AUTOMATED CVD REACTOR CLEANING SYSTEM USING RELAY

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***Abstract* -Automated CVD reactor cleaning system has replaced the manual process of cleaning the CVD reactors. A CVD reactor consists of chemical deposits on its inner wall, due to the coating process of industrial components performed using these reactors. This necessitates removing of these chemical deposits by cleaning, which would otherwise have caused a rejection of the components during the next coating process. Traditionally, the cleaning process was performed by using abrasive brushes manually by workers. This posed many problems to workers, such as handling of heavy abrasive brushes to remove the hardened chemical deposits. The Automated reactor cleaning machine is equipped with a steam generator, abrasive power brush and a relay system, which performs the operation automatically in a sequential manner thereby eliminating the manual tasks. The systemthus improves the ergonomic conditions for the workers and also improves the cleaning action resulting in a better efficiency.**

***Index terms* – Automated, CVD reactor, globes.**

1. INTRODUCTION

The problems associated with manpower in industries have been ever increasing in the recent years. When a certain task is difficult to accomplish, it declines the productivity of the worker, which results in an overall decreased output of the system. The other problems associated with manpower include rising costs, changing priorities, diverse workforce and continuing of education. These factors have forced the industrialists to automate their existing process, such that the tasks can be accomplished automatically without the aid of manpower and gain better output.

The major benefits of automation are high repeatability, better quality control and waste reduction, integration with business systems, increased productivity and reduction of labor. Every coin has two faces; likewise even automation has certain disadvantages in spite of its benefits. High initial costs and increased dependence on maintenance are the major drawbacks of automation.

Automated CVD reactor cleaning system is designed to perform the cleaning of CVD reactors automatically without the aid of manpower. The system employs an abrasive power brush, steam generator and a blower for its functioning. The steam generator allows steam into the reactor for a definite interval of time and then employs the power brush to clean the inner walls of the reactor from contaminants. The dust produced during the cleaning process is drawn by the suction system consisting of a blower and a duct, which collects the dust into a dust collector equipped with an air filter.

A. What is CVD?

Chemical Vapor Deposition (CVD) is a technique involving chemical reactions to produce high purity, high performance solid materials.[3] The process is carried out at elevated temperatures of about 1200°C. Thin film coatings are formed as a result of the reaction between various gases and the heated surface of substrates within the CVD reactor.

ISSN: 2278 – 7798

For example, TiN is formed as a result of the following reaction: TiCl4 + N2 + H2 1000° C → TiN + 4 HCl + H2. Titanium carbide (TiC) is formed as a result of the following chemical reaction: $TiCl_4 + CH_4 + H_2$ 1030° C → TiC + 4 HCl + H_2. These reactions result in a hard, wear-resistant coating that exhibits a chemical and metallurgical bond to the substrate.

CVD coatings are more commonly used in many manufacturing applications, as wear resistant coating for carbide milling and turning inserts, wear components, etc. The chemical / metallurgical bonding that results from the CVD coating process creates adhesion characteristics. This enhanced adhesion protects forming tools from the sliding friction wear-out caused by the severe shearing stresses generated in heavy metal-forming applications.

B. Procedure for coating of metal inserts using a CVD workstation.

A CVD workstation consists of a cooling tower, furnace and two reactors. The workstation is operated as follows:

- The reactor is opened and the tools/components to be coated are loaded into the reactor.
- The reactor is now closed and the furnace is placed on top of the reactor and heated to the required temperature.
- Various gases are introduced into the reactor through gas pipes. The gases react with the substrate for duration of 16-24 hours at 1200°C, at vacuum pressure.
- At the end of the reaction process, the furnace is removed and the cooling tower is placed over the reactor and the reactor is cooled down to normal room temperature.
- The components are now unloaded and the reactor is cleaned to remove the chemical deposits from the internal wall of the reactor. Charge preparation process is carried out, which involves thorough cleaning of pipe lines and chemical mixing chambers.
- The cleaning and charge preparation process is carried out to avoid the mixing of the previous chemicals with the chemicals introduced during the next coating cycle.

