METAL PART CLEANING PROTOTYPE FOR SME's AUTOMOTIVE INDUSTRY IN THAILAND*

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ABSTRACT

In an automotive industry, fabricating metal automotive parts requires a painting process as the final step for manufacturing. A jig can be used to hold the parts and handle the position of the automotive workpiece to prevent errors in the painting process. The jig is sprayed repeatedly several times so that it is sprayed over several layers, resulting in excessive paint thickness. As a result, error of the workpiece's position can affect the color quality of the workpiece. Currently, there are two cleaning methods for paint removal including mechanical process and chemical process. This research examines the equipment design for the paint removal process by using chemical solvent. Next, the prototype is developed to reduce the manufacturing cost of equipment set, in which the performance is equivalent to the conventional version. The result shows that the equipment manufacturing cost can be reduced by 39 percent. This research is expected to be useful for small and medium-sized industrial plants to develop the cleaning equipment set at an affordable cost and to enhance the metal cleaning service in the automotive industry or other industries that need to clean the metal parts in the painting process.

Keywords: Metal part cleaning, Automotive industry, Paint removal, Design for manufacturing, Control and automation.

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INTRODUCTION

In Thailand, automotive industries are immensely found in Chonburi and Chachoengsao provinces, the Eastern Special Development Zone. This is due to that these areas account for the largest portion of industrial estates in Thailand. These small and

medium-sized enterprises (SMEs) have grown greatly as suppliers in the supply chain of the assembly plants, such as Toyota, Honda, BMW, and Mitsubishi. In the manufacturing processes of automotive metal parts, the final process is the painting process, in which jig and fixture are required to hold the workpiece in the proper position. These devices are repeatedly sprayed several times resulting in an excessive paint thickness. Thus, they must be cleaned for painting removal to avoid an ineffectiveness in quality control process.

According to entrepreneurs' interview in the supply chain of the automotive industry, two cleaning methods have been used in the paint removal process: 1) mechanical processes, such as sandblasting, high-pressure water jets, and rubbing off by hand; 2) chemical process, such as immersion in the paint stripping solution. Based on the examination of the real cases in the automotive industry in Chonburi and Chachoengsao provinces; SMEs, however, have a cost limitations for the investment of paint removal equipment. Thus, there is a need to examine an alternative solution for these SMEs. The high-pressure water jets have been mostly used in the automotive assembly plants for paint cleaning with the water pressure at 2,000 bar or more. This method has the advantage of fast cleaning and can completely remove painting residue. The disadvantages, however, are concerned with very high-water pressure that is dangerous for the workers and the high cost of machine and maintenance processes. Therefore, the chemical processes have been alternatively applied in some assembly plants and SMEs automotive plants. The jig will be cleaned by a large bulk of solvent in a tank and the chemical reaction will be accelerated by heat until the temperature meets the required level. Then, the jig is put to boil in the tank to remove the painting residue. This chemical method can peel off residue for many jig parts at a time. Moreover, chemicals can also be reused without an expiration date with a condition to be fulfilled sometimes. The disadvantage is that the cost of equipment is quite high, and some SMEs are inaccessible.

Many years ago, mechanical paint removal using natural-particle blasting was investigated in the painting removal process for the surface morphology of aeronautical composite materials with minimal or no damage to the aircraft skin substrate. Natural particles, such as white corn but is also harmless to the environment (Guy, Lankarani, & Talia, 1991). Then, the high-pressure water

stripping process was certified to replace the chemical process in the aircraft maintenance industry. This process involves process optimization for metal substrates involving the coating removal rate, residual stresses, surface roughness, preliminary process envelopes, and technical plans for process validation testing (See, Hofacker, Stone, & Harbaugh, 1993). The water jets for paint removal processes have also been investigated for the effects of water jet kinetic energy and stand-off distance on the mass loss of an organic paint system applied to a steel substrate (Teimourian, Shabgard, & Momber, 2010). Moreover, the literature was reviewed focusing on the needle gun technology as an alternative to conventional abrasive blasting technology to remove lead-based paint from steel. Many factors, such as worker health and safety, environmental protection, hazardous waste generation, and costs are compared to those arising from conventional abrasive blasting. In addition, the needle gun system has the potential to be economically competitive with conventional abrasive blasting (Randall, Kranz, Sonntag, & Stadelmaier, 1998). Although paint removal by blasting techniques has been widely used for surface preparation in marine and offshore engineering, conventional blasting has intrinsic problems, such as noise, explosion risk, contaminant particles, vibration, dust, as well as processing wastes. Therefore, laser cleaning was also used as a good alternative approach to conventional blasting, which is an environmentally friendly technique to overcome the drawbacks of conventional blasting (Chen, Kwee, Tan, Choo, & Hong, 2010). The laser paint removal process usually incurs traces of combustion product (i.e., ashes on the surface). A water-jet with laser paint removal process thus has been investigated for paint removal from the surface in a single step (Madhukar, Mullick, & Nath, 2013).

