DESIGN AND DEVELOPMENT OF A PARKERIZING TANK

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ABSTRACT

The work focused on the development of a 70 litrescapacity Parkerizing tank incorporating electric resistance heating elements. The burning of fuels such as coal, kerosene, and wood is an inefficient process for coating guns and other ferrous metals. For this, an automatically controlled Parkerizing tank was developed and fabrication was done using stainless steel and electric resistance heating elements. It contains two 6kW heaters. The tank has a unique trapezium shape which can permit coating of large parts, with high efficiency and is capable of boiling the phosphate solution in less than 20minutes. From test results, the tank was able to boil 15litres of phosphate manganese solution in 12minutes. All the mild steel engine parts coated in the solution appeared to be dark gray in colour after 6minutes of submerging it in the solution showing that the chemical mixture is accurate.

Key words: Trapezium shape, Parkerizing tank, coating, phosphate solution, submerging.

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INTRODUCTION

Parkerizing, bonderizing, phosphating, or phosphatizing is a method of protecting a steel surface from corrosion and increasing its resistance to wear through the application of an electrochemical phosphate conversion coating. This method is commonly used on firearms as a more effective alternative to bluing, which is another electrochemical conversion coating that was developed earlier. It is also used extensively on automobiles to protect unfinished metal parts from corrosion [1].Phosphate coatings have been around in one form or another since the late 1800’s. The process was, and is, used primarily as an industrial coating and many times as an undercoating, or primer, for paint, waxes or other protective coatings [2].

The Parkerizing process cannot be used on non-ferrous metals such as aluminum, brass, or copper. It similarly cannot be applied to steels containing a large amount of nickel, or on stainless steel.The process involves submerging the metal part into a phosphoric acid solution whose key ingredient is often zinc or manganese, with varying additional amounts of nitrates and chlorates and copper. In one of the many processes that have been developed, the solution is heated to a temperature of 88–99°C for a period ranging between 5 and 45 minutes. A stream of small bubbles is emitted from the metal part as the process takes place; when the bubbling stops, the process is complete. In addition to this particular processing temperature, there have also been various similar Parkerizing processes developed and patented that permit using either lower temperatures (for energy efficiency) or higher temperatures (for faster processing) [1].

BrownellsParkerizing Solution consists of metal phosphates dissolved in a carefullybalanced solution of phosphoric acid. As long as the acid concentrationof the Parkerizing Solution remains above a critical point, themetal phosphate remains in solution. When the steel is immersed inthe phosphating solution, a light acid pickling takes place and theacid concentration is reduced at the liquid-metal interface. It is here,at this surface, that the steel from the firearm is dissolved, hydrogen isreleased, and a phosphate coating is deposited onto the steel. The factthat these coatings are formed in place at the surface of the steel,incorporating metal ions dissolved from the surface itself, makes them"conversion" coatings which are integrally bonded to the metal [2].

Zinc phosphating results in a non-reflective, light to medium-gray finish. Manganese phosphating produces a medium to dark-gray or black finish. Iron phosphating produces a black or dark-gray finish similar to manganese phosphating. The grain size of the zinc phosphating is usually the smallest among the three processes, providing a more appealing cosmetic appearance in many applications.Manganese and iron phosphating coatings are usually the thickest electrochemical conversion coatings, being thicker than electrochemical conversion coatings such as zinc phosphating and bluing.As for all electrochemical conversion coatings, the parkerized surface must be completely covered with a light coating of oil to maximize corrosion and wear resistance, primarily through reducing wetting action and galvanic action. A heavy oil coating is unnecessary and undesirable for achieving a positive grip on parkerized metal parts.Alternatively, the parkerized surface may be painted over with an epoxy or molybdenum finish for added wear resistance and self-lubricating properties [1].

