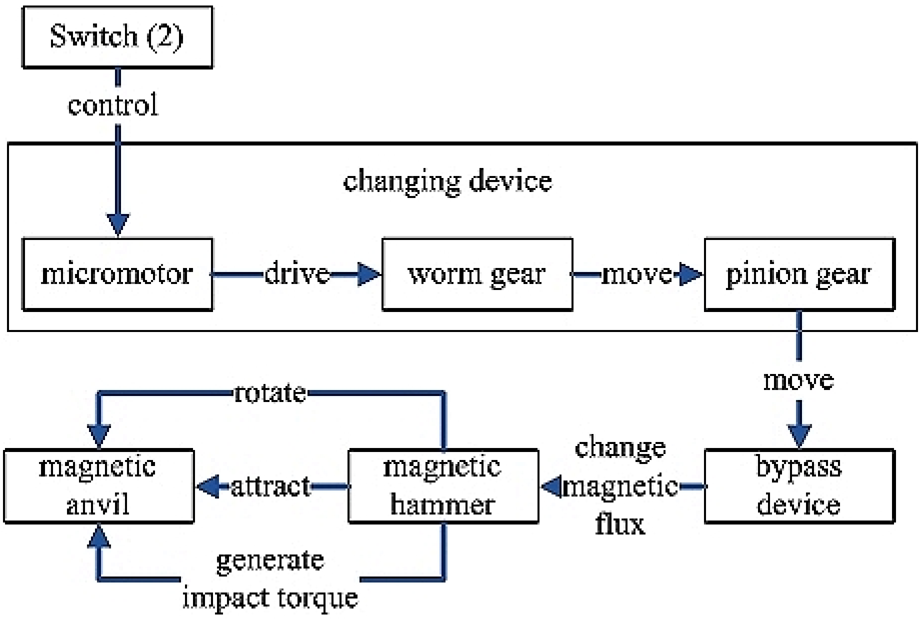

Figure 7(a). Original design of the adjustment device of magnetic flux

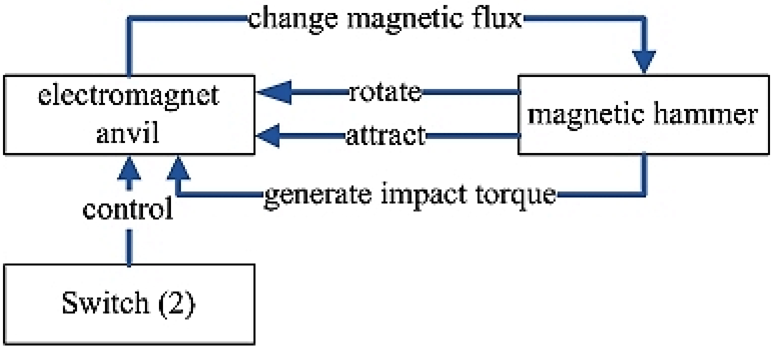

Figure 7(b). Simplified design of the adjustment device of magnetic flux

Figures 8 and 9 illustrate this new design concept in more details. The basic structure of the magnetic impact tool remains unchanged. The motor assembly comprises a motor and a reduction gear, with an output shaft protruding from the reduction gear. As shown in Figure 9, the magnetic hammer comprises four magnets, and the magnetic hammer rotates with the drive shaft.

The magnetic anvil comprises an axle unit that has a bit hole for attaching a tool bit (not depicted) to the tip, and four L-shaped magnetic anvil arms. The magnetic anvil arms are positioned at equal intervals along the circumference and are orthogonal to the axle unit. The magnetic anvil has four solenoids as shown in Figure 9. When the voltage is applied to the solenoids, it generates a current in the solenoids that in turn produces a magnetic field. Therefore, by changing the electric current, the intensity of the magnetic field changes correspondingly.

In order to provide electric current to the solenoids, there are two electro-convulsive metal rings positioned in front of the output shaft of the magnetic anvil, as shown in Figure 8. One of the electro-convulsive metal rings has a positive electrode and the other has a negative electrode. The rotational force is magnetically generated in a non-contact manner by the magnetic anvil in conjunction with the rotation of the magnetic hammer. The torque generated between the magnetic hammer and magnetic anvil can be changed by varying the distribution ratio of the magnetic flux by operating a switch for setting the output of the electric current value of the four solenoids.

