The innovative design of balancing mechanism by TRIZ

Shuai MA1, Yue-jiang SHI1, Yun-kun GAO1, Yue SUN1, Na ZHANG1, Yu-xiang WANG1 and Shi-gang ZHOU1

1 Information and control technology department China north vehicle research Institute, Beijing, China
E-mail: 1164635991@qq.com

Abstract. In this paper, an innovative design of balancing mechanism is completed after solving the problem of collision between balancing weight and barrel by TRIZ. For the original design of adding a balancing weight, the Functional Model Analysis is set and the key point of the collision problem is found. For the sake of improving the original design, this paper find out the key point of collision problem and adequate analysis by TRIZ theory, and proposed an innovative solution at last.

1. Introduction

With the development of science and technology, the requirement of miniaturization and lightweight of armored weapon is higher and higher. So the volume limitation will bring many challenges to weapon design [1-2]. Due to the limited installation and movement space given by the turret to the tail of barrel, in the tank design, it usually leads to the situation that the head of barrel is heavier than tail. In this case, a large unbalanced moment relative to the rotating center of barrel will appear. When the barrel is swinging, this unbalanced moment will not only increase the driving power of the motor, but also bring great difficulty to the designer to improve the dynamic control precision. For this unbalanced moment, designers usually choose to install a balancing weight to decrease it. Owing to the volume limitation, however, the small turret will collided with the balancing weight installed on the tail of the rotating barrel. So it is very necessary to develop an ideal solution to reduce the unbalanced moment.

TRIZ theory is a kind of method for solving the specific engineering problem which is widely used. This paper takes advantage of TRIZ to improve the solution of installing balancing weight to get a better innovation solution to reduce the unbalanced moment.

2. Overview of TRIZ Theory

TRIZ is the acronym for the Theory of Inventive Problem Solving which was put forward in 1946. The inventor named Altshuller and was a mechanical engineer. He summarized the TRIZ after studied more than 2.5 million patents for invention written by the Russian Navy [3-4]. In TRIZ theory, the key point of solving an engineering problem is to resolve the most important contradiction. For the sake of making easier for solving of the contradiction, Altshuller summed up a lot of technical contradictions and extracted 39 parameters from them [5]. In the meantime, 40 invention principles and its separation principles was invented for coping with the problem which has technical contradictions. Then, the relationship between 39 engineering parameters and 40 inventive principles will be established and the complicated relationship was named the Technical Contradiction Matrix [6]. The engineers can refer to the inventive principles to resolve the problem on the basis of the two contradiction parameters in the Technical Contradiction Matrix, and get the solution with the help of elect inventive principles.
The usage process of solving problem by TRIZ theory can be split into three steps as shown in Fig. 1: At first, the specific problems are abstracted into the standard problem in TRIZ. Then, the standard problems are transformed into the standard solution by TRIZ tools. Finally, the specific solution of the problem is obtained based on the standard solution by referring to the actual situation [7-8].

3. Problem Solving by TRIZ theory

3.1. The model building of balancing system
As shown in Fig. 2, balancing weight is installed on the tail of barrel. If the barrel rotates relative to the turret, balancing weight will collide with the upper and lower edges of turret. In this balancing system, the component is turret, balancing weight, barrel support, mechanical drive, trunnion solver, motor and control system. The object is barrel.

3.2. Functional Model Analysis of Problem
In the TRIZ theory, the functional model will give engineers a hand to know the problem systems deeply and seek out the crucial concern of the problem. So the functional model analysis is applied normally before solving the problem [9-10].

For the interference problem between turret and balancing weight, we set the functional model of the barrel balance schem. In the functional model, we can analysis the relationship among the components of the barrel system after being balanced. In this balancing solution, the balancing weight fixed on the tail of barrel can realize the balance of barrel relative to the center of rotation. At the same time, balancing weight is rotating with barrel as well. However, owing to the compact structure of turret, turret will collide with balancing weight, as shown in Fig. 3. Although the balancing weight can reduce the eccentric torque of barrel, it also leads to the harmful collision. So we should remove this harmful effect based on the critical point.
3.3. Define Technical Contradiction Problem

According to the analysis of functional model in the barrel balance system, collision problem happened between turret and balancing weight was defined as a contradiction problem. In the basis of the concrete structure and the principles in TRIZ, the problem can be transform into this technical contradiction: “if the barrel is balanced relative to the axis of rotation by installing the balancing weight, the stability of the structure will be improved. But the collision will happen between balancing weight and turret”.

According to the definition principle, technical contradiction must be defined by using 39 engineering parameters. In this paper, the improved engineering parameter is “the stability of the structure”, and the worsening engineering parameter is “the volume of a moving object”. In this way, the engineering problem was turned into a standard problem.

3.4. Define Technical Contradiction Problem

According to the analysis above, this paper starts to solve the technical contradiction with the help of invention principles in TRIZ. Referring to the conflict matrix, the inventive principles can be found out as shown in Table 1. The inventive principles, “10 prior action principle”, “19 periodic action principle”, “28 replacement of mechanical system principle” and “39 inert environment principle”, was recommended in conflict matrix table.

| Improve parameter | Worsen parameter | 7. The volume of a moving object | 13. The stability of the structure |
|-------------------|------------------|---------------------------------|----------------------------------|
| 28, 10, 19, 39    |                  |                                 | 28, 10, 19, 39                   |

After a series of analysis above, the standard solution according to the inspiration of periodic action principle was used to resolve the technical contradiction. In TRIZ theory, periodic action principle consists of three application directions as shown in table 2. In the barrel balance system, owing to the rotating of balancing weight and at the same frequency of the barrel, the collision happened between turret and balancing weight. If we can change the rotating periodic of balancing, the collision may be avoided. So based on the meaning of application direction 2 of periodic action principle, we decide to add a mechanical system to change the frequency of balancing weight.
Table 2. The three application directions of periodic action principle

| No. | Application direction                                                                 |
|-----|--------------------------------------------------------------------------------------|
| 1   | Replace continuous action with periodic action or pulse.                               |
| 2   | If the periodic action is going on, change its motion frequency.                       |
| 3   | Another useful action is performed with pause during the pulse period.                  |

3.5. Get the specific solution

Based on the inspiration of periodic action principle, an innovative solution of balancing mechanism is obtained. As shown in Fig. 4, the balancing mechanism consists of trunnion resolver, bearing, balancing weight, sector, safety clutch, reducer and motor. The bearing is installed on the shaft of barrel, the balancing weight is fixed on the bearing and rotate freely. The sector is fixed on the one side of balancing weight and concentric with the shaft of barrel. The motor fixed on the tail of barrel drives the gear to rotate and mesh with the sector through safety clutch and reducer.

Figure 4. The specific solution of the collision problem by TRIZ

In order to realize the balance of barrel, the balancing weight exerts its gravity on the tail of barrel through the meshing of sector and gear. Once the barrel starts to rotate, the trunnion solver will collect...
the real-time rotation angle of the barrel and transmit it to the control system. According to the real-time rotation angle of the barrel, the motor will drive the gear to rotate so that the balancing weight can keep stationary relative to the turret. In this way, the balancing weight can reduce the unbalanced moment to make the barrel balance no matter how the barrel rotates as shown in the Fig. 5.

4. Summary
For the imbalance problem of barrel, this paper proposed an innovative solution by using TRIZ theory to improve the collision defect between balancing weight and barrel. The technical contradiction was defined after the analysis of functional model. At last, the innovation solution was obtained by TRIZ to make the balancing mechanism more practical.

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