MATERIALS AND METHOD

Material selection decision for components that are exposed to elevated or sub ambient temperature, temperature changes or thermal gradient allows the designer to understand the thermal response of a wide variety of materials, and also gives the designer access to their thermal properties. Thermal property simply means the response of a material to the application of heat. When a solid absorbs energy in the form of heat, its temperature and dimensions increases. Therefore, specific heat capacity, thermal expansion and thermal conductivity are properties that must be considered during the process of material selection. Other properties considered include corrosion resistance, ability to resist the effect of the phosphate solution, strength, electrical resistivity, weldability, formability, availability and cost. Some important properties are discussed below:

Specific Heat Capacity

A solid material when heated, experiences an increase in temperature signifying that energy has been absorbed. Heat capacity is a property that indicates the materials ability to absorb energy from the surroundings. Specific heat capacity represents the amount of energy required to raise the temperature of 1kg of a substance by one degree [3]. Mathematically, specific heat capacity C is expressed as [4]:

$$C = {}^{dQ}/_{dT}$$

Where,
dQ = change in energy and
dT = change in temperature

Thermal Expansion

Solid materials expand when heated and contracts when cooled. The change in length with temperature for a solid material is expressed as:

$$\frac{L_{i} - L_{f}}{L_{i}} = \alpha(T_{f} - T_{i})$$

Where,
L_i = Initial length
L_f = Final length
T_i = Initial temperature
T_f = Final temperature
α = Linear coefficient of thermal expansion

Thermal Conductivity

Thermal conduction is a phenomenon where by heat energy is transported from a region of higher temperature to a region of lower temperature within a substance. The property of a material that characterizes the ability of the material to transfer heat is the thermal conductivity. It is expressed mathematically as [4]:

$$Q = -k\,{}^{dt}/_{dx}$$

Where,
k= Coefficient of thermal conductivity
${}^{dt}/_{dx}$= Temperature gradient through the conducting medium.

Corrosion Resistance

Corrosion is a physiochemical interaction between a metal and its environment which results in changes in the properties of the metal and which may often lead to impairment of the function of the metal, the environment, or the technical system of which these form a part. Rusting applies to the corrosion of iron or iron-base alloys with formation of corrosion products consisting largely of hydrous ferric oxides. Nonferrous metals, therefore, corrode, but do not rust. Corrosion processes are chemical reactions taking place at the surface of the metal.Proper engineering analysis can reduce the overall cost, minimize service problems, and optimize the construction of corrosion free structures.

Material Selection

Considering the properties discussed above, the materials that can be used for construction of the Parkerizing tank includes: stainless steel, fiberglass, mild steel, and plastic material.

Stainless Steel

Stainless Steels are iron-base alloys containing more than 10% Chromium [5]. They are classified as austenitic, ferritic and martensitic. Stainless steels usually contain less than 30% Cr and more than 50% Fe. They attain their stainless characteristics because of the formation of an invisible and adherent chromium-rich oxide surface film. This oxide establishes on the surface and heals itself in the presence of oxygen. Some other alloying elements added to enhance specific characteristics includes: nickel, molybdenum, copper, titanium, aluminum, silicon, niobium, and nitrogen. Carbon is usually present in amounts ranging from less than 0.03% to over 1.0% in certain martensitic grades. Corrosion resistance and mechanical properties are commonly the principal factors in selecting a grade of stainless steel for a given application.

Mild Steel

Mild steel is a type of steel alloy that contains a high amount of carbon as a major constituent. The amount of carbon determines the hardness of the steel alloy. Though, increased carbon content increases the hardness of the steel alloy, it causes a decrease in its ductility.Mild steel cannot be used for the sink of the Parkerizing tank, because it has poor resistant to corrosion, low resistance to abrasion and erosion and may not withstand the chemical attack. If mild steel is used for the tank, the phosphate solutions will parkerize the tank instead of the intended metal. The tank will shorten the Parkerizing Solution life and building up an excessive amount of sludge, making it difficult to clean. However, mild steel was used for the control panel since it has no direct contact with the chemicals.

Fiberglass

Fiberglass is a fiber reinforced polymer made of a plastic matrix reinforced by fine fibers of glass. It is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. They are useful because of their high ratio of surface area to weight. However, the increased surface makes them much more susceptible to chemical attack.

Selected Materials for the Tank

Materials were selected for the various components of the Parkerizing tank according to their different functions.