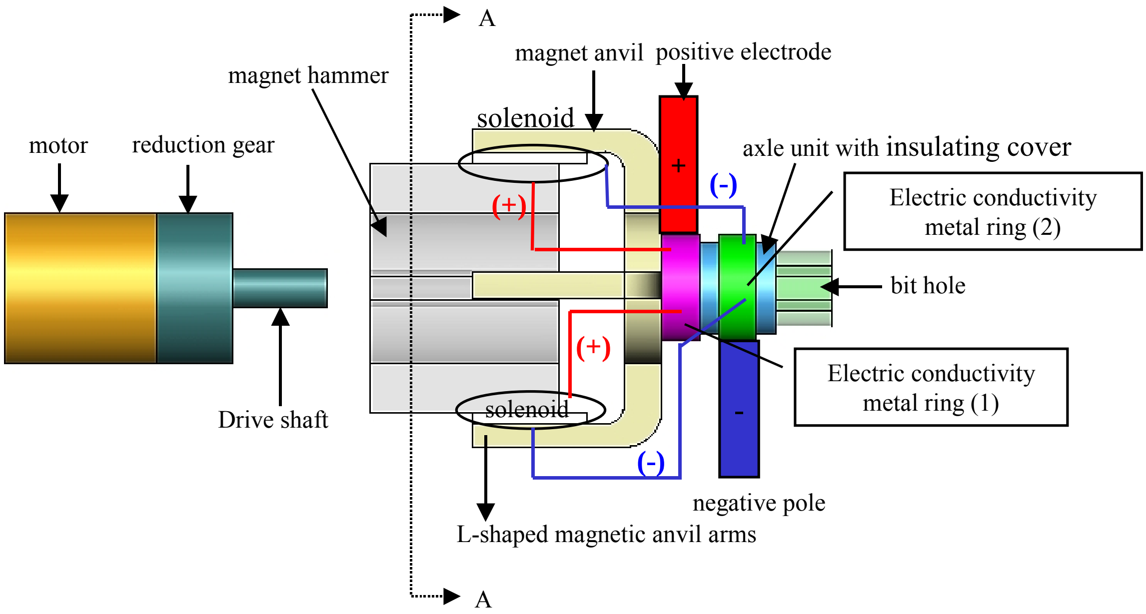

Figure 8. New concept of the portable magnetic impact tool (1)

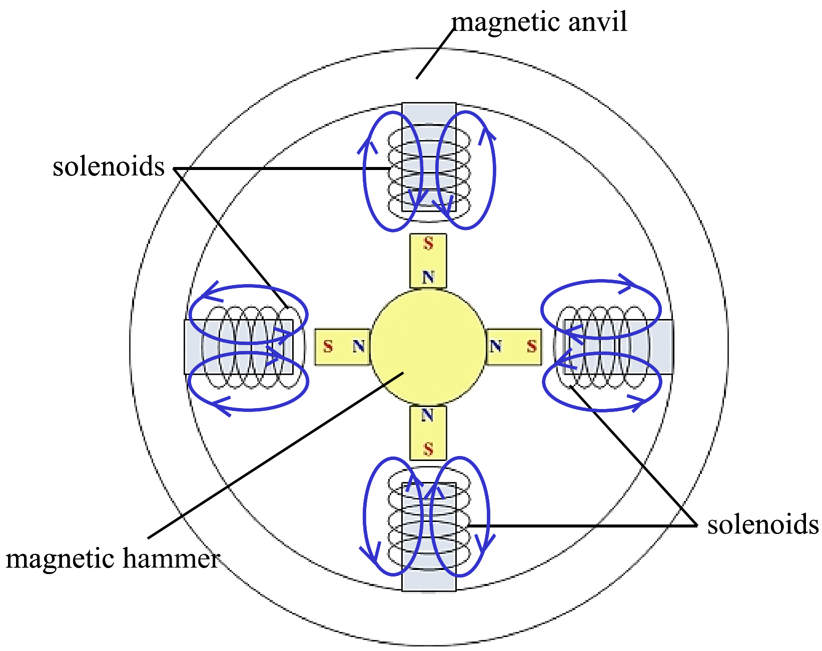

Figure 9. New concept of the portable magnetic impact tool (2)

4. An alternative design concept of the portable magnetic impact tool

In Section 3, the contradiction table and the inventive principles from TRIZ are used to generate a new design concept, in which the changing device and the bypass device are eliminated, and their functions are built into the magnetic anvil. Referring to Figure 1, the other approach for designing around is "to make way/function/result substantially different". In this section, the Substance-Field Analysis from TRIZ is used to generate an alternative design concept, in which the way to generate and adjust impact torque is substantially different from the original patent.