The above literature review similarly point out that the paint removal in metal cleaning processes includes chemical processes, water-jet, laser, and blasting. Regardless, the high technology processes with an environmental friendly criterion has a tradeoff with high costs. As such, a number of SMEs including those from Thailand cannot economically afford the high-cost technology. Accordingly, the chemical process becomes a viable and suitable alternative for paint removal in the SMEs' automotive industry. In this research, we explore the experimental design of using chemical processes and develop a prototype of equipment to reduce the manufacturing cost of equipment set. The performance of the designed equipment is expected to be equivalent to other existing commercial ones. This study is useful for SMEs industrial plants, especially those in Thailand in order to afford the cleaning equipment set at an acceptable cost as well as to enhance the metal cleaning service in the automotive and similar industries of interest.

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RESEARCH OBJECTIVES

The research objective is to design and develop a prototype of metal cleaning equipment with lower cost of equipment set for SMEs industrial plants.

RESEARCH METHODOLOGY

Research framework

As illustrated in Fig 1, the research framework involves the study of the functioning of a conventional cleaning process in the automotive industry, an evaluation of the paint remover selection, a new system design, the process of material selection, conducting the cost analysis of cleaning equipment set, as well as developing an equipment prototype.

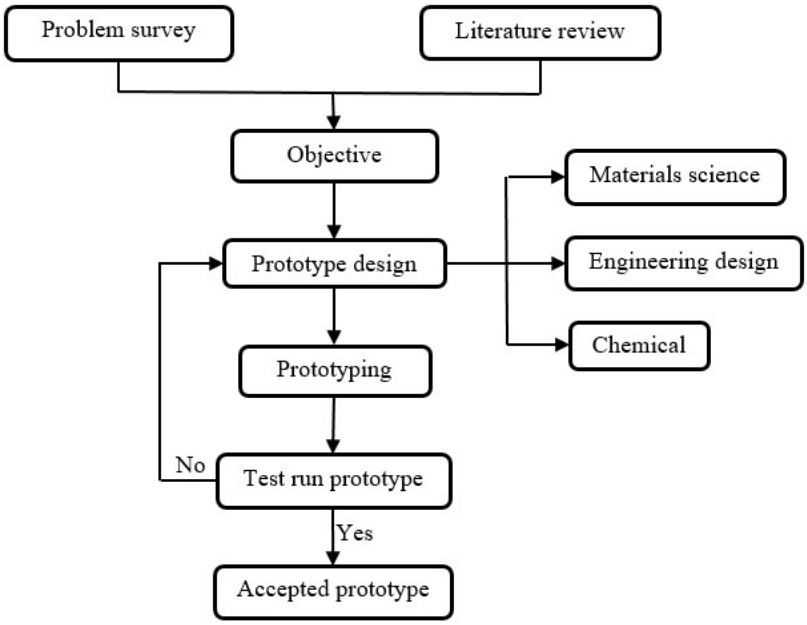


Figure 1 Framework of research methodology

Prototype design

Based on interview with six company in the automotive industry in Thailand, two of assembly plants and four manufacturing plants which supply raw material to assembly plants, the paint removal processes were investigated to conduct the conceptual design of prototype. The processes can be analyzed to classify type of removal, material using, and cleaner component. According to data analysis, the prototype design has developed by steps as to study the conventional paint removal process and design the new system.

After prototype was examined, it was evaluated by at least three manufacturing companies to assess the suitability of prototype for the real situation. The assessment was considered in two opinion topics respectively as 1) the suitable of the prototype concerning capability and investment cost 2) the outputs that related to the research objectives.

