A TRIZ-Based Systematic Problem Solving Approach for Heat Treatment Processes for Screw Manufacturing – A Case Study of Oil Mist Purifying Equipment

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Abstract

The screw manufacturing industry is an important industry for Taiwan. However, as the costs of processing pollutants increases, further study is required. This paper uses a TRIZ-based systematic approach and demonstrates a series of TRIZ tools for problem solving. In fact, TRIZ includes many tools and it is very useful as researchers can use diverse methods combining many tools to solve problems with different approaches. In this paper, we focus on a systematic approach consisting of some TRIZ tools such as problem definition, function analysis, cause and effect chain analysis, effects database along with Pugh's Matrix to solve the targeted problem and to evaluate the possible solutions. A TRIZ-based systematic approach for problem solving is demonstrated using a case study of suggestions to improve oil mist purifying equipment. The procedures proposed can be used as general problem solving procedures. Therefore, it contributes a feasible reference method for improving manufacturing process or equipment in screw industry or other industries.

Keywords: Function Analysis, Knowledge Effect Database, Pugh Matrix, Oil Mist Purifying.

1. Introduction

The screw manufacturing industry is an important industry for Taiwan (Chen, 2012). In 2012, the production value was more than 420 Million US Dollars. 93% of production is for export worldwide. The export quantity was 1.38 million metric tones. There are more than 1,300 factories and 24,000 workers in the industry. The market shares were 40.66% to the USA, 8.96% to Germany, 5.22% to the Netherlands, 4.78% to Japan, 4.04% to the UK and 36.34% to other countries (ibid). The market shares for 2012 are shown in Figure 1.

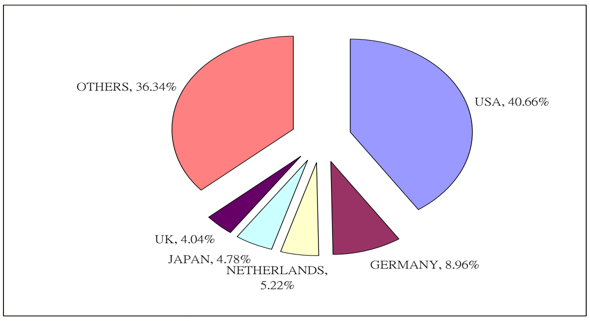


Fig. 1 Worldwide market share in 2012 (Chen, 2012).

In screw manufacturing process, a problem occurs frequently when an oil mist purifying unit catches fire occasionally and must be stopped for cleaning after periods of operation. The production will be interrupted by this problem as the heat treatment operation needs to stop operation. Therefore, it is necessary to improve waste processing equipment. Therefore, in this paper, we want to focus on implement a systematic approach consisting of some TRIZ tools such as problem definition, function analysis, cause and effect chain analysis, effect database along with Pugh's Matrix to solve the targeted problem and to evaluate the possible solutions. This paper uses a series of TRIZ tools for problem solving. In fact, TRIZ includes many tools and it is very useful as researchers can use diverse methods combining many tools to solve problems with different approaches. In this paper, the authors only adopted some tools because the object of this paper is to demonstrate a systematic quick approach with some TRIZ tools to effectively solve practical problem in industry. A case study is demonstrated to suggest methods to improve oil mist purifying equipment.

The first section of the paper gives the background of the screw industry and details the importance of the waste process. The second section gives brief introductions of the TRIZ tools adopted in this paper such as Function Analysis, Cause and Effect Chain Analysis and the Pugh Matrix (Burge, 2009). The third section explains the problem solving methodology used in this paper. The fourth section provides a case study that uses the proposed methodology. The last section is the conclusion and suggestions for future work.

2. Related Work

TRIZ is a Russian term - Teoriya Resheniya Izobreatatelskikh Zadatch - which means the Theory of Inventive Problem Solving (Altshuller, 1996). It was invented by the Russian inventor, Genrish Saulovich Altshuller. He proposed a step by step problem solving method (ibid). Recently, there have been many industrial studies of the improvement of manufacturing processes or equipment. Sheu and Hou used a TRIZ-based integrated trimming process to redesign the problematic processing machine for real-world semiconductor equipment (Sheu & Hou, 2013). Song et al. used TRIZ-based tools, such as function analysis techniques, the Laws of Technical Systems Evolution and Su-field analysis, to predict prioritized directions of innovation and to create the most promising practical concept design using lab-on-a-chip technology (Song et al, 2012). Yeh et al. (2011) proposed a methodology that uses a four-phase QFD along with TRIZ-based tools such as a contradiction matrix and inventive principles for process improvement for R&D for notebooks (Yeh et al, 2011). Typically, the first step in TRIZ-based problem solving is to generalize a specific problem to a TRIZ problem. The second step is to find the TRIZ solutions. The TRIZ solutions are then applied to the specific solution. The TRIZ method is shown in Figure 2.