- **Apply the approaches of designing around**

In the original design of U.S. Patent 6,918,449, the magnetic anvil rotates together with the magnetic hammer. In order to make way/function/result substantially different from the original design, we attempted to generate an alternative design concept that changes the method of generating rotational impact force. Analogous to the mechanical impact tool as shown in Figure 3, in which the chuck is stationary while the hammer is rotated by the motor, the magnetic anvil is kept stationary in the new design concept.

Figure 10 shows the functional model of this alternative design concept. Now the magnetic anvil does not rotate with the magnetic hammer. The function "impact torque" is magnetically generated in a non-contact manner by the rotational magnetic hammer and the fixed magnetic anvil. The other function "change magnetic flux" originally provided by the changing device and bypass device will be provided by the magnetic anvil, and the two components are eliminated.

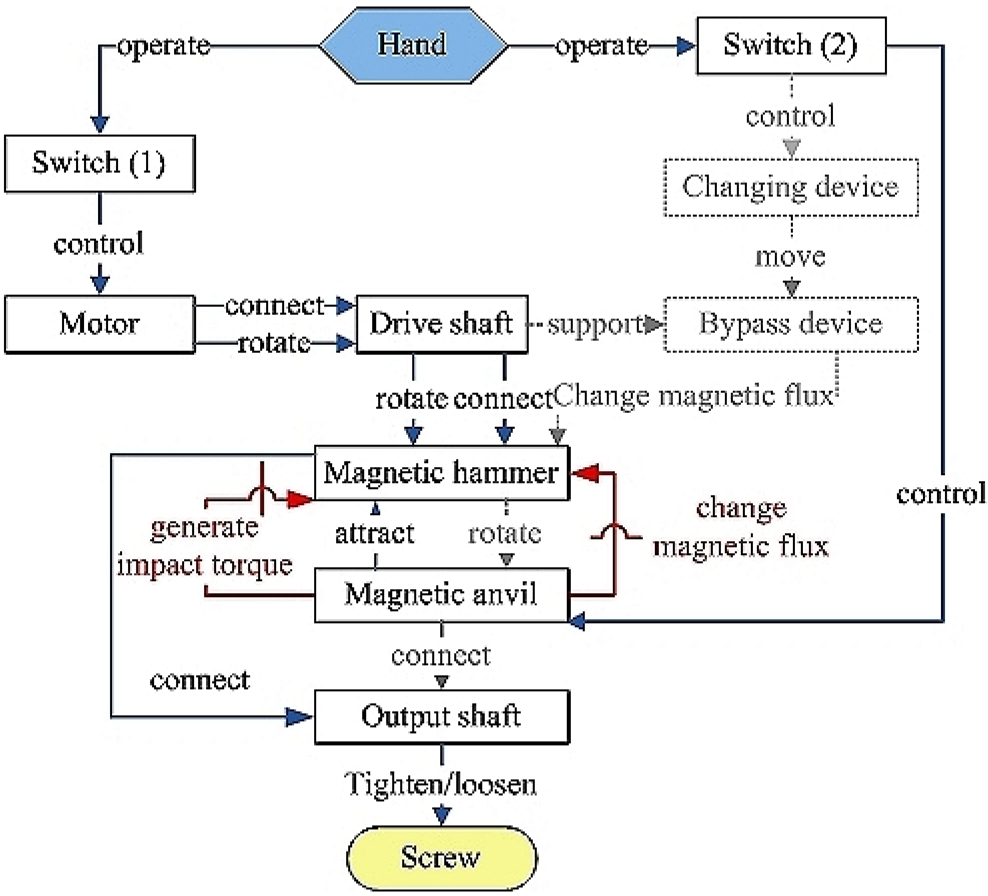

Figure 10. Functional model of the alternative design of U.S. Patent 6,918,449

- **Formulate the new design problem**

Again, two new design problems occur during the design around process:

a. How to generate the function "*impact torque*" between the fixed magnetic anvil and the rotational magnetic hammer?
b. How to add the function "*changing magnet flux*" to the fixed magnetic anvil?

In the previous section, the contradiction matrix and the inventive principles in TRIZ were used to solve the design problems occur in the designing around process. Here we deliberately chose the Substance-Field Analysis from TRIZ to solve these tow design problems.