2. OBJECTIVE OF THE PAPER

The objective of the project is to automate the reactor cleaning process. Traditionally, the reactors were cleaned manually using abrasive brushes. The construction of the brush includes a long shaft on 1600mm, made of MS material, nylon bristles and SiC abrasives[1]. The heavy weight of the shaft and SiC abrasives posed difficulty in handling the brush. This led to poor cleaning of the reactors; as a result the chemical deposits of the previous coating cycle were mixed with next coating cycle that led to the rejection of components due to inappropriate chemical coat.

The project is thus focused to automate this process of reactor cleaning to improve the cleaning efficiency and minimize the rejection rates of components. The automated reactor cleaning system is designed on wet cleaning principle that generates steam into the reactor for a definite time interval and then performs the brushing operation with the help of an abrasive power brush. A suction system is introduced in the reactor cleaning system to draw the dust particles generated during the cleaning process.

The operating system is designed to perform the various operations of the machine in an automatic sequential manner. This is achieved with a help of a relay system consisting of a relay-solenoid, timer, temperature switch and a thermostatic expansion valve. The cleaning machine is operated by using START and STOP push buttons.

ISSN: 2278 – 7798

3. METHODOLOGY

A. DESIGN

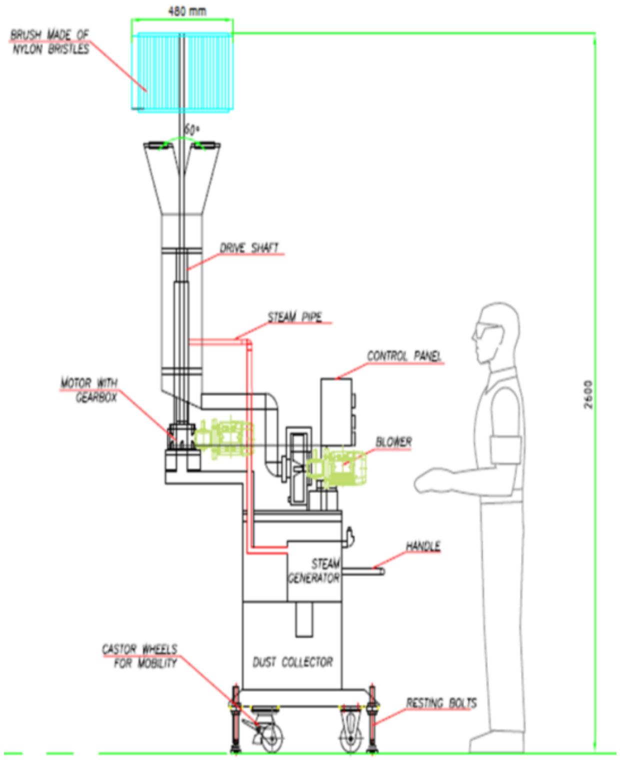

Figure 1: Design of Automated CVD reactor cleaning machine

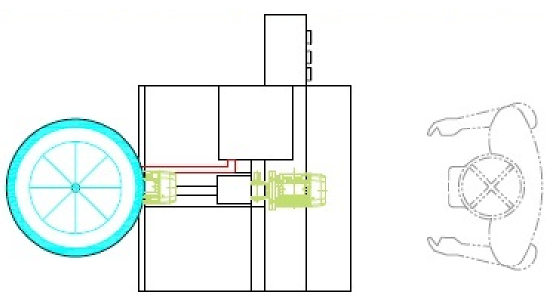

Figure 2: Top view of Automated CVD reactor cleaning machine.

The front portion of the reactor cleaning system is designed to have a "7" shape. This enables the front portion of the machine to glide over the table of CVD workstation as shown in figure 4.1.4. The brush can thus be placed exactly at the center of the reactor, while the reactor is at its top most position which is operated using a crane. Once the machine is switched ON the reactor is lowered until it reaches its bottom most position to facilitate thorough cleaning of the reactor throughout its length.

