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Innovative Conceptual Design on a Tracked Robot Using TRIZ Method for Passing Narrow Obstacles

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Abstract

Background/Objectives: One of the problems of tracked robots in ragged roads is to pass narrow obstacles. As a primary solution, the process of come back and pass another way is usually time consuming or impossible. **Methods/Statistical Analysis:** In this paper, first, we evaluate the usual solution for this problem, which is preparation of a drive system at the middle area and then by using of innovative problem solving method (TRIZ), by answering ISQ questionnaire and extracting some technical contradictions, we try to match them in contradiction matrix and finally by applying 40 innovative principles we solve these technical contradictions which lead us to the solution of the problem. **Findings:** Using this method, one innovative principal says, we can consent to pass partly narrow obstacles and for very narrow ones we can find another solution. Another principal says, existing elements can do the duty of new elements and for it flippers location can be changed from outside of driving tracks to inside of them and make universality for flippers. In the other hand Using flippers and middle dive system separately causes when one of them is in service the other become out of service. **Applications/ Improvements:** Using such a system without adding any new element when responding all requested functions means that "ideality degree of system increased".

Keywords: Energy Consumption, Flipper, Ideality Degree, Tracked Robot, TRIZ

1. Introduction

One of the most popular problems of tracked robots in passing roads (specially ragged roads) is to pass narrow obstacles[1]. Usually, the process of come back and pass another way is time consuming or impossible. This problem put manufacturers of these robots through finding an adequate solution for this problem. A primary solution is preparation of a drive system, which is a rotary track at the middle area and under robot chassis[2]. When robot meets the obstacles, this system do as an auxiliary drive system which helps robot to pass it.

Using such a system, causes several harmful effects such as multiplicity of robot elements, total weight increase, mechanism complexity increase and difficulty of maintenance and repair[1]. By this reason and using of TRIZ approach, we want to solve these contradictions and as a guideline, we use 39 engineering innovative principals. Finally, we represent an innovative design to solve this problem.

2. TRIZ at a Glance

Expression "TRIZ" is combined from first letters of four Russian words that means "organized and innovative solving of a problem"[3]. It should be noticed that TRIZ is not intuition which suddenly increases the ability of team to solving the problem[4]. Additionally, because of algorithmic construction of TRIZ, it can increase repeatability, predictability and reliability in problem solving process[5].

The best guideline in using TRIZ is "innovative situation questionnaire" or ISQ[4].

Based on ISQ, TRIZ process is as following:

The first step is "problem explanation". In this step we describe both existing and desirable situations and in fact, our problem is the gap between these situations[6].

After it, usually, we draw a diagram from problem and by using of harmful and useful effects analysis (PHF and PUF), we get an illustrative explanation of the problem.

At the next step, side issues and side problems are extracted from the diagram and the main problem will

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be detected and formulated. This main problem, usually, involves one or some "technical contradictions" which can be named as TC's[7-9].

Resolving of these technical contradictions, will perform by different TRIZ tools. The most common tools here are "Contradiction Matrix" and "40 innovative principals". In each TC, improvement of one or more engineering parameters may cause weak in one or more other engineering parameters. The contradiction matrix will suggest one or some innovative principals which will be forceful in resolving of noted contradiction[7].

Finally and after using of contradiction matrix, often we find solutions which will cause innovative solving of the problem.

3. Existing Construction and Function of System

Tracked Robots, usually, involve a chassis which other robot elements such as electronic parts, arms, controllers and other parts mounted on it. This type of robots, usually, have two tracks in sides as drive system and two tracked arms in sides of drive tracks (as flippers) to help crossing ramps and step obstacles[9-11].

As we discussed, to solve the problem of passing obstacles with a width less than interspace between two drive tracks, an elementary solution is to prepare a drive system at the middle area and under chassis. It is clear that, adding of such a system needs motor, gearbox, power transmission system and other related parts.

Figure 1 shows a tracked robot and identifying the location of additional drive system.

As we know, this type of robots, based on their defined mission, maybe move in different environments and thereupon in different road types such as sandy roads, stony roads, muddy roads and rugged roads, so they must use the drive system which be adequate for all of these conditions[12,13].

Location of middle drive system

Figure 1. A common tracked robot.

4. Formulation of Problem based on PUF and PHF

Expression "PUF" means "primary useful function" and expression "PHF" means "primary harmful function".

As we know, adding a middle drive system can have several PUF's and PHF's. The most sensible function of this system is increasing the order of multiplicity of robot elements.

5. Diagram of the Problem

Based on above, now, we can draw the diagram of problem. This diagram is very useful in general conception of it.

The main rule in drawing of this diagram is showing of useful functions by circle and harmful functions by square. Also, maybe one useful function has several useful or harmful functions and similarly one harmful function has several useful or harmful functions.

Directions of arrows show the direction of effects. As we can see in Figure 2, existence of middle drive system has a very clear useful function that is possibility of passing obstacles with small width and this can be explained as road adaptability, meanwhile, it can make several harmful functions too, such as weight increase, complexity increase, difficulty of maintenance and more waste of power.