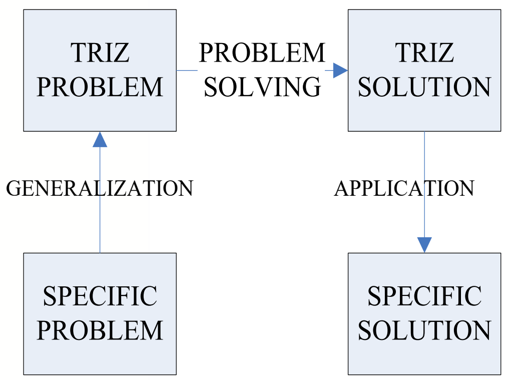


Fig. 2 The typical TRIZ method (Altshuller, 1996).

2.1 Function Analysis

Function Analysis models a system to identify the relationships between components (Mann, 2009). The action between a tool and an object is stated. The typical relation for a tool-act-function on an object along with the symbols for the possible functions in Function Analysis is shown in Figure 3.

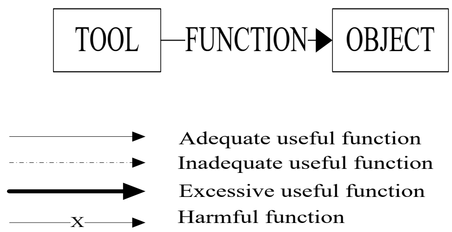
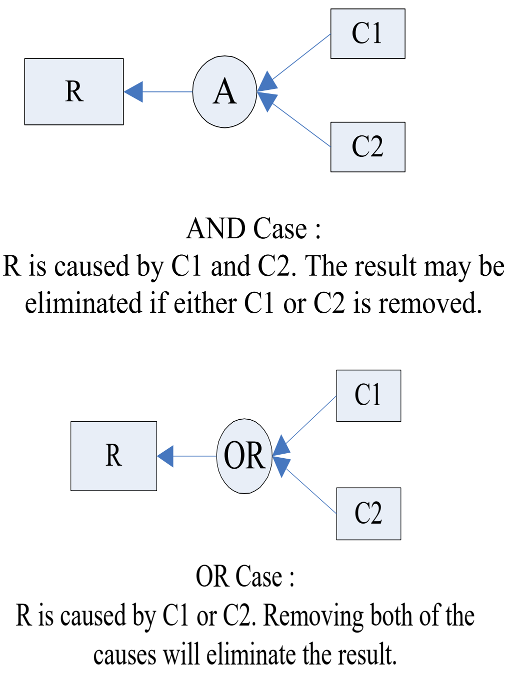


Fig. 3 Symbols of tool-act-function on object along with possible functions (Sheu & Hou, 2013).

2.2 Cause and Effect Chain Analysis

Cause and Effect Chain Analysis (Ikovenko, 2014) is used to find the target disadvantages from surface disadvantages. When the causes of problems and the relationships between causes are known, problems can be solved by addressing one or more causes. A problem can be a result of causes with AND, OR, COMBINE, STRAIGHT and NOT. The possible relationships between causes and the result are shown in Figure 4.



