Modular Mixer Machine Design for Liquid Fertilizer

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Abstract. Purpose: The design of the stirrer in making liquid organic fertilizer. Methodology: The TRIZ model is used in the design process. Results: The appropriate engineering characteristics to overcome the contradiction problem between the ability to rotate the mixer and the weight of the motor are the ‘force’ characteristic (parameter 10) and the ‘weight of stationary object’ characteristic (parameter 2). The solution is to move the weight of the motor on the object that will provide a ride. Applications/Originality/Value: Modular product development by applying the TRIZ concept has not been widely used. This paper will help position the TRIZ method in the design of modular products.

1. Introduction

1.1. Modularity In Design
A product like a robot is a system that combines subsystems that interact between themselves and the environment [1]. Combining subsystems can be interpreted as combining into a system by removing subsystems or maintaining subsystems then assemble them into one system. The second meaning is known as modularity. The process of making products is complex enough to increase production and improve quality [2] so that the right method is needed.

Modularity is an approach to managing complex products and processes into simpler activities so that these can be managed efficiently and independently [3]. A relatively simple product architecture can produce a large number of product variations [4]. Components used in modular products should have features that allow them to be combined together to form complex products. Modular design in preparation can also involve customers to determine the type of modular to be applied [5]. Modular products have the potential to produce competitive advantages and their importance in the product development process [6].

The perspective of the use of modular is divided into 2, modularity in design (MID) and modularity in production (MIP) [7]. Modularity in design (MID) aims to break down complex products into functional subsystem units, which are independently designed and produced; enables the construction of various products by combining subsystems, reducing complexity while integrating functions [8]. Modularity in production (MIP) is characterized by organizing production processes into groups, enabling balancing and tooling with little loss of functionality, each production module working as an autonomous unit. It focuses on the organization of manufacturing processes to increase flexibility, reduce complexity, and reduce time and costs, by building more independent and autonomous processes, which characterize the entire manufacturing process as modular [9].

In this context, an important problem that arises is the modular design of liquid fertilizer makers. Strengthening the relevance of this study, [10] points to the fact the results of modular
architecture in the manufacturing process appear as interesting opportunities for future research.

1.2. Definition of TRIZ
TRIZ is an abbreviation for Theory of Inventive Problem Solving. This theory is obtained when analyzing inventive principles. TRIZ provides a set of basic knowledge to resolve contradictions and potentially generate new knowledge. TRIZ theory uses 39 technical parameters as seen in Table 1 and 40 inventive principles as seen in Table 2 to be applied in research.

The TRIZ method is used to solve the contradiction problem. Contradiction is an increase in one characteristic will cause other characteristics to be worse [10]. TRIZ is a methodology for discovery and creative thinking that has various advantages, systematically organized, and comprehensive [11]. Most robotic manipulators are faced with characteristic conditions to maximize stiffness and to minimize the end-effector vibrations to achieve good positioning accuracy [12]. The solution is achieved by using a bulky design and heavy material. The design results obtained are rigid and heavy manipulators so it is inefficient in terms of power consumption or speed.

Table 1: Technical parameters [13]

| No | Parameters                                      | Explanation |
|----|------------------------------------------------|-------------|
| 1  | Weight of moving object                        | The mass of the object, in a gravitational field. The force that the body exerts on its support or suspension. |
| 2  | Weight of stationary object                    | The mass of the object, in a gravitational field. The force that the body exerts on its support or suspension, or on the surface on which it rests. |
| 3  | Length of moving object                        | Any one linear dimension, not necessarily the longest, is considered a length. |
| 4  | Length of stationary object                    | Any one linear dimension, not necessarily the longest, is considered a length. |
| 5  | Area of moving object                          | A geometrical characteristic described by the part of a plane enclosed by a line. The part of a surface occupied by the object. OR the square measure of the surface, either internal or external, of an object. |
| 6  | Area of stationary object                      | A geometrical characteristic described by the part of a plane enclosed by a line. The part of a surface occupied by the object. OR the square measure of the surface, either internal or external, of an object. |
| 7  | Volume of moving object                        | The cubic measure of space occupied by the object. Length x width x height for a rectangular object, height x area for a cylinder, etc. |
| 8  | Volume of stationary object                    | The cubic measure of space occupied by the object. Length x width x height for a rectangular object, height x area for a cylinder, etc. |
| 9  | Speed                                          | The velocity of an object; the rate of a process or action in time. |
| 10 | Force                                          | Force measures the interaction between systems. In Newtonian physics, force = mass X acceleration. In TRIZ, force is any interaction that is intended to change an object’s condition. |
| 11 | Stress or pressure                              | Force per unit area. Also, tension. |
| 12 | Shape                                          | The external contours, appearance of a system. |
13 Stability of the object’s composition
The wholeness or integrity of the system; the relationship of the system’s constituent elements. Wear, chemical decomposition, and disassembly are all decreases in stability. Increasing entropy is decreasing stability.

