PAPER • **OPEN ACCESS**

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To cite this article: Zhaohuan Zhang *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **242** 052026

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Solving the problem of *blocked water washing tower* using TRIZ

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Abstract. TRIZ theory is a set of systematic innovation methodology and invention problem solving theory. It is a comprehensive theoretical system composed of various methods to solve technical problems and realize innovation. System components analysis of the water washing tower, located in the olefin separation unit of coal-to-methanol plant, was carried out using the TRIZ theory. The interaction of the components of the water wash tower system and the resulting causal chain are analysed. By the principle of the characteristics transfer invention and contradiction analysis, the solutions to solve the problem of blocked washing tower are initially proposed in the paper.

1. Introduction

TRIZ is the Russian acronym for "Teoriya Resheniya Izobretatelskikh Zadach", i.e. the "theory of the resolution of inventive problems". It is a product and process innovation method that uses various tools that propose paths to possible innovations and solutions [1].its system theory includes: conflict resolution theory, material-field and standard solutions, functional analysis, effect knowledge base, technological system evolution theory, and invention problem solving algorithm (ARIZ).etc. [2]. TRIZ can help engineers and technicians break off conventional thinking, get out of the mindset of the profession, and find out solutions to problems from divergence to convergence, subjective to objective, or the field to other fields.

Four-stage compression and pre-depropanation process were adopted in the olefin separation unit of Shenhua Baotou coal-to-methanol plant. The water washing tower is set after the second stage of compressor to remove a large amount of oxides (methanol, dimethyl ether, ethanol, propionaldehyde, acetone, etc.) in the product gas produced by the methanol to olefin unit. In actual operation, the water tower is frequently blocked, which seriously affects the long-term operation of the device. Therefore, it is essential to alleviate and eliminate the blocked problem for the long-term operation of the washing tower [3].

2.TRIZ theory

The evolution process of the technical system is not random, but has objective laws that appear repeatedly in different fields can be followed. The most effective principles and methods for solving technical problems in one field often come from another field. TRIZ's technical conflicts and physical conflicts are the main tools for solving technical system problems. A typical engineering compromise problem in the event of a technical conflict, that is, when one of the technical characteristics (parameters) of the system is increased, the other technical characteristic (parameter) deteriorates. TRIZ identified 39 technical standard features through patent analysis and resolved these conflicts with 40 innovative principles. Physical contradictions arise when technical systems have opposite

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requirements. Physical contradiction is a sharper contradiction in engineering and must be solved in design, which are often solved by separation principles [4, 5].
TIRZ's process of solution to technology system problem is shown in Figure 1:

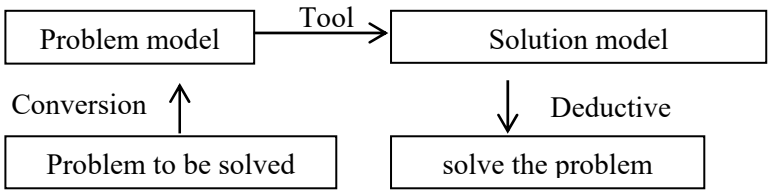


Figure 1. TIRZ thinking route

3.Applying TRIZ theory to solve the problem of blocked washing tower

3.1 Problem Description

The water washing tower is a three-stage packed tower, which uses a loose-packed saddle ring packing, and the operating temperature is 37.5 °C and the pressure is 0.766 Mpag. The quenching water from the bottom of the chilling tower of the MTO unit is heated and then enters the water washing tower. The water coming out from the bottom of the washing tower is sent to the sedimentation tank of the MTO unit, and the gas from the top of the tower is heated and sent to the alkali washing tower to remove the acid gas like CO_2 contained in the gas [3]. The process flow is shown in Figure 2. The saddle ring filler is attached with a large amount of black gray, solidified into cement-like particulate matter, which are difficult to remove from the filler, as shown in Figure 3.

The consequences of the blockage:

- Severe drift and liquid seal
- Mist entrainment, then liquid flooding, which brings moisture into alkali scrubbing tower, causing acid gas content exceed the standard.
- The amount of purified water is forced to decrease from 60t/h to 15t/h to prevent the water wash tower from being overpressured.
- The oxygen content (acetaldehyde, acetone, dimethyl ether, etc.) in the product gas rises sharply, and then be condensed to form butter in alkali washing tower, causing the blockage. if oxygenates enter the post-system, which eventually cases the oxide content of the polymer grade propylene product to exceed the standard, which affects the polymerization of propylene.
- The discharge temperature of the second stage of the compressor rises because of large pressure drop due to blockage