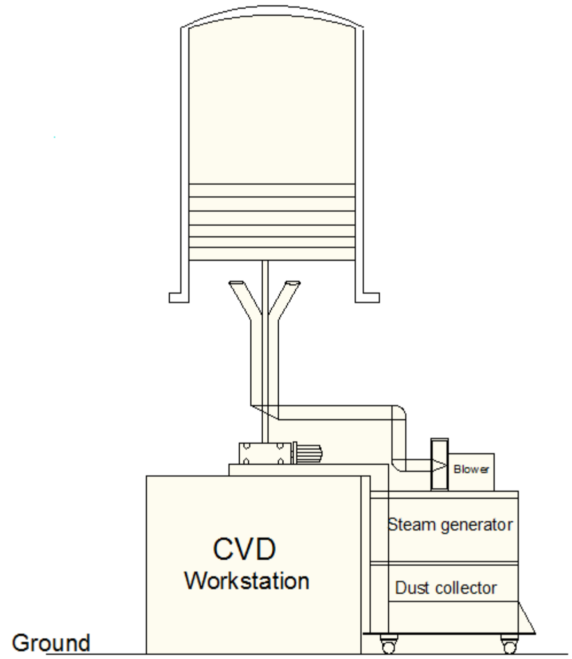

Figure 3: Side view of Reactor cleaning system located at a CVD workstation.

B. TECHNICAL SPECIFICATIONS

The technical specifications of the automated reactor cleaning system are:

1. Brush made of nylon bristles and silicon carbide abrasives with a grit size of 180.
2. Shaft for connecting the brush to the motor made of SS304 seamless pipe with perforations, so as to allow flow of steam through the shaft.
3. 1 HP motor to rotate the brush connected by the shaft.
4. Speed reduction bevel gear box with a gear ratio of 12 to connect the motor to the shaft and reduce the speed to 120 rpm.
5. 1 KW steam generator to generate the steam into the reactor.
6. 1 HP blower for dust collection.
7. Duct system for suction of dust during the cleaning process.
8. Dust collector with air filter.

ISSN: 2278 – 7798

9. Control panel with a relay system for automatic sequential control operation.
10. Trolley/mechanical structure with castor wheels for mounting of above components.

C. Calculations to determine the motor specifications

The torque required by the motor[5] to rotate the brush is calculated by;

$T = ½*D*W$ (N-m) ………… (1)

Where,

D = Diameter of the brush in meters (m) = 0.48 m

W = weight acting on the shaft in Newton (N) 9 * 9.81 = 88.29 N

Therefore, the torque required is calculated as,

T = ½ * 0.48 * 9 * 9.81 = **22.07 N-m**

The power required by the motor is calculated by;

Power required by the motor,

P = T * n / 5250 in hp ………… (2)

Where,

n = speed of rotation of the brush in rpm = 120 rpm

T = Torque required = 22.07 N-m

Therefore, the power required by the motor is calculated as,

P = 22.07 * 120 / 5250 = **0.5 hp**

Considering a safety factor of 2 for friction and interference fit;

Power required, P = 2 * 0.5 = **1 hp**

D. Calculation of power required by the blower

Volumetric flow rate of the blower[4] in terms of m^3/s;

Q (m^3/s) = V (m/s) * A (m^2) ………. (3)

Where,

V = Average velocity of suction = 25 m/s

A = Area of opening = $(\pi d^2)/4 = \Pi * 0.1^2 / 4 = 0.00785$ m^2

d = diameter of opening = 100 mm.

Therefore the volumetric flow rate is calculated as;

Q = 25 * 0.00785 = 0.19625 m^3/s = **11.775 m^3/min**

Now, 1 m^3/min = 35.314 CFM

Therefore, 11.775m^3/min = 11.775 * 35.314 = 415 CFM

Power required by the blower;

P = (CFM* Psi)/ (229*η b*η m) …………. (4)

Where,

Psi = pressure = 0.45 psi, for 96% vacuum

ηb = blower efficiency = 85%

ηm = mechanical efficiency = 90%

Therefore the power required by the blower is calculated as,

P = (415*0.45)/ (229*0.85*0.9) = **1 hp**

E. Calculations for power required by steam generator

Internal area of the reactor,

$A = \pi r^2 h$ .... (5)

Therefore internal area of the reactor is calculated as;

A = $\pi *$ (240) ^2*1600 = 314285714.28 mm^3 = **11.099 ft^3**

Referring to table 2.2.1, the power of the steam generator required for a room size of **11.099 ft^3** is **1 KW.**

ISSN: 2278 – 7798

4. EXPERIMENTAL SETUP

A. Simulation

A simulation model of the Automated CVD reactor cleaning machine has been developed to demonstrate the working of the machine.

The simulation images below indicate the flow of steam from the steam generator through the hollow shaft and exits from the perforations provided at the brush.