14 Strength
The extent to which the object is able to resist changing in response to force. Resistance to breaking.

15 Duration of action by a moving object
The time that the object can perform the action. Service life. Mean time between failure is a measure of the duration of action. Also, durability.

16 Duration of action by a stationary object
The time that the object can perform the action. Service life. Mean time between failure is a measure of the duration of action. Also, durability.

17 Temperature
The thermal condition of the object or system. Loosely includes other thermal parameters, such as heat capacity, that affect the rate of change of temperature.

18 Illumination intensity
Light flux per unit area, also any other illumination characteristics of the system such as brightness, light quality, etc.

19 Use of energy by moving object
The measure of the object’s capacity for doing work. In classical mechanics, Energy is the product of force times distance. This includes the use of energy provided by the super-system (such as electrical energy or heat.) Energy required to do a particular job.

20 Use of energy by stationary object
same

21 Power
The time rate at which work is performed. The rate of use of energy.

22 Loss of Energy
Use of energy that does not contribute to the job being done. See 19. Reducing the loss of energy sometimes requires different techniques from improving the use of energy, which is why this is a separate category.

23 Loss of substance
Partial or complete, permanent or temporary, loss of some of a system’s materials, substances, parts, or subsystems.

24 Loss of Information
Partial or complete, permanent or temporary, loss of data or access to data in or by a system. Frequently includes sensory data such as aroma, texture, etc.

25 Loss of Time
Time is the duration of an activity. Improving the loss of time means reducing the time taken for the activity. “Cycle time reduction” is a common term.

26 Quantity of substance/the matter
The number or amount of a system’s materials, substances, parts or subsystems which might be changed fully or partially, permanently or temporarily.

27 Reliability
A system’s ability to perform its intended functions in predictable ways and conditions.

28 Measurement accuracy
The closeness of the measured value to the actual value of a property of a system. Reducing the error in a measurement increases the accuracy of the measurement.

29 Manufacturing precision
The extent to which the actual characteristics of the system or object match the specified or required characteristics.
30 External harm affects the object
Susceptibility of a system to externally generated (harmful) effects.

31 Object-generated harmful factors
A harmful effect is one that reduces the efficiency or quality of the functioning of the object or system. These harmful effects are generated by the object or system, as part of its operation.

32 Ease of manufacture
The degree of facility, comfort or effortlessness in manufacturing or fabricating the object/system.

33 Ease of operation
Simplicity: The process is NOT easy if it requires a large number of people, large number of steps in the operation, needs special tools, etc. “Hard” processes have low yield and “easy” process have high yield; they are easy to do right.

34 Ease of repair
Quality characteristics such as convenience, comfort, simplicity, and time to repair faults, failures, or defects in a system.

35 Adaptability or versatility
The extent to which a system/object positively responds to external changes. Also, a system that can be used in multiple ways for under a variety of circumstances.

36 Device complexity
The number and diversity of elements and element interrelationships within a system. The user may be an element of the system that increases the complexity. The difficulty of mastering the system is a measure of its complexity.

37 Difficulty of detecting and measuring
Measuring or monitoring systems that are complex, costly, require much time and labor to set up and use, or that have complex relationships between components or components that interfere with each other all demonstrate “difficulty of detecting and measuring.” Increasing cost of measuring to a satisfactory error is also a sign of increased difficulty of measuring.