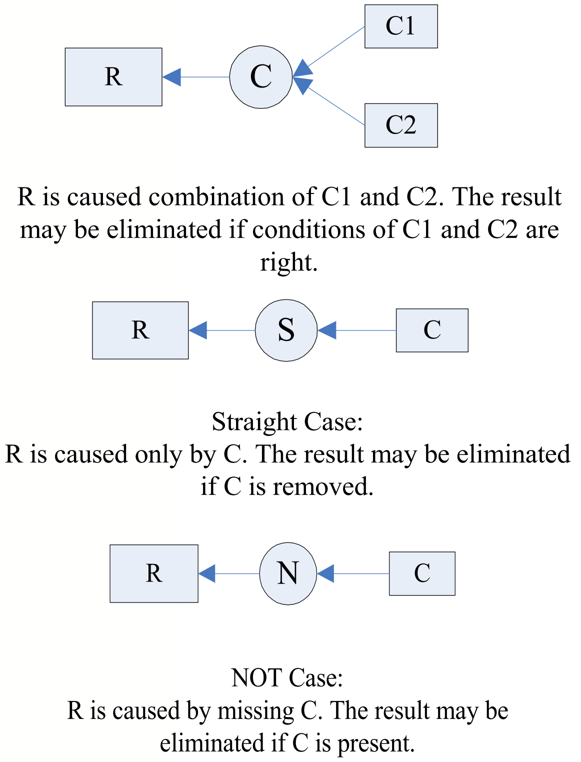


Fig. 4 Possible relations among causes and result (Ikovenko, 2014).

2.3 Knowledge Effects Database

A Knowledge effects (Yeh et al, 2011) base standardizes problems to generic functions and generic attributes so that similar problems in different fields can be easily used to solve particular problems. A commonly used TRIZ effects database is available at http://www.oxfordcreativity.co.uk/.(Oxford Creativity – TRIZ Effects Database, 2014)

2.4 Pugh's Matrix

The Pugh's Matrix was invented by Dr. Stuart Pugh at the University of Strathclyde in Glasgow, Scotland (Burge, 2009; DeCarlo et al, 2012). This paper uses this tool to eliminate the inferior solutions proposed by a Knowledge Effects Database. The three steps for Pugh's Matrix are:

1. Determine a baseline (Datum)
2. Select the concepts to be evaluated
3. Define the evaluation criteria

3. Research Process

Figure 5 shows the research processes that are proposed in this paper. The problem is firstly defined and then the component and function relationships between the components are identified using Function Analysis. In order to determine the root causes of the problem, Cause and Effect Chain Analysis is used to identify the causes. When the causes are identified, a Knowledge Effects Database is used to find the suggested solutions. Pugh's Matrix is used to narrow down possible solutions to the application. Feasible solutions are then identified for further study.

The processes are shown in Figure 5.

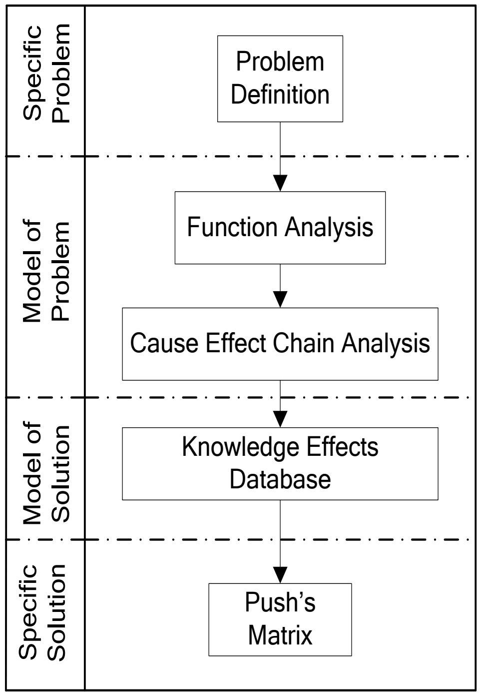


Fig. 5 The Proposed Process.

4. Case Study

A case study is used to illustrate the process of problem solving. The problem for the case study was that an oil mist purifying unit catches fire occasionally and must be stopped for cleaning after periods of operation. As the heat treatment operation runs continuously, any stop for cleaning means lost production. This study suggests new design concepts for a new oil mist purifying machine that can be operated without downtime and which does not catch fire.

The old oil mist purifying system has an electro-static cleaning system. A function-oriented search was conducted to understand it. U.S. Patent 5,925,170 (Nojima, 1999) gives useful technical information. The cleaning unit is similar to the proposed unit, as shown in Figure 6.