1) Study of the conventional paint removal process in Thailand's automotive industry

Fig. 2 shows the conventional equipment set consisting of the chemical tank and the rinsing tank. In particular, the chemical reagent tank will be equipped with a heater at the bottom of the tank to heat the chemical reagent. During the cleaning work, the first pump is used to draw the chemical solvent through the chemical filter to percolate the paint residue and to re-inject the solvent into the tank. The rinse tank is filled with water for cleaning, which encompasses the similar process to the chemical reagent tank, but there is no heater to heat the second pump. In particular, there

are two main concerns in the conventional cleaning process: 1) paint residues on the heater surface will cause burn in the sheath pipe because the heater is installed at the bottom of the tank, 2) transferring liquids between the two tanks is required an additional pump (third pump) and a large pipe to draw liquid and to transfer it to another tank.

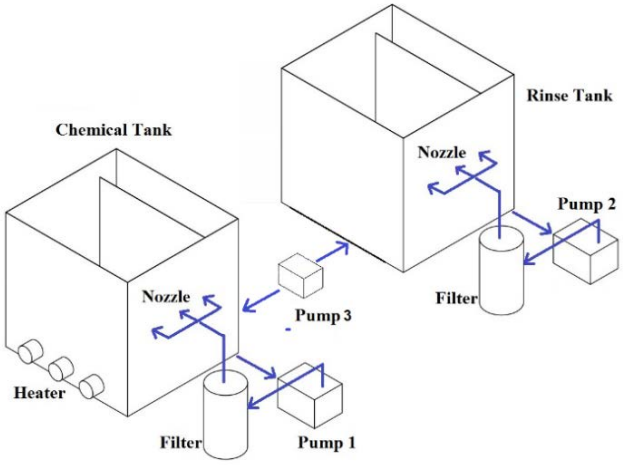


Figure 2 A conventional equipment set for paint removal of
the case study from Thailand's automotive industry

2) Paint remover There is widely use of many types of paint removers for metal parts. The main issue of the chemical process is the smell of chemical liquid that is potentially affects worker. Therefore, the paint remover selection is considered for the high potential approach to remove paint residue with less smell for the prototype equipment. In particular, two types of paint remover are selected in this research as follows.

2.1 Product name: Cleaner002 Paint remover (Water based)

This chemical solvent has been used in the general painting industry, which can be used for both metal and plastic at a room temperature or at to 60˚C heating to remove paint residue easily with less smell, reuse many times, and low evaporation rate (Table 1).

Table 1 The component of cleaner002 paint remover

Component	Proportion (%)
Alcohol	15-25
Peroxide	10-20
Organic compound	50-60
Additive	1-3
Water	5-10

2.2 Product name: Cleaner003 Paint remover (water based)

This particular solvent has been used in the general painting industry for metal and plastic also at room temperature or at 40˚C to remove paint residue easily with less smell, reuse many times, and low evaporation rate (Table 2).

Table 2 The component of cleaner003 paint remover

Component	Proportion (%)
Potassium Hydroxide	5-10%
Organic Compound	5-10%
Additive	1-5%
Water	70-80%