38 Extent of automation
The extent to which a system or object performs its functions without human interface. The lowest level of automation is the use of a manually operated tool. For intermediate levels, humans program the tool, observe its operation, and interrupt or re-program as needed. For the highest level, the machine senses the operation needed, programs itself, and monitors its own operations.

39 Productivity
The number of functions or operations performed by a system per unit time. The time for a unit function or operation. The output per unit time, or the cost per unit output.

| No | Principles               | Explanation                                                                 |
|----|--------------------------|-----------------------------------------------------------------------------|
| 1  | Segmentation             | Divide an object into independent parts. Make an object easy to disassemble.|
|    |                          | Increase the degree of fragmentation or segmentation.                        |
| 2  | Taking out               | Separate an interfering part or property from an object, or single out the only necessary part (or property) of an object. |
|    |                          | Change an object’s structure from uniform to non-uniform, change an external environment (or external influence) from uniform to non-uniform. |
| 3  | Local quality            |                                                                                            |

**Table 2:** Inventive principles [14]
Make each part of an object function in conditions most suitable for its operation.
Make each part of an object fulfill a different and useful function.
Change the shape of an object from symmetrical to asymmetrical.
If an object is asymmetrical, increase its degree of asymmetry.

Bring closer together (or merge) identical or similar objects, assemble identical or similar parts to perform parallel operations.
Make operations contiguous or parallel; bring them together in time.

Make a part or object perform multiple functions; eliminate the need for other parts.
Place one object inside another; place each object, in turn, inside the other.
Make one part pass through a cavity in the other.

To compensate for the weight of an object, merge it with other objects that provide lift.
To compensate for the weight of an object, make it interact with the environment (e.g. use aerodynamic, hydrodynamic, buoyancy and other forces).

If it will be necessary to do an action with both harmful and useful effects, this action should be replaced with anti-actions to control harmful effects.
Create beforehand stresses in an object that will oppose known undesirable working stresses later on.

Perform, before it is needed, the required change of an object (either fully or partially).
Pre-arrange objects such that they can come into action from the most convenient place and without losing time for their delivery.

Prepare emergency means beforehand to compensate for the relatively low reliability of an object.
In a potential field, limit position changes (e.g. change operating conditions to eliminate the need to raise or lower objects in a gravity field).
Invert the action(s) used to solve the problem (e.g. instead of cooling an object, heat it).

Make movable parts (or the external environment) fixed, and fixed parts movable).
Turn the object (or process) ‘upside down’.

Instead of using rectilinear parts, surfaces, or forms, use curvilinear ones; move from flat surfaces to spherical ones; from parts shaped as a cube (parallelepiped) to ball-shaped structures.
Use rollers, balls, spirals, domes.
Go from linear to rotary motion, use centrifugal forces.
Allow (or design) the characteristics of an object, external environment, or process to change to be optimal or to find an optimal operating condition.
Divide an object into parts capable of movement relative to each other.
If an object (or process) is rigid or inflexible, make it movable or adaptive.

16 Partial or excessive actions

If 100 percent of an object is hard to achieve using a given solution method then, by using ‘slightly less’ or ‘slightly more’ of the same method, the problem may be considerably easier to solve.

To move an object in two- or three-dimensional space.

17 Another dimension

Use a multi-story arrangement of objects instead of a single-story arrangement.

Tilt or re-orient the object, lay it on its side.

Use ‘another side’ of a given area.

Cause an object to oscillate or vibrate.

Increase its frequency (even up to the ultrasonic).

18 Mechanical vibration

Use an object’s resonant frequency.

Use piezoelectric vibrators instead of mechanical ones.

Use combined ultrasonic and electromagnetic field oscillations.

Instead of continuous action, use periodic or pulsating actions.

19 Periodic action

If an action is already periodic, change the periodic magnitude or frequency.

Use pauses between impulses to perform a different action.

20 Continuity of useful action

Carry on work continuously; make all parts of an object work at full load, all the time.

Eliminate all idle or intermittent actions or work.

21 Skipping

Conduct a process, or certain stages (e.g. destructible, harmful or hazardous operations) at high speed.

22 “Blessing in disguise” or “Turn Lemons into Lemonade”

Use harmful factors (particularly, harmful effects of the environment or surroundings) to achieve a solution.