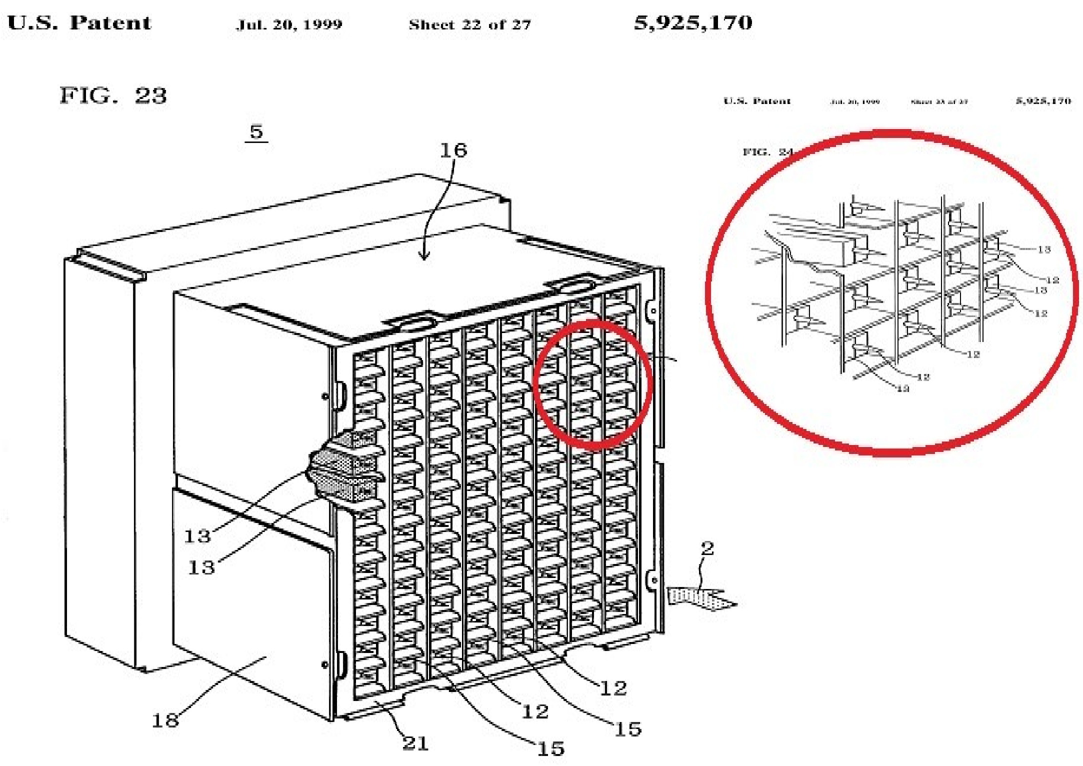


Fig. 6 Electro-Static Type Smoke Cleaner (Ikovenko, 2014).

The smoke to be cleaned consists of water vapor, oil vapor and odor. The particles are different sizes. Water particles are the largest. These are removed by passing through a filter. The oil particles then undergo electro-static cleaning. The particles are charged and then attracted by the cathode wall. Then odor is cleaned by passing through an active carbon filter. After these three cleaning stages, the air is clean and can be released into atmosphere. The process is shown in Figure 7.

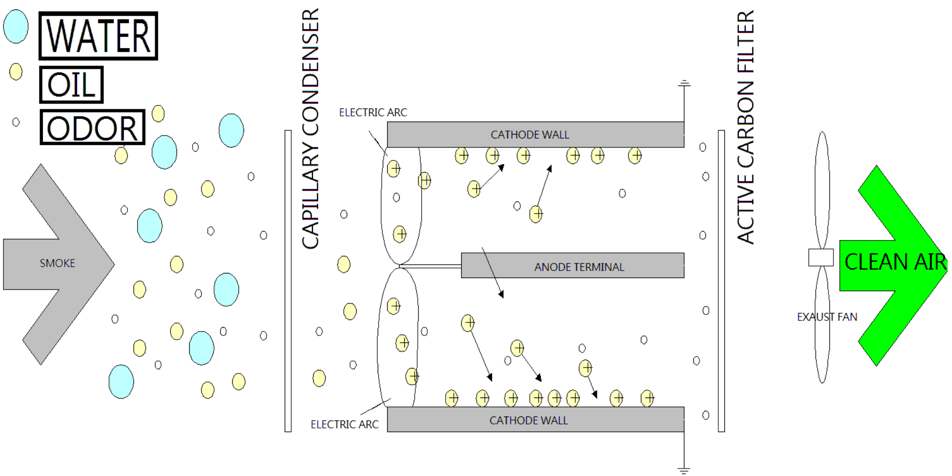


Fig. 7 Graphical Illustration.