- **Substance-Field Analysis and apply the 76 standard solutions**

Substance-Field Analysis (Su-Field Analysis) is a TRIZ analytical tool for modeling problems related to existing technological systems. Designers construct Su-Field models to clear the contradictions in their design problems. The function model must contain more than two substances and their interactions. Figure 11 shows the smallest block triangle of Su-Field model. The identification of substances depends upon the application. Either substance could be a material, tool, part, person or environment. In Figure 11, Substance 1 is the recipient of the system action. Substance 2 is the means by which some source of energy (or field) is applied to Substance 1. Relationships between the substances in the Su-Field model are depicted by different connecting lines.

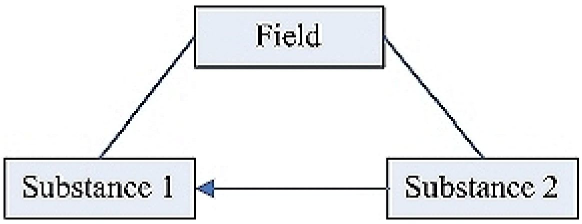

Figure 11. The smallest block triangle of Su-Field model

Figure 12 (left) shows a simple Su-Field model for our design problem. In this model, the impact torque is provided by a magnetic force (F_M). Currently the function "impact torque" is "insufficient", as represented by the dotted line between the magnetic anvil and the magnetic hammer.

Applying the Class 2 standard solutions from the 76 standard solutions of Su-Field Analysis suggests that, the problem can be solved by adding another field F2 in addition to field F1. According to this solution, a new impact torque system making use of "Su-E_Fields" was designed. "Su-E_Fields" means that "uses electric current to create magnetic fields, instead of using magnetic particles". As shown in Figure 12 (right), an added field into the system is an electrical field (F_E). In the new design concept, stationary electromagnets, solenoids with ferromagnetic cores, are used to compensate for the magnetic force.

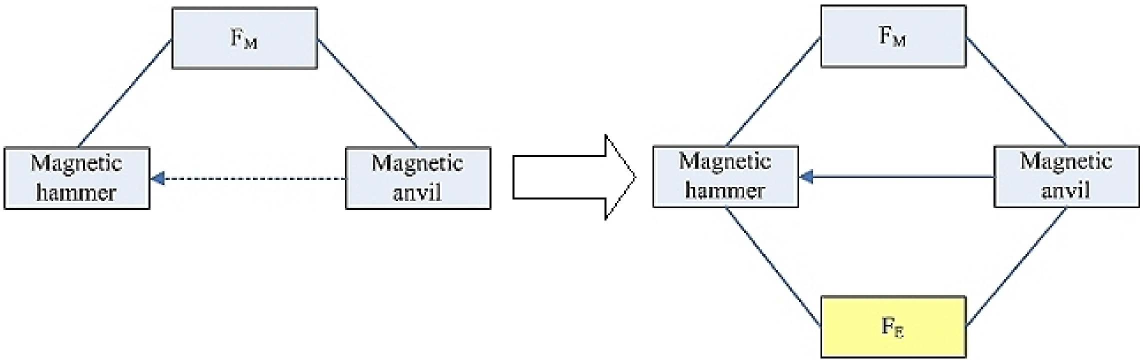

Figure 12. Ineffective Su-Field model (left) and Complete Su-Field model (right)

- **New concept of the portable magnetic impact tool**

Figure 13 illustrates the derivation of the solution using the idea described above. In this new concept, the magnetic impact tool comprises a magnetic hammer, a motor assembly, a pair of electromagnetic anvils, a drive shaft, two torsion hinges and a holder. As shown in Figure 13, the motor assembly comprises a motor and a reduction gear, with a drive shaft protruding from the reduction gear. The magnetic hammer is attached to a holder by two torsion hinges. The magnetic hammer comprises four magnets and eight pole plates that sandwich the poles. The magnetic hammer is driven by the motor and has an axle unit that has a bit hole for attaching the tool bit to the tip.

The electromagnetic anvil comprises two solenoids, which are positioned at 180 degrees relative to each other. When a voltage is applied to the solenoids, it produces a magnetic field. The force of the solenoid's magnetic field attracts the magnetic hammer. By changing the voltage, the intensity of the magnetic field can be changed.