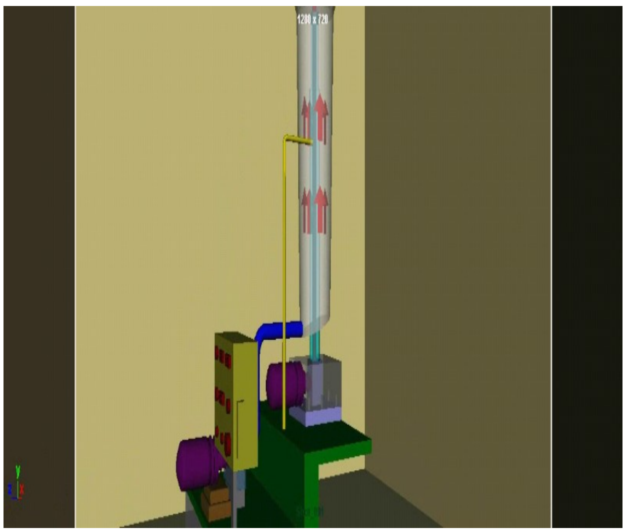

Figure 4: Flow of steam from steam generator into the hollow shaft.

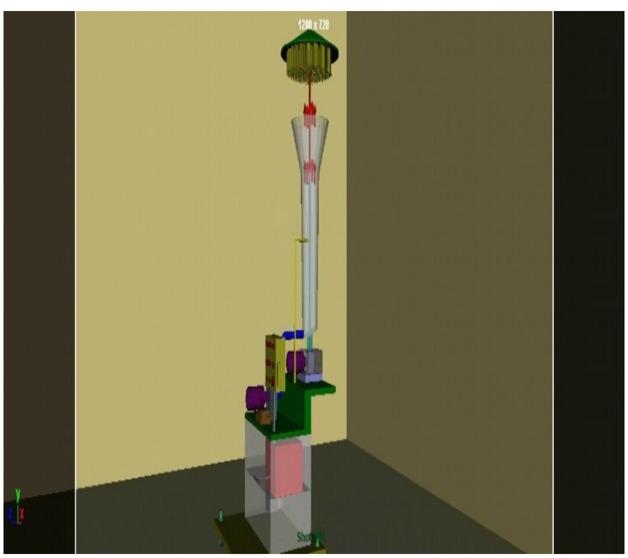

Figure 5: Flow steam into the reactor through the perforations.

B. Working

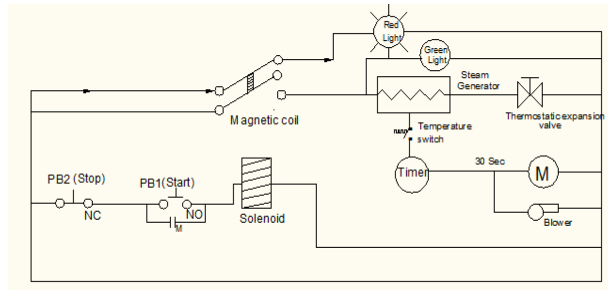

Figure 6: Circuit indicating the operation of the machine.

The control system circuit consists of two push buttons PB1 and PB2. The push buttons are used to start and stop the machine. A relay system consisting of a solenoid and a magnetic coil acts as an interface between the inputs and the outputs, and is used to transfer the signals from the input devices (push buttons) to the output devices such as the steam generator, brush with motor and the blower.

Following are the steps involved in the operation of the machine:

- The push button PB1 is pressed, which is normally opened. Now the magnetic latch circuit latches this push button.
- The current now flows through the solenoid and actuates the magnetic coil, as a result the magnetic coil gets attracted towards the solenoid and current starts flowing through the steam generator and a green light, indicating that the machine is switched ON.
- The steam generator now transforms the water from the inlet into steam until the desired temperature has been achieved.
- Once the desired temperature of steam has been attained, the thermostatic valve opens and the steam flows into the reactor through this thermostatic expansion valve. Simultaneously a temperature switch provided in the circuit actuates and passes the current to the timer in the circuit.
- The timer begins the countdown operation for a definite interval of time, for e.g. 30 seconds. After the

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timer has completed its countdown operation, it actuates the motor and the blower for further cleaning and suction operations of the reactor cleaning respectively.