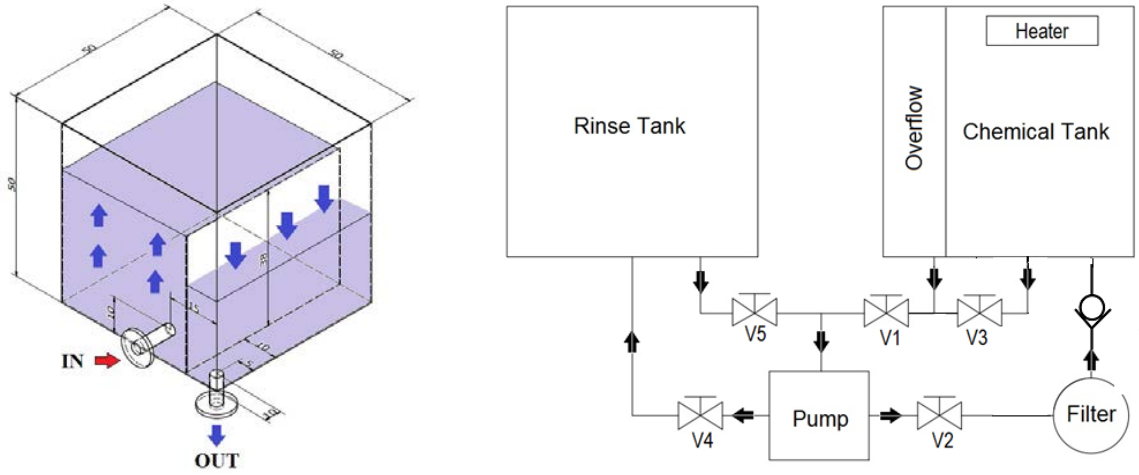
3) Material selection

The main material used in the prototype is Stainless304 for the chemical tank, rinse tank, and water pipes. The chemical-resistant rubber gasket is, in particular, used at the connection points of the pipes, which are resistant to the corrosion of chemicals for cleaning paint. However, the prototype has used hot-dip galvanized steel sheet in the rinse tank because it can not only resist water corrosion but also significantly reduce material costs by five times compared to the stainless304 at the same size.

4) New system design of the prototype

As shown in Fig.3 (a) and 3(b), the new system design of the prototype can be operated with a single pump. The circulating water system in the rinse tank will be excised while increasing the ability of liquids flow by automatic system between the two tanks. The valve position adjustment at various operating modes is presented in Table 3.

The nozzle position of conventional version is set up in the middle of the tank so that solvent injection process affects paint residues burning on the heater surface. Therefore, in this design, the nozzles are relocated to the bottom as shown in Fig.3 (a) to reduce the burning problem.



(a) Drawing design of nozzle position (b) Drawing design of operating system

Figure 3 The operating system of prototype

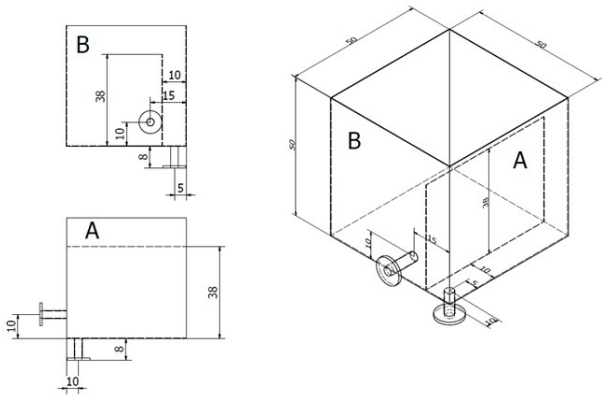
Table 3 The valve position adjustment

Valve No.	Process		
	Normal	Water transfer Chemical tank => Rinse tank	Water transfer Rinse Tank => Chemical tank
V1	On	On	Off
V2	On	Off	On
V3	Off	On	Off
V4	Off	On	Off
V5	Off	Off	On

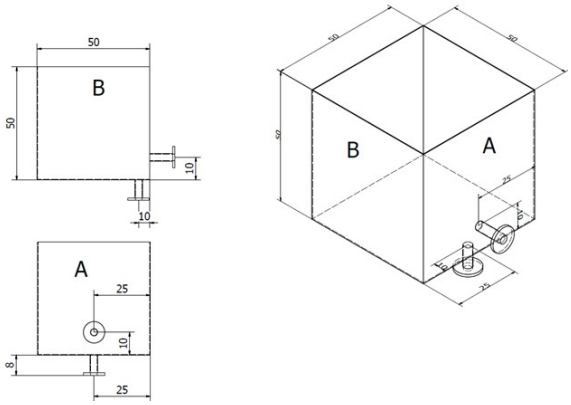
FINDINGS

1. Prototype description

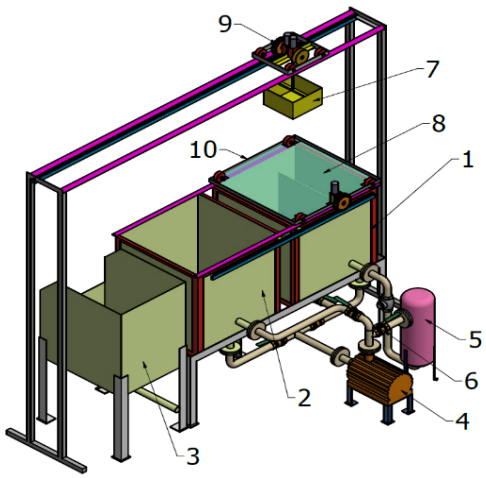
The drawing design of tanks, nozzle position, and the prototype are illustrated in Fig.4 (a), 4(b), 4(c), and 4(d) respectively. Furthermore, the parts description of prototype has also been discussed in Table 4.