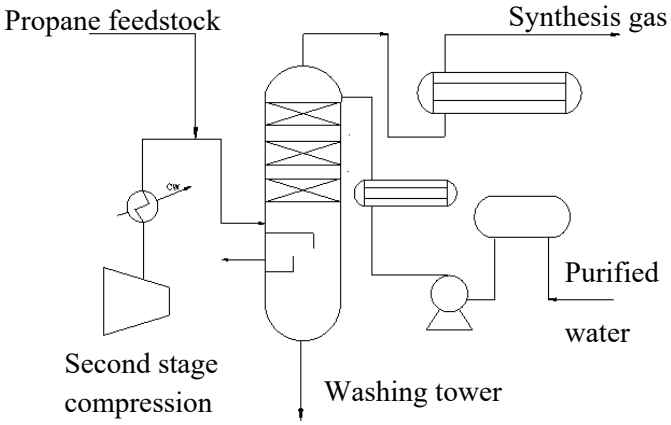


Figure2. Washing tower process



Figure 3. Blocking filler particles

3.2 System analysis

System components analysis of the water wash tower was carried out using the TRIZ. The filler is defined as the system object, and impurities and gaseous hydrocarbons as super system components, among which are system components, and their interaction relationship is shown in Fig. 4.

3.3 Causal chain analysis

The interaction of the components of the water wash tower system is analyzed, and the resulting causal chain analysis is shown in Fig. 5.

3.4 Find solutions through problem anatomy

By dissecting the problem of the wash tower, the typical method is to use 5W1H to define the problem, which includes：

What—Washed tower blockage

Where—Bonding dirt on the filler

When—Tower pressure rises, and purified water increases

Whom—Alkaline washing tower, subsequent separation system

What extend—In severe cases, it will cause shut-down

How do I know—The water content of the washing tower and the propylene content of the polymerization grade exceeded the standard; the discharge temperature of the second stage of the compressor increased. Through the analysis of the problem and the causal chain analysis of the components, and through the principle of the characteristics transfer invention, the solution is initially proposed:

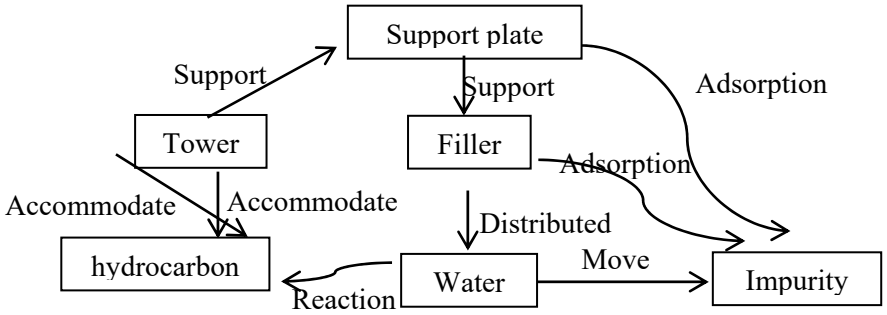


Figure4. Analysis of the washing tower system

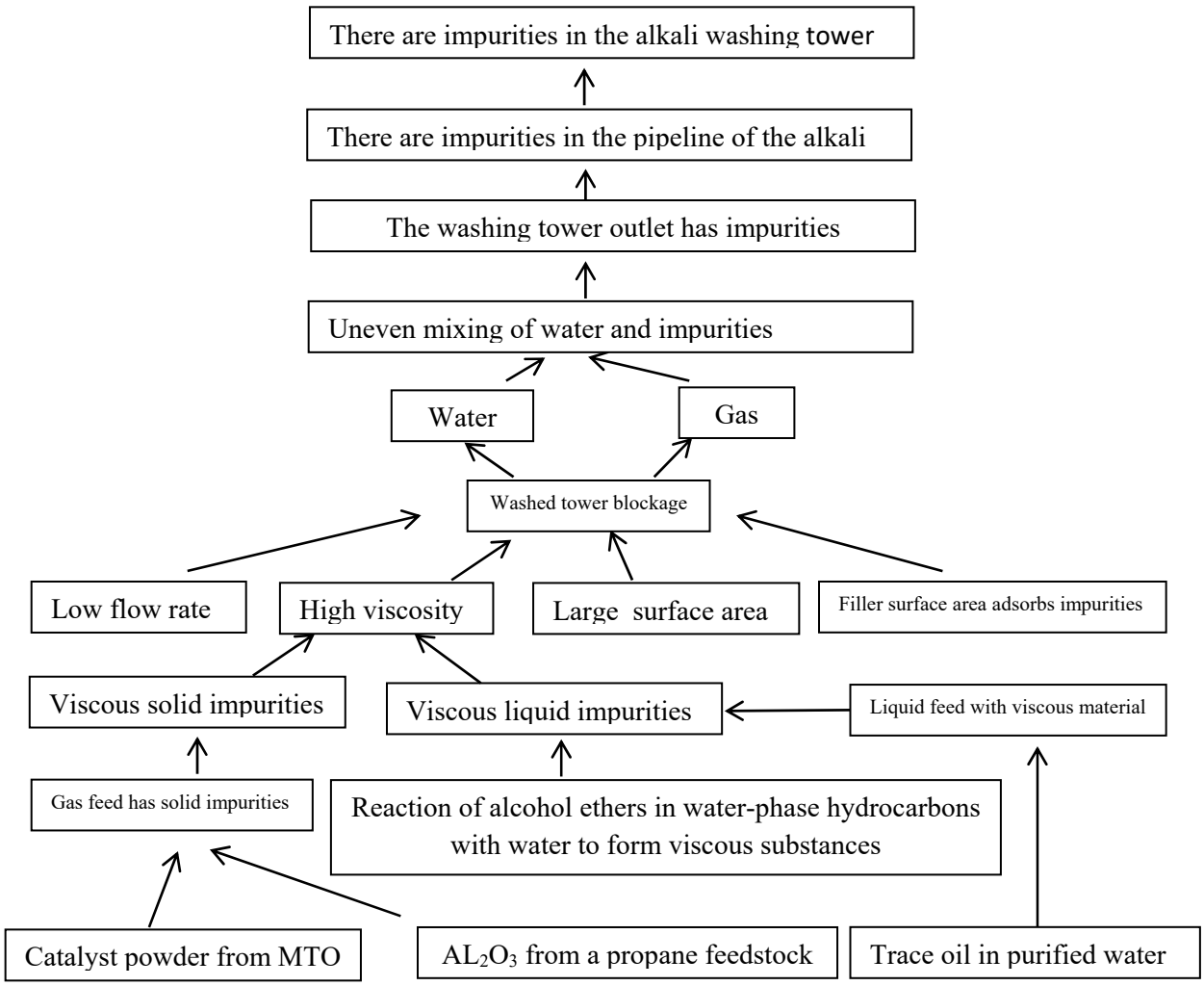


Fig. 5 Analysis of causal chain of washed tower

- Hydro cyclone or high speed centrifuge is used to separate AL_2O_3 powder from the liquid propane in the polypropylene unit before entering the water wash tower
- Grease be removed from purified water in the MTO unit before entering the water wash tower
- Oil separation measures can be set in the second-stage suction tank of compressor to initially separate the oil from water before the condensate is discharged into the MTO water system.

3.5 Use contradiction analysis to find a solution

For physical contradictions, the four separation principles be used to solve the physical contradictions encountered. First, if spatial intersection does not exist between the two sides of the contradiction, the principle of spatial separation to be used to solve the problem. If there is a spatial intersection, but no time intersection between the two sides, the principle of time separation is used. Otherwise, the principle of conditional separation and system separation is considered.

Based on the principle of spatial separation, the following solutions for blocked are proposed:

- The purified water inlet is changed into multiple sections, so that the flow rate of the purified water in the lower part of the washing tower is high, the upper flow rate is low, and the swirling state is obtained.
- Gas segmentation into the water wash tower to increase water vapor contact.
- Change the filling method of the packing so that the surface area of the packing in the lower part of the washing tower is small, which can alleviate the serious clogging of the lower part.

Based on the principle of time separation, the following solutions for blockd are proposed:

- The purified water periodically enters the water washing tower, so that the dirt adhered to the filler can be cleaned online under the influence of different water speeds, prolonging the operation time thereof.
- Scouring with hot water at a certain time (by closing the purified water cooler valve).

3.6 Use the Cropping principle to find a solution

Cropping is a tool for analyzing problems, which remove one or more components and replace the useful functions performed by them with the remaining components in the system or supersystem. When we implement clipping, the useful functions of its components must be preserved, or the useful functions of the components must be allocated among the remaining components.

For the water washing tower system, the main problem is the clogging caused by impurities carried in the material being bonded to the filler. It can be seen from the analysis of its system components that the main problem component is the filler. Then, cutting the filler can be considered while ensuring the distribution of gas and liquid:

- anti-blocking vertical tray
- Replace the easy-bonded Pall ring with a non-bonding filler by means of the non-stick principle

4.Conclusion

In this paper, the TRIZ is applied to solve the blocked of water washing tower of in coal-to-methanol plant. Through the analysis of the causal chain of the blockage of the washing tower, the problem is defined by the method of 5W1H, and the contradiction analysis is used to find the solution and the method to solve the problem. Three methods are proposed to alleviate the blockage of the washing tower from the source. By contradiction analysis, based on the principle of spatial separation, time separation and tailoring, 3/2/2 kinds of ideas for solving the blockage of the washing tower are proposed respectively. It is worth noting whether these scenarios can really solve the problem of plugging the washing tower in engineering, and further experimental research and engineering implementation are needed.

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