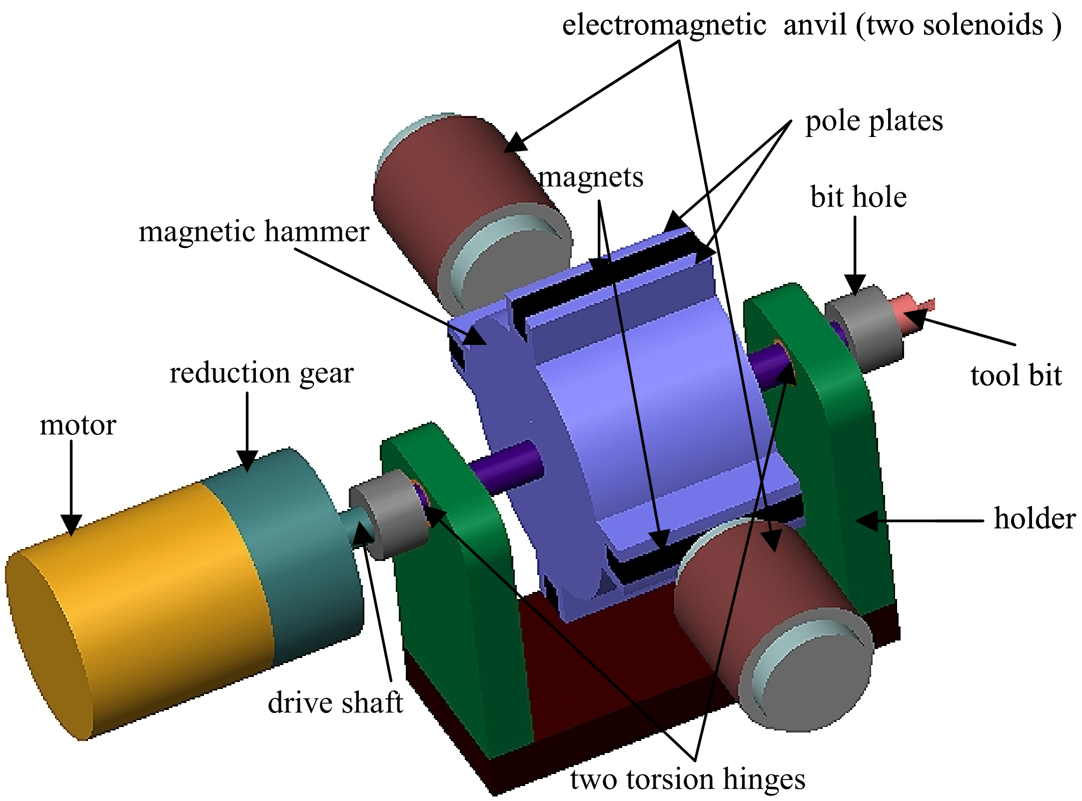

Figure 13. New concept of the portable magnetic impact tool

The function of impact torque in this new design concept is explained in Figures 14(a) ~ 14(c). In these figures, only a hammer and an anvil are illustrated to simplify the explanation. Referring to Figure 14(a), a small clockwise rotation of the hammer (for example, 5 degrees) makes the hammer attracted magnetically towards the forward anvil. Under the torque of magnetic attraction, voltage is applied to the solenoid and the hammer accelerates towards the forward anvil. In Figure 14(b), the shifting angle formed between the hammer and the anvil is equal to zero. At this angle, magnetic field lines emanating from the anvil travel through the ferromagnetic material of the corresponding hammer to complete the magnetic circuit. Accordingly, the hammer is at a stable equilibrium, being attracted strongly to the anvil. Note that the voltage is still applied to the solenoid during their action. Referring to Figure 14(c), if the hammer rotates slightly in a clockwise direction (for example, 5 degrees), the hammer feels a pull towards the anvil due to magnetic attraction. If the electric current in the solenoid is briefly cut off, the magnetic attraction torque is reduced, establishing the magnetic impact condition.