(a) The drawing design of chemical tank



(b) The drawing design of rinse tank



(c) Drawing design of prototype

d) The prototype of equipment set

Figure 4 The drawing design and prototype

Table 4 The parts description of prototype

No.	Parts description
1.	Chemical tank
2.	Rinse tank
3.	Washing tank (Water)
4.	Electric pump
5.	Filter
6.	Ball valve, SUS316
7.	Basket
8.	Tank cover
9.	Electric hoist: DC 12V
10.	Electric heater: 1500w, 220V, 30-120 C

2. Cost analysis

Next, given that it is expected to design and develop a prototype of paint removal equipment with a reasonable manufacturing cost of equipment set as well as with equivalent performance to the conventional version, we further discuss the cost analysis in this subsection. The only material cost for the prototype is calculated based on the tank capacity of 10,000 cm^3 as shown in Table 5. That is, the material cost for the prototype is found to be approximately at 323,200 Baht, while the conventional equipment set is much higher at about 651,300 Baht. Thus, the cost improvement for this equipment design is expected to be reduced by around 47%.

Table 5 The material cost of paint cleaning equipment

No.	Equipment	Conventional		New Prototype	
		Qty.	Cost (Baht)	Qty.	Cost (Baht)
1.	Water pump	3 pump	105,000	1 pump	35,000
2.	SUS Pipe 2”	18 m.	45,000	12 m.	30,000
3.	Flange 2”	60 pcs	30,000	40 pcs	20,000
4.	Bolts	240 set	4,800	160 set	3,200
5.	SUS304 sheet 4”x 8” thick 5 mm for chemical tank	12 sheet	156,000	12 sheet	156,000
6.	SUS304 sheet 4”x 8” thick 5 mm for rinse tank	12 sheet	156,000	-	-
	Galvanized sheet 4”x 8” thick 2.3 mm for rinse tank	-	-	12 sheet	36,000
7.	Ball valve 2”	20 pcs	40,000	8 pcs	16,000
8.	Chemical resistant rubber gasket	30 pcs	3,500	20 pcs	2,000
9.	Chemical filter	3 set	75,000	1 set	25,000
Total material cost (Baht)			**615,300**		**323,200**

DISCUSSION

The prototype was designed involving the coating removal by chemical solvent (See, Hofacker, Stone, & Harbaugh, 1993). In the large assembly plants, the water jets for paint removal processes have also been investigated for the effects of water jet kinetic energy and stand-off distance on the mass loss of an organic paint system applied to a steel substrate (Teimourian, Shabgard, & Momber, 2010). However, SME's automotive industry in Thailand has faced the higher cost in manufacturing and paint removal processes. Therefore, this prototype is an equipment set with automation processes that SMEs can be applied with lower cost.

The prototype design for metal-part cleaning device in this research can be potentially used as the cleaning equipment set for SME's automotive industry with an affordable cost and with the improved service, the results from this study can also be extended and used for other similar industries that need to clean the metal parts in the painting process.

SUGGESTIONS

We highlight the key contributions of this study as follows;

1. The material part and equipment cost of the newly designed is 47 percent lower than the traditional cleaning equipment

2. The liquid flow of the designed system is more efficient than the conventional system with a single pump.

3. The chemical reagent in a conventional system manually transferred by the worker may be harmful to workers, the automatic process of the new operating system is safer for workers to transfer chemicals between tanks. That is, the piping circuits are designed to automatically transfer chemical reagent by a pump in the main system and to reduce the hazards of exposure to chemicals.

In further research, the research knowledge and prototype will be transferred to the SMEs that they can apply knowledge in the paint cleaning process. Furthermore, the air filter will be developed to relieve vapor from the chemical process that can be harmless for the worker.

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