4.1 Function Analysis

Function Analysis is used to identify the functions and the relationships between components, as shown in Figure 8. When a fire occurs,

- The water condenser solidifies water vapor.
- The anode creates a spark.
- The spark creates a positive charge.
- The positive charge ionizes the oil vapor.
- The cathode tube absorbs the oil vapor.
- The spark and the oil vapor together produce a fire.
- The active carbon filter absorbs odor.
- The water condenser solidifies water vapor.
- The cathode tube is cleaned manually.
- Oil vapor is harmful to the environment.
- Odor is harmful to the environment and to humans.

These tool-function-object statements allow a Function analysis diagram to be drawn and this is shown in Figure 8.

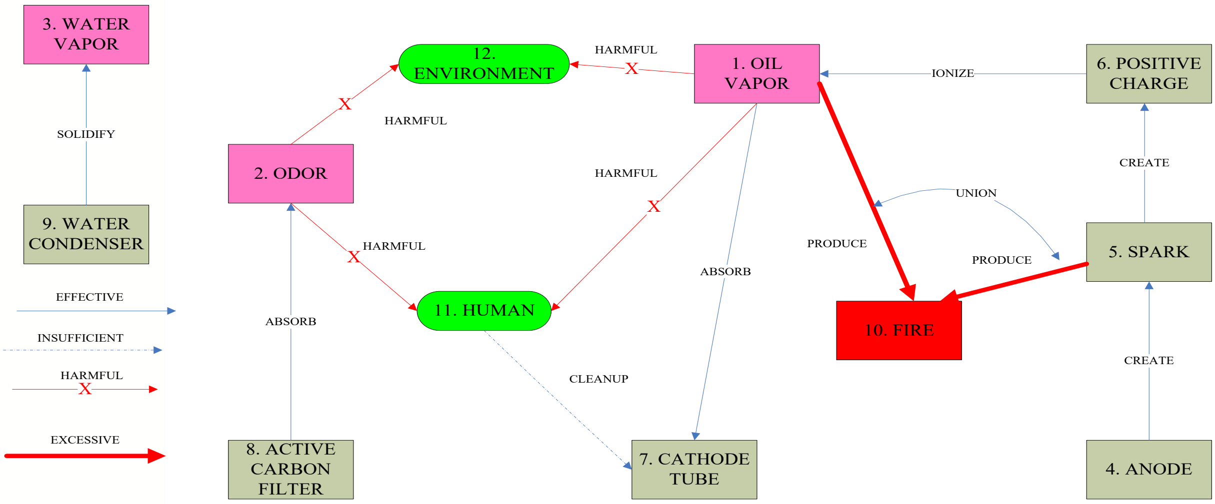


Fig. 8 Function Analysis.

4.2 Cause and Effect Chain Analysis

The target disadvantage in the system is that the unit catches fire occasionally. Heat, fuel and oxygen are the three necessary elements for ignition. The system is an open-air unit so there is oxygen everywhere in the system. The oil accumulates on the electrostatic unit. When the cleaner runs for a while, the oil that accumulates becomes thicker. The electrostatic unit cannot be cleaned during operation. The high temperature is a by-product of the emission of charges.

These statements a low a cause and effect chain analysis to be derived. The key disadvantages of the system are:

1. The electrostatic unit cannot be cleaned during operation.

2. The emission of electric charge causes high temperature.

3. Oxygen.

If any one of the key disadvantages can be eliminated, the risk of fire is eliminated. The cause and effect chain analysis diagram is shown in Figure 9.

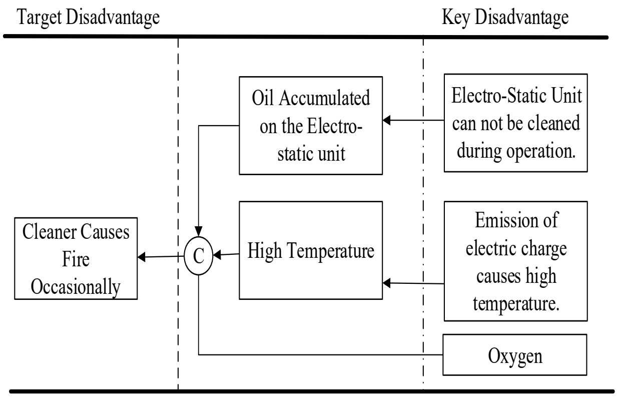


Fig. 9 CECA diagram of Smoke Cleaner Causing Fire.

4.3 The Knowledge Effects Database

To identify other solutions for cleaning smoke, the knowledge effects database was searched with the function query, Function Clean and Object Gas. The snapshot for the query is shown in Figure 10. 59 suggestions for clean gas were identified, as shown in Figure 11.