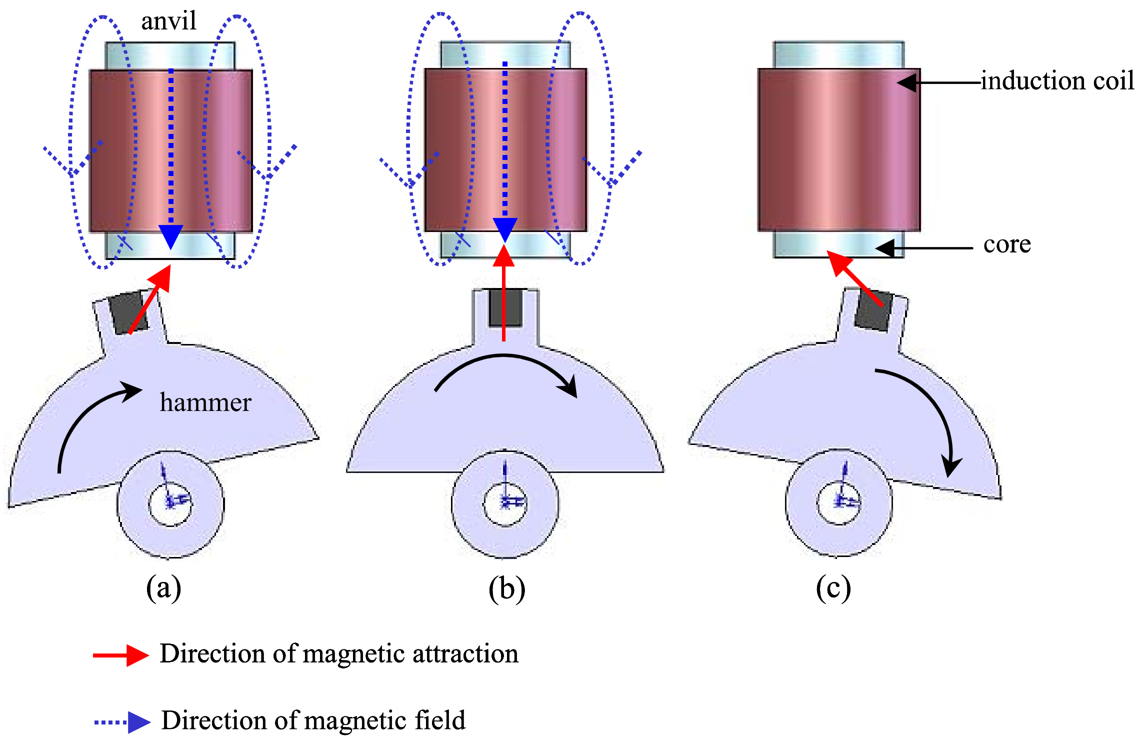

Figure 14. The operation of the new design concept

5. Infringement analysis

Two new design concepts (concept A described in Section 3 and concept B described in Section 4) of the portable magnetic impact tool have been generated. Referring to Figure 1, when a new solution is generated, the last step is to carry out an infringement analysis to make sure the new solution does not infringe with the original patent.

In general, the judgment of infringement in patent lawsuits consists of three steps. They are the judgments by “all elements rule”, “doctrine of equivalents”, and “doctrine of file wrapper estoppel”. The first two judgments are usually used to make sure whether or not the new design concepts infringe on the original patents. First, if the elements of claims can be literally read on the components that appear in the accused subject matter, the all elements rule is satisfied with a literal infringement. In other words, if the accused subject matter contains all of the elements that constitute the claim, the infringement may occur. Secondly, if the all elements rule is not satisfied, but the elements in the accused subject matter corresponding to those in the claims substantially use the same way, perform the substantially the same function, and obtain the substantially the same result (also named triple identity test, way/function/result testing), the techniques under investigation are considered to be equivalent to those in the claims.

Table 3 and Table 4 list the unclaimed elements from the two new design concepts and the claimed elements from U.S. Patent 6,918,449. As shown in Tables 3 and 4, both the new design concepts omit the two elements (magnetic bypass device and changing device) of the claimed system so that the results of innovation are not equivalent to the existing patent regarding the “all elements rule”.

Furthermore, the “triple identity test” makes sure that the two new design concepts do not infringe on the original patent regarding the “doctrine of equivalents”. In the original patent, the rotational impact force is magnetically generated in a non-contact manner for the magnetic anvil in conjunction with the rotation of the magnetic hammer. The assembly of the magnetic bypass device and changing device varies the magnetic flux. The magnetic bypass device can be moved toward or away from the magnetic hammer by the changing device. Therefore, the impact torque can be changed by the magnetic bypass without varying the gap between the magnetic hammer and the magnetic anvil.