The Sink

The sink is a deep container in which the chemicals is mixed and heated to the required temperature before the metal is deepened into it and coated. Stainless steel was chosen for the sink due to its high temperature resistance, strength, formability, durability and high resistance to the chemical attack. Mild steel, if used for the sink will parkerize whenever the chemical is heated thereby reducing the volume and efficiency of the solution. Fiberglass and plastic was not selected either, due to formability, poor strength and temperature gradient.

The Frame

The frame is the structural support that holds the sink, the control panel and other parts suspending it from the ground level. It was designed with stainless steel as well, because of the frequent use of water with the chemicals in the tank which may build up spotting corrosion on the frame if mild steel is used.

Heating Element

Copper heaters which are not easily affected by chemical attacks were used in the tank to enable the attainment of higher temperatures as required by the Parkerizing processes. Copper element was selected due to its cost relative to stainless steel.

Thermocouple

The thermocouple is a compound device that functions both as a thermostat and as a thermometer. It regulates the amount of heat supplied to the solution and maintains constant heat. There are different types of thermocouple but the most common types are those that operate based on the principles of bimetallic strip and those that utilize special type of heat sensor, thus operating digitally. The type used for this project is the digital type having a stainless steel sensor, because it has high resistance to the chemical attack.

Wire Channel

PVC pipes were used to channel all the wires to the control panel, to avoid melting of the wires due to high temperature of tank body, and to prevent electric shock. The PVC material was chosen due to light weight and considerable low cost.

Part Holders

A plastic basket is chosen for use in sinking small parts into the solution. It has high resistant to corrosion, light weight and considerable cost. Some aluminum wires may also be used to suspend hollow parts in the solution, due to their noble nature.

Method of Design

The following factors that determine the dimensions of the system, the shape, the volume and the power requirement:

1) The dimension of the sink was determined by the maximum size of parts/ the largest part to be coated in the Parkerizing tank. In this particular case, the Parkerizing tank was for laboratory use and therefore the dimensions were determined by the size of the laboratory.
2) The shape of the tank was chosen as trapezium so that larger parts like pipes, which cannot enter the sink, can be arranged above the tank at the side and coated by pouring the solution over it.
3) The maximum volume of solution required for daily operations determined the volume of the tank.
4) The dimensions of all other parts of the Parkerizing tank was in relation to the size of the sink.

Design Calculations

All the calculation was based on the dimensions of the sink. The sink is a trapezium which has both triangular and rectangular shapes joined together.

Area of the sink
The area of sink was determined as follows:

Area of the rectangle A_R
$A_R = 25.4 \times 35.6 = 904.2cm^2$

Area of the triangle A_T
$A_T = {}^1/_2 \times 20.4 \times 35.6 = 363.1cm^2$

Area of the sink A_S
$A_S = 904.2 + 363.1 = 1267.3cm^2$

Volume of the sink V_S
$V_S = 1267.3 \times 60.9 = 77178.6cm^3$

Capacity of Tank C_T
$1000cm^3 = 1litre$
Therefore,
$$C_T = \frac{V_S}{1000} = \frac{77178.6}{1000} = 77.2litre$$

Parkerizing Process

Parkerizing is intended to create a new, good looking and/or durable corrosion-resistant finish that makes for a good oiling or painting surface. This can only be achieved by the use of good phosphate based solutions containing metals like zinc, manganese, nickel and some other metals capable of welding into the surface of the carbon steel.

Degreasing/Cleaning of Parts

Cleaning a machine part is crucial for a good finish. Any finish, be it wood or metal is all about surface preparation. This first cleaning step should remove all oils in the parts. It is best to boil whatever parts you can in a degreaser to make sure all the hidden areas are oil free or soak it in hot water overnight and scrub everything. Make sure the part is clean then rinse it well to make sure there is no residue. For large parts, sandblasting is advisable while sand paper could be used for rusted parts.