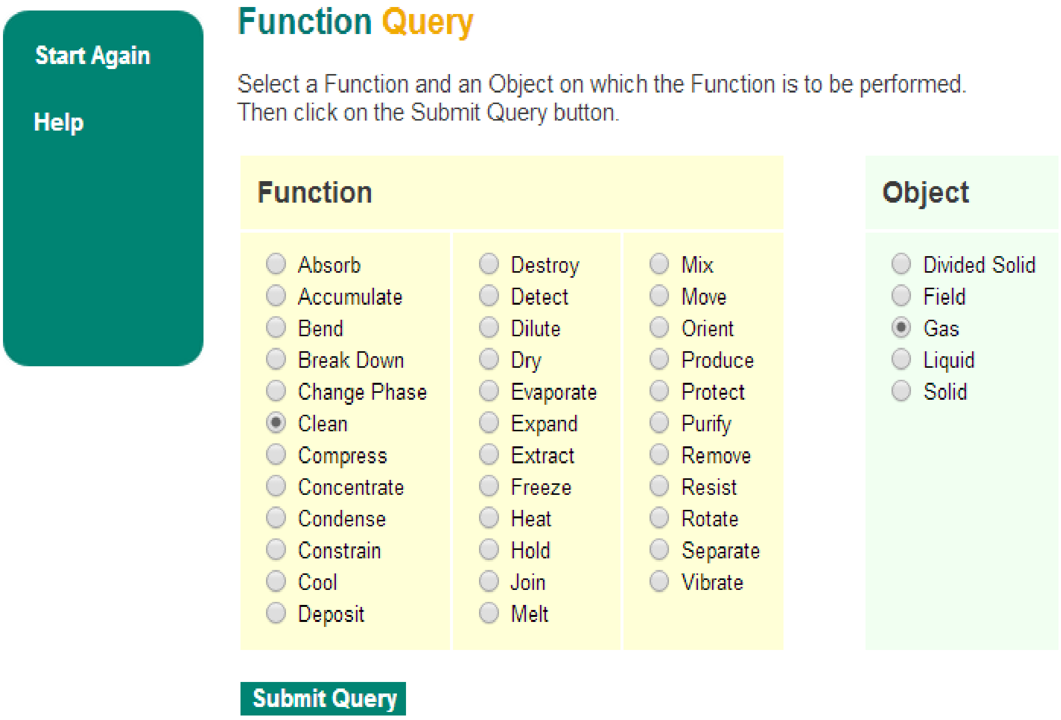


Fig. 10 The snapshot of query in this study.

Fig. 11 Suggestions for Clean Gas from Knowledge database.

4.4 Pugh's Matrix

To minimize the number of suggestions, the effects with 4 criteria were evaluated.

The scalability of the operation: As the cleaning process requires large scale cleaning, it is necessary to determine whether the effects can be used on a large scale.

Ease of Operation: To make the system as simple as possible, it is necessary to determine whether the effects are easy to operate.

The disadvantage of the previous system is that it catches fire occasionally so it is necessary to determine whether the effects are fireproof.

As the heat treatment process runs continuously, it is necessary to determine whether the process is interrupted.

The effect is evaluated with respect to the 4 criteria and assigned values of 1: positive, 0: neutral and -1: negative. The evaluated results are shown in Figure 12.

Table 1 The evaluated results with Pugh's Matrix.

No.	Effects	Scalability of operating area	Ease of operation	Fireproof	Avoidance of interrupting process	Sum
	Weighting of effects	0.2	0.2	0.3	0.3	1.0
1	Absorption	1	1	1	1	1.0
2	Adsorption	-1	1	1	0	0.3
3	Sorption	0	1	1	0	0.5
4	Activated Alumina	0	1	1	-1	0.2
5	Activated Carbon	1	1	1	-1	0.4
6	Aero Gels	-1	-1	1	-1	-0.4
7	Ceramic Foam	-1	1	1	-1	0.0
. . .	. . .	. . .	. . .	. . .	. . .	. . .
53	Setting	-1	-1	1	1	0.2
54	Sorption	-1	-1	1	0	-0.1
55	Sponge	1	1	0	0	0.4
59	Supercritical Fluid	0	0	-1	-1	-0.6
57	Thermophoresis	0	1	-1	-1	-0.4
58	Valve	0	0	1	-1	0.0
59	Zoelite	-1	-1	1	-1	-0.4

The Pugh's Matrix analysis shows that there are 4 effects that have a sum of 1.0. These effects are Absorption, Cyclone Separation, Phase Change and Capillary Condensation. These 4 suggestions are feasible and can be used to perform more experiments to determine the most feasible solution.