The original patent and the new design concept A are substantially different regarding “change of magnetic flux”. In design concept A, the electromagnetic anvil is constructed out of four solenoids. The torque generated between the magnetic hammer and electromagnetic anvil can be changed by varying the distribution ratio of the magnetic flux by setting the voltage from the electromagnetic anvil. A high voltage increases the electromagnetic anvil’s magnetic force, and vice versa.

The original patent and the new design concept B are also substantially different in both “generation of impact torque” and “change of magnetic flux”. First, the magnetic hammer rotates in sync with the motor but the electromagnetic anvil is fixed. Second, the torque generated between the electromagnetic anvil and magnetic hammer can be changed by varying the distribution ratio of the magnetic flux by setting the voltage from the electromagnetic anvil. Third, the magnetic impact condition is controlled by the supply of electric current.

Table 3. Comparison table of U.S. Patent 6,918,449 and the new design concept A

	U.S. Patent 6,918,449	New design concept A	Comparison
Ways description	Functions		
Motor	To generate rotational force.	To generate rotational force.	Substantially equivalent
Drive shaft	● To transmit power. ● To connect with a magnetic hammer.	● To transmit power. ● To connect with a magnetic hammer.	Substantially equivalent
Magnetic hammer Magnetic anvil	● A rotational impact force is magnetically generated in a non-contact manner for the magnetic anvil in conjunction with the rotation of the magnetic hammer. ● To produce impact torque.	● To change magnetic flux with an electromagnetic anvil. ● A rotational impact force is magnetically generated in a non-contact manner for the electromagnetic anvil in conjunction with the rotation of the magnetic hammer. ● To generate impact torque.	Substantially different
Output shaft	● To transmit power. ● To connect with a tool.	● To transmit power. ● To connect with a tool.	Substantially equivalent
Magnetic bypass device	To change magnetic flux between the magnetic anvil and the magnetic hammer.	None	Substantially different
Changing device	To move the magnetic bypass device.	None	Substantially different

Table 4. Comparison table of U.S. Patent 6,918,449 and the new design concept B

	U.S. Patent 6,918,449	New design concept B	Comparison
Ways description	Functions		
Motor	To generate rotational force.	To generate rotational force.	Substantially equivalent
Drive shaft	● To transmit power. ● To connect with a magnetic hammer.	● To transmit power. ● To connect with a magnetic hammer.	Substantially equivalent
Magnetic hammer Magnetic anvil	● A rotational impact force is magnetically generated in a non-contact manner for the magnetic anvil in conjunction with the rotation of the magnetic hammer. ● To produce impact torque.	● To change magnetic flux with an electromagnetic anvil. ● A magnetic hammer rotates in sync with a motor. ● To generate impact torque.	Substantially different
Output shaft	● To transmit power. ● To connect with a tool.	● To transmit power. ● To connect with a tool.	Substantially equivalent
Magnetic bypass device	To change magnetic flux between the magnetic anvil and the magnetic hammer.	None	Substantially different
Changing device	To move the magnetic bypass device.	None	Substantially different

As discussed above, results of innovation are patentable and does not infringe upon the existing patent. In these two new design concepts, the number of system components is reduced but all design requirements can still be met. Further product development can be carried out; issues in commercialization such as reducing the manufacturing cost of each component should also be considered.

6. Conclusion

Systematic product design processes commonly seen in research literature or design textbooks often start from need finding, specification development, conceptual design, detail design, to production. However, the design problems constantly faced by engineering designers in industries is how to design around existing patents, which requires a completely different design approach and knowledge.

This paper proposes an integrated process for designing around existing patents through TRIZ. This process integrates patent design around strategies, innovative design methods in TRIZ and rules of patent infringement judgment. Facing the innovation barriers and possible patent dispute, the design problem to be solved is first identified using the design around strategies, as well as the function model and value analysis in TRIZ. This "local innovation" design problem is then solved by TRIZ methodology, which not only avoids a trial and error design approach but also increase the degree of innovation. Finally, the feasible solutions generated by TRIZ are analyzed using the "triple identity test (way/function result testing)" to make sure that the new design concepts do not infringe on the original patent.

In this design around process, the rules of patent infringement judgment present the major constraints to the local innovation design problems. Designers may have to sacrifice the performance of the product in order not to infringe with existing patents, and the performance of the new design may not exceed that of the original patent. However, this process provides a systematic way to generate a new design that is patentable and less likely to infringe upon the existing patent. This integrated process should be especially helpful to technology followers in developing their products speedily and with a lower cost.

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