Sandblasting

Sandblasting is one of the most time consuming part of this process. For the blasting, 70 grit or 80 grit aluminum oxide can be used to achieve good results. Something that makes this process go a lot faster is taking a wire wheel brush on a 4" grinder and brushing off the top layers of the finish before blasting. This prevents contamination of the blast media, but also posed a danger as the wire wheels might fling off the wires. These are dangerous and eye protection is a must. Full face shield is recommended but not necessary.

Mixing of Parkerizing Solution

This step should occur during the blasting, if labor allows. Read the instructions on the product carefully and verify this step before using it. The kit will contain: phosphoric acid 85%

solution, powdered calcinated zinc oxide or manganese oxide, powdered atomized steel. To mix the solution, 30mL of phosphoric acid should be mixed with every 1000mL of water. Bring solution to 180°F - 190°F. The solution must not go below 170°F. Add 14g calcinated zinc or manganese oxide and 5g atomized steel per 1000mL water. Maintain boiling solution for 30 minutes before any immersion. Add smaller scaled amounts of solution to replace evaporated or solution lost to steam and then stir.

Parkerizing

Connect the Parkerizing tank and set the temperature to the required temperature between the ranges of 75-90℃, cover the solution and allow it to boil. Once the temperature is attained, the boiling will stop automatically. Dip the basket containing the parts or suspend the part in the solution for 5-15minutes, depending on the thickness. Small parts need to be stirred in the strainer. This is a piece by piece step as all metals will react differently with the acid bath. The part starts bubbling when immersed in the solution and stops bubbling before 20min if the temperature is ok. No part should sit in the tank for longer than 20 minutes. The bubbling is the reaction of the phosphoric acid with the metal and the zinc or manganese oxides depositing on the metal. This is what is required.

Post Treatment Rinse

When parts are removed they must be immediately rinsed, again preferably with boiling water as to promote rapid drying. A toothbrush will be handy for scrubbing off any flock (zinc or manganese residue) or film that might coat the part from the tank. Large parts should be hung to dry while small parts can be placed on paper towels.

Post Treatment

Make sure the parts are dry and preferably still hot, Parkerizing loves to absorb. If you are not applying duracoat immediately, put the parkerized parts into any oil of your choice. WD40 is recommended as it is a water displacer and will immediately absorb into the finish. The parkerized oil soaked parts can be heat cured in an oven at low temperatures to yield different colour results. The coveted patina green of WWII was achieved through this method.

Equipment

1) The Parkerizing Tank
2) Hot water
3) Buckets (one for cleaning, one for rinsing)
4) Degreasing solution (can be commercial degreaser, laboratory degreaser, or chemical such as TSP)
5) Large 3M pads for scrubbing
6) Toothbrushes for cleaning small parts and crevasses
7) Blasting cabinet
8) Air compressor and nozzle
9) Blast media (70 or 80 grit aluminum oxide)
10) Laboratory goggles
11) Rubber laboratory apron and Rubber gloves1000mL Beaker
12) Scale (gram resolution)
13) Large stainless steel or chrome spoon for stirring

14) Basket or strainer

Phosphating Solution

The total acidity of the phosphating solution is maintained as follows;

i. Manganese-Base Phosphate Solution: add a solution of manganese phosphate, manganese nitrate and phosphoric acid.
ii. Zinc-Base Phosphate Solution: add a solution of zinc phosphate, zinc nitrate and phosphoric acid.

Maintenance

i. Always remember to turn off the switch and unplug the Parkerizing tank after complete use, to save the solution from boiling and wasting away.
ii. Ensure that the tank is properly filled with liquid to cover the heaters before switching on the power.
iii. In the normal operation of the phosphating process, a quantity of sludge is formed. This sludge consists primarily of ferric phosphate. The sludge should be removed every three months and the solution should be changed as well.

Safety Precautions

i. Parkerizing concentrate contains phosphoric acid, phosphates, and/or mineral acids.Avoid contact with skin and eyes. If swallowed do not induce vomiting. Call a physician immediately. Keep from children. If contact with skin occurs, flush with water.
ii. Phosphoric acid can burn contact lenses. Wear fully enclosed goggles, rubber gloves and rubber laboratory apron.
iii. Phosphoric acid fumes can make you sick. Don't stand over the tank and breathe real deep and Proper ventilation is necessary during the process.
iv. For parts where the fizzing does not stop right away due to metal or contaminant, and the part is either Parkerized, as shown by full color, or will not color completely, do not let it sit longer, as etching of the metal will take place until there is no part left over.