Clearly, each of these harmful functions can have other harmful or useful functions too.

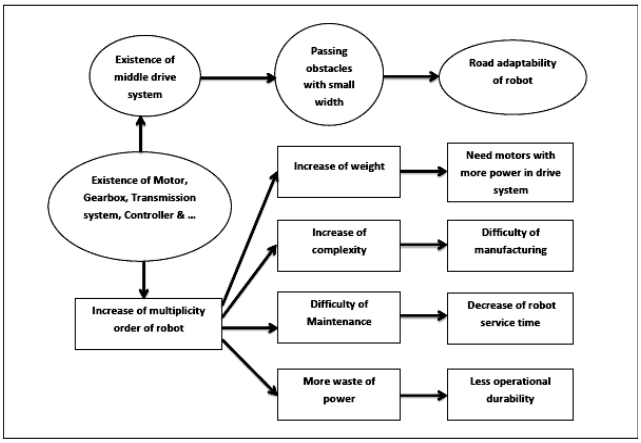

Figure 2. Diagram of the problem.

6. Extraction of Side Issues and Side Problems

In this section, we can extract all questions which can help us to solve the problem. Questions are proposed in this section, are very important and if we can't to achieve the solution in this step, these questions can help us while we use contradiction matrix (at the next step). Possible side problems are as following:

- Find a solution to minimize number of moving elements.
- Find a way to use power of other sections for middle drive system.
- Find a method to minimize the weight of moving elements of middle drive system.
- Find a solution to reach energy consumption of middle drive system to zero when it has no duty.
- Find another method instead of using middle drive system.
- Find a way to use middle drive system for other duties of robot.
- Find a method to avoid obstacles except passing them.
- Solve the following contradiction:

Denoted middle drive system provides needed force to pass narrow obstacles, but because of increasing number of robot elements and making more complexity, it has several harmful effects such as increasing of weight, difficulty of repair and maintenance and waste of power (energy).

7. Analysis of Problems

Since, solutions of some of above problems need to make basic changes in robot and this is very undesirable for robot manufacturers; we cannot apply them as general solution of the problem. But by solving some of these problems and defining some contradictions which can be extracted when the problem is formulating; we can propose some solutions as following:

- We can use motors and gearboxes with minimum weight.
- We can use power of other sections of robot to drive middle track by power transmission systems, but this makes some harmful effects such as more complexity.
- We can use some sensors which activate middle drive system only when the robot encountered an obstacle and be inactive other times.
- We can use motors of middle drive system to help other sections of robot such as main drive system.

As we can see, some adequate solutions obtained from formulating of problems which proposed in previous steps. Meanwhile, they make some contradiction because of their possible harmful effects. Now, we analyze these contradictions by applying "*contradiction matrix*" and finally proposed solutions will be formulated and represented.

8. Solving Contradictions by use of Contradiction Matrix and 40 Innovative Principals

As we saw before, there are two main contradictions are sown in Figures 3 and 4.

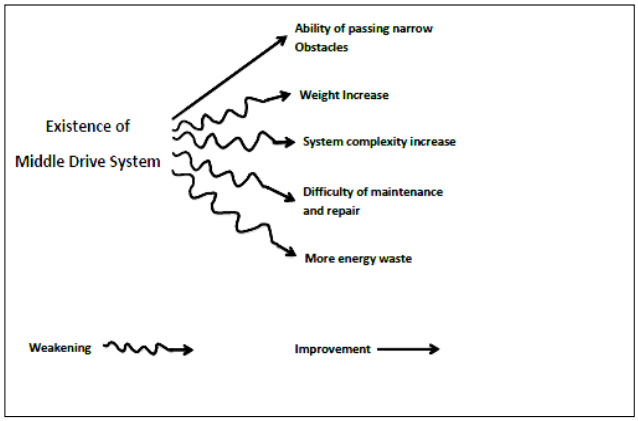

Figure 3. Diagram of Technical Contradiction TC1.

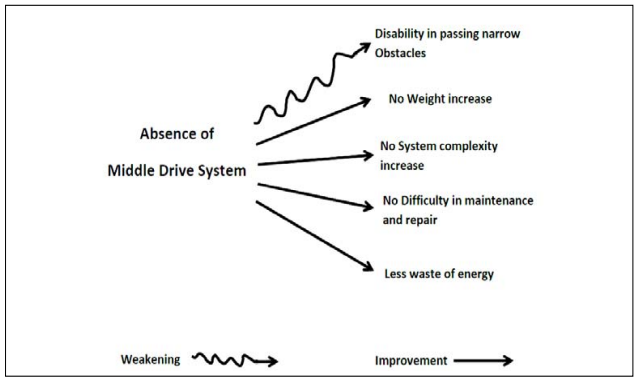

Figure 4. Diagram of Technical Contradiction TC2.