Eliminate the primary harmful action by adding it to another harmful action to resolve the problem.

23 Feedback

Introduce feedback (referring back, cross-checking) to improve a process or action.

If feedback is already used, change its magnitude or influence.

24 ‘Intermediary’

Merge one object temporarily with another (which can be easily removed).

25 Self-service

Make an object serve itself by performing auxiliary helpful functions

Use waste resources, energy, or substances.

Instead of an unavailable, expensive, fragile object, use simpler and inexpensive copies.

26 Copying

Replace an object, or process with optical copies.

If visible optical copies are already used, move to infrared or ultraviolet copies.

27 Cheap short-living objects

Replace an inexpensive object with a multiple of inexpensive objects, comprising certain qualities (such as service life, for instance).

Replace a mechanical means with a sensory (optical, acoustic, taste or smell) means.

28 Mechanics substitution

Use electric, magnetic and electromagnetic fields to interact with the object.
Change from static to movable fields, from unstructured fields to those having structure.
Use fields in conjunction with field-activated (e.g. ferromagnetic) particles.

29 Pneumatics and hydraulics
Use gas and liquid parts of an object instead of solid parts (e.g. inflatable, filled with liquids).

30 Flexible shells and thin films
Use flexible shells and thin films instead of three dimensional structures
Isolate the object from the external environment using flexible shells and thin films.

31 Porous materials
Make an object porous or add porous elements (inserts, coatings, etc.).
If an object is already porous, use the pores to introduce a useful substance or function.

32 Color changes
Change the color of an object or its external environment.
Change the transparency of an object or its external environment.

33 Homogeneity
Make objects interacting with a given object of the same material (or material with identical proper

34 Discarding and recovering
Make portions of an object that have fulfilled their functions go away (discard by dissolving, evaporation).
Conversely, restore consumable parts of an object directly in operation.
A. Change an object’s physical state (e.g. to a gas, liquid, or solid.
Change the concentration or consistency.
Change the degree of flexibility.
Change the temperature.

36 Phase transitions
Use phenomena occurring during phase transitions (e.g. volume changes, loss or absorption of heat, etc.).

37 Thermal expansion
Use thermal expansion (or contraction) of materials.
If thermal expansion is being used, use multiple materials with different coefficients of thermal ex
Replace common air with oxygen-enriched air.
Replace enriched air with pure oxygen.

38 Strong oxidants
Expose air or oxygen to ionizing radiation.
Use ionized oxygen.
Replace ozonized (or ionized) oxygen with ozone.

39 Inert atmosphere
Add neutral parts, or inert additives to an object.

40 Composite materials
Change from uniform to composite (multiple) materials.

The conventional method of solving the problem of contradiction by optimal exchange or compromise as seen in Figure 1.

The Inventive Principle is one of TRIZ’s best-known and most used tools. The Inventive Principles were initially focused on solving physical and chemical problems and subsequently developed in other fields including software, information technology [15] and management [16–18]. Various studies show the application of TRIZ in solving the problem of contradiction. Some application objects include a passively adaptive compliant robotic gripper [19] and aquatic products with food traceability systems [20]. The application of TRIZ in the construction industry helps help the industry increase its innovation capacity [13].
1.3. Problem Solving in TRIZ
Contradictions in TRIZ can be divided into technical and physical contradictions. Technical contradiction is a condition where an increase in a system parameter will cause other parameters to be bad. These problems are solved by identifying system parameters, selecting engineering parameters from 39 appropriate parameters, choosing inventive principles from the contradiction matrix, choosing solutions, and evaluating available solutions as seen in Figure 2.

Physical contradiction is a condition where an increase in one system parameter will cause other parameters to increase and others to become bad. These problems are solved by separation in time, separation in space, separation between parts and whole, and separation upon condition.

The remainder of this paper is organized as follows. Section 2 explains the research method used to conduct this research. Section 3 discusses the results. Section 4 conclusions. The paper concludes with further research opportunities.

2. Research Design and Methods
This paper aims to design a liquid fertilizer maker. The argument developed in this paper uses a modular concept in the design process. In addition, this paper highlights the relationships between the modules, and offers several contradictory solutions that occur.