The absorption effect is commonly used in cleaning applications. The oil mist is absorbed by surface-active agents, so the oil mist can be cleaned continuously.

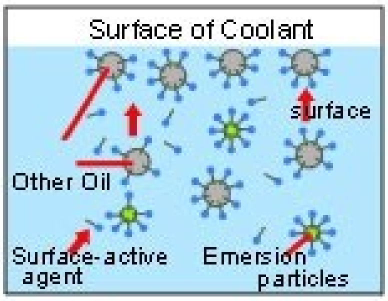


Fig. 12 Absorption by surface active agents (Surface Active Agent, 2015).

Cyclone separation is used to separate oil mist from air.

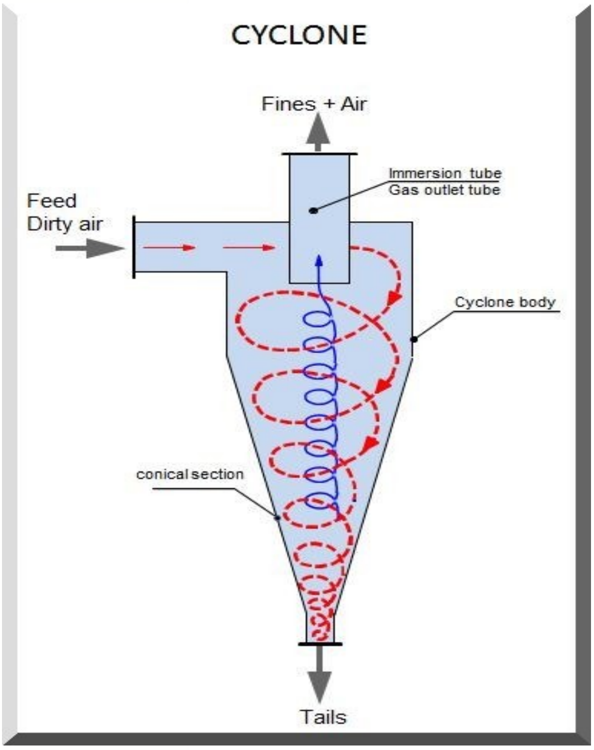


Fig. 13 Cyclone separation (Separators in the Cement Grinding Circuits, 2015).

Phase change allows airborne oil mist to condense into large particles and be separated from air.

Capillary condensation swaps a single air pipe for smaller pipes so the surface area is increased. The increased surface area helps to remove oil mist faster.

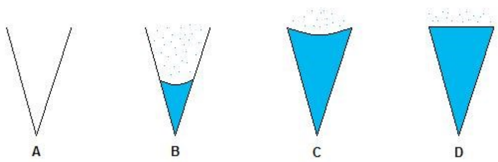


Fig. 14 Capillary Condensation (Capillary Condensation, 2015)

5. Conclusions and Future Works

It is necessary to minimize the cost for cleaner screw production. The screw manufacturing industry faces severe competition in the market and it is necessary to improve waste processing equipment. This paper demonstrates a TRIZ-based systematic approach for problem solving and there is a case study of suggestions to improve oil mist purifying equipment. This provides a feasible reference method for improving the manufacturing process or equipment in the screw industry. The process for improving equipment by using tools such as Function Analysis, Cause and Effect Chain Analysis, a Knowledge Effects Database and Pugh's Matrix is also shown. In fact, TRIZ is a very useful method to solve industrial problem and it contains many other powerful tools such as Ideal Final Result, Su-Field analysis and standard solutions, Trimming and Trends of Evolution evaluation. The procedures proposed in the paper only adopt some tools but it also can be used as a general problem solving method. Therefore, in this paper, we provide a feasible reference for improving manufacturing processes or equipment for the screw industry or other industries.

This paper shows a superficial use for function-oriented search. In future works, other TRIZ tools, such as ideal final results, Trim, ARIZ or Trends of Evolution may be used to identify further possibilities. Biomimetics can also be used, as these are naturally proven ways for filtering and cleaning waste.

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