8.1 Analysis of Contradiction TC1

If we refer to contradiction matrix, we cannot see parameter "Ability to pass narrow obstacles", so, it is necessary to superpose this parameter to one or some existing parameters. In this case the best selection is parameter "adaptability". So, by use of contradiction matrix we can arrange the following Table:

Based on Table 1 we can see:

Principal No. 15, "Dynamics" is repeated 3 times. Principal No. 1, "Segmentation" is repeated 2 times. Principals No. 6,"Universality", No. 10,"Preliminary action", No. 29,"Use of pneumatic and hydraulic systems", No. 37,"Thermal expansion", No. 28,"Mechanics substitution", No. 18,"Mechanical vibration", No. 16,"Patial or excessive action", No. 4,"Asymmetry", No. 7,"Nested doll" are repeated only one time.

8.2 Analysis of Contradiction TC2

Here, unlike contradiction TC1, parameters "weight of moving object", "complexity of device", "waste of energy" and "repairability" reveals as improving parameters and "adaptability" appears as weakening parameter. So, based on contradiction matrix we can arrange the following Table 2:

After it we can see:

Principal No. 15, "Dynamics" is repeated 2 times. Principal No. 29, "Use of pneumatic and hydraulic systems" is repeated 2 times. Principals No. 5, "Combination", No. 10,"Preliminary action", No. 8, "Anti-weight", No. 37, "Thermal expansion", No. 28, "Mechanics substitution", No. 16,"Partial or excessive action", No. 4, "Asymmetry", No. 7, "Nested doll" are repeated only one time.

Based on all above, the following practical solutions can be represented:

By using principal No. 16 "Partial or excessive action", if achievement to 100% complete and exact goal be difficult, we can consent to a little less or a little more than it (approximate goal), so head function do not become disturbed. In our case it means that if passing of narrow obstacles be difficult, we can consent to pass partly narrow obstacles and for very narrow ones we can find another solution such as forward or backward movement and so on.

Also, by using principal No. 6 "universality", one part or body can has several functions and by some small changes, existing elements can do the duty of new elements. Study in robot elements shows that flippers location can be changed from outside of driving tracks to inside of them. This change makes universality for flippers.

Of course, because of existence of interspace between two flippers, it perhaps to have some difficulties in passing very narrow obstacles but it is generally negligible shown in Figures 5 and 6.

Otherwise, based on principal No. 15 "Dynamics", characteristics of a body or its surrounding should

Table 1.

Weakening / Improvement	Wight of moving object	Complexity of device	Waste of energy	Repair ability
Adaptability	6, 10, 8, 15	15, 28, 29, 37	1, 15, 18	1, 4, 7, 16

Table 2.

Weakening / Improvement	Adaptability
Wight of moving object	5, 8, 15, 29
Complexity of device	15, 28, 29, 37
Waste of energy	---------
Repair ability	4, 7, 10, 16

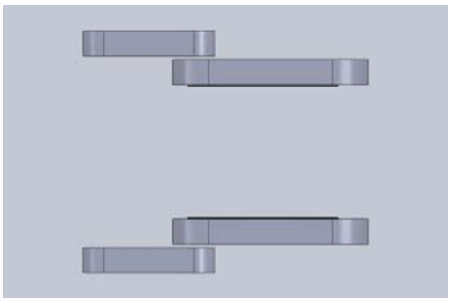

Figure 5. Flippers arrangement before change.

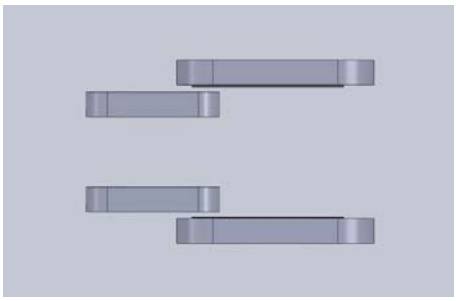

Figure 6. Flippers arrangement after change.

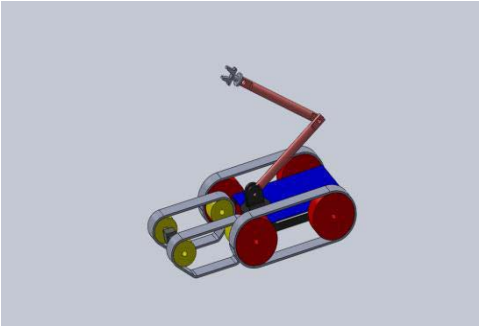

Figure 7. Conceptual design after utilization of TRIZ.

be defined so has the best function in each step. Using flippers and middle dive system separately causes when one of them is in service the other become out of service. By using denoted principal this harmful effect removed and replaced by a useful effect.

9. Conclusion

The above solutions, as for used method, obtained from a systematic procedure, based on logic and existing data, by utilization of TRIZ algorithm, its contradiction resolving techniques, Mechanics fundamentals and nowise they cannot earned from intuition.

Study in new conceptual design shows that, the problem of passing narrow obstacles (adaptability) solved and moreover, harmful effects such as weight increase, more complexity, waste of energy and hardening of repair and maintenance wouldn't be created shown Figure 7.

In other word, by using existing system and without adding any new element all requested functions performed and this means "Our system ideality degree increased".

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