TESTING

Figure 1 shows the developed Parkerizing tank. Three major tests were carried out on the tank to ensure that it was working properly and also safe to use. The test includes leakage test, power test and Parkerizing test.

Figure 1: Parkerizing Tank

Leakage Test
After completing the welding, the tank was erected and filled with clean water. The water was allowed in the sink for 5min, while thorough check was carried out along the welded edges to ensure that there are no leakages. Little leakages were discovered around the holes of the heaters and that of the temperature sensor. The holes were then sealed withdefcon gum and the test was repeated to ensure that the holes have been properly sealed.

Power Test
Power test was carried out after the electrical wiring and connections had been completed. This test was carried out to ensure that all the components are working properly and the tank well isolated to prevent electric shock. The procedure for the test is as follows:

1) Proper checks to ensure that all the components are well connected.
2) Confirmation checks to ensure that the power switch is in the off-position.
3) Water was poured into the sink to cover the heaters properly.
4) The power plug was connected to a three phase socket.
5) The thermostat was adjusted to 70^0C and the power switch was turned on.
6) An electric current tester was used to test the body of the tank to ensure that no current flows to it.
7) The electric current tester was also used to touch the water in the sink to check if a current flows through it as a result of current leakage from the heater element.
8) The covers were placed, allowing the water to heat up quickly.

Observations during power test
The power was observed to cut-off as soon as the water temperature reaches$68℃$, indicating that the magnetic contactor and the thermocouple is working accurately. The test also revealed that no current flows to the tank body or the liquid solution, meaning that the electric heaters have no current leakage and all the components are well connected and are working properly.

Parkerizing Test
The Parkerizing test was carried out in the Mechanical Engineering Workshop of the Federal University of Technology Minna.The procedure for the test is as follows:

1) A bolt was machined on the lathe machine using mild steel materials.
2) Also two metal parts (a circular gear and a cork opener) showing evidence of corrosion was also considered.
3) All the parts were thoroughly cleaned. The machined bolt was washed with detergent and rinsed in clean water to remove oily material from the surface. The corroded parts was also cleaned with sand paper and rinsed in clean water as well.
4) A solution of manganese phosphate was mixed with the water inside the Parkerizing tank as appropriate and stirred thoroughly.
5) The tank was connected to a three phase socket.
6) The thermostat was set to$75℃$and the power switch was turned on.
7) The tank was covered allowing the solution to heat up.
8) The process was timed with a stop clock.
9) At $75℃$the tank went off automatically.
10) All the parts were placed in a plastic basket and dipped into the solution for 5minutes.

11) After 5minutes the basket was drawn out of the solution and the parts were rinse, placed to dry on a clean table.
12) After then the parts were cleaned in a container with diesel.

Observations during Parkerizing test

Figure 2 and Figure 3 shows the parts before cleaning and the parts after cleaning respectively. The temperature of the solution was raised to 75℃ in 12minutes and the electric power tripped off automatically. All the parts appeared to be dark gray in colour as shown in Figure 4. The bolt was looking matty and capable of retaining lubricant better that before. This shows that the Parkerizing tank is capable of Parkerizing metals efficiently.

Figure 2: The parts before cleaning

Figure 3: The parts after cleaning

Figure 4: Theparts after Parkerizing.

CONCLUSION

The Parkerizing tank has over 70litres capacity. It is fabricated with 304 stainless steel plate, which has high resistance to corrosion, light weight, good strength and durable. The tank contains two 6kw heater elements and is capable of boiling the solution in less than 20mins. The shape of the tank is a unique trapezium which can permit Parkerizing of threaded pipe ends if they are well arranged on a stand. The tank automatically controls the Parkerizing processes. Less skilled operation is necessary; therefore the tank can be used domestically.

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