In this context, this article aims to offer three main contributions. The first contribution is to design a liquid fertilizer maker. The second contribution is to present and analyze the relationships between modules. The third contribution is to offer propositions on how to overcome the problem of contradiction in the design process. The object of this research is a
liquid fertilizer maker. The study was conducted by conducting a modular analysis and problem solving using the TRIZ method. The research questions are:

(i) RQ1: How many modules are needed to design a liquid fertilizer maker?
(ii) RQ2: What is the solution offered on the contradiction problem?

3. Discussion

3.1. Modular in Design

The design of a liquid fertilizer maker is divided into 2 modules, namely the liquid fertilizer production process module and the mixer machine module.

3.2. Design with TRIZ

The object of this research is a liquid fertilizer maker. Making liquid fertilizer is traditionally done by using barrels as a medium for making fertilizers. The manufacturing procedure is to insert liquid fertilizer ingredients and stir them regularly. Stirring is done manually.

This research developed a liquid fertilizer maker tool by adding a stirrer automatically. The addition of the motor allows automatic stirring and facilitates the process of making fertilizer, but increases the burden that must be borne by the fertilizer barrel. The mixer is automatically driven by the motor. Thus, there is a technical contradiction between motorcycle procurement and the burden that must be borne.

The application of TRIZ is done by identifying 39 technical parameters that correspond to contradictory characteristics (torque and motor weight). One of the 39 technical characteristics does not directly fit the parameters provided. We can choose the most appropriate by analogy.

3.3. Technical Contradictions

Stirring is automatically done by adding a motor as a mover and giving the consequence of increasing the burden borne by the barrel. This condition is a technical contradiction. The resolution of the contradiction problem is as follows:

(i) Identify contradiction characteristics. Motor rotation strength is a characteristic that must be improved. Motor weight is a characteristic of getting worse.

(ii) Determine the appropriate engineering characteristics. Motor rotation strength according to the ‘force’ characteristic (parameter 10, “Any interaction that is intended to change an object’s condition”). The weight of the motor is according to the ‘weight of stationary object’ characteristics (parameter 2, “The mass of the object, in a gravitational field. The force that the body exerts on its support or suspension, or on the surface on which it rests.”).

(iii) Determine inventive principles. The recommended principles as seen in Figure 3

![Figure 3: Recommended principles](image)
(iv) Find possible solutions. From principle 8 (anti weight), balance the weight of the motor by combining it with other objects that provide lift. From principle 10 (preliminary action), stir the fertilizer before it is needed. From principle 18 (mechanical vibration / oscillation), the barrel oscillates or vibrates. From principle 37 (thermal expansion), use thermal expansion to stir.

(v) Evaluate possible solutions and choose the most promising. Transferring the weight of the motor by combining it with another object that provides lift can be considered a good solution because the application process is simpler and cheaper as seen in Figure 4.

3.4. Physical contradiction
Physical contradiction is a situation when a parameter has to be increased (motor weight) in one situation and must be reduced (or, it should not be) in another condition. In this study, the motor weight will be reduced if the motor power is lowered and vice versa motor power will increase if the motor weight is increased (using higher motor specifications). Some possible solutions are as follows:

(i) Separation in time. Increase motor power in the high fertilizer requirements, and decrease in the low fuel requirements.

(ii) Separation in space. Use a large motor on a large barrel and a small motor on a small barrel.
(iii) Separation between parts and whole. Increase the production process in small barrels that require a motor with a small power.

(iv) Separation based on conditions. Use a small barrel available then use a small motor and use a large motor when a small barrel is not available.

4. Conclusions

The design of a liquid fertilizer maker is divided into 2 modules, namely the liquid fertilizer production process module and the mixer machine module. This research shows that the TRIZ method can be used in the design of liquid fertilizer production equipment. The appropriate engineering characteristics to overcome the problem of contradiction between motor power and motor weight are the 'force' characteristic (parameter 10) and the 'weight of stationary object' characteristic (parameter 2). A possible solution is 'anti weight' (8). The solution is done by balancing the weight of the motor by combining it with other objects that provide lift can be considered as a good solution because the application process is simpler and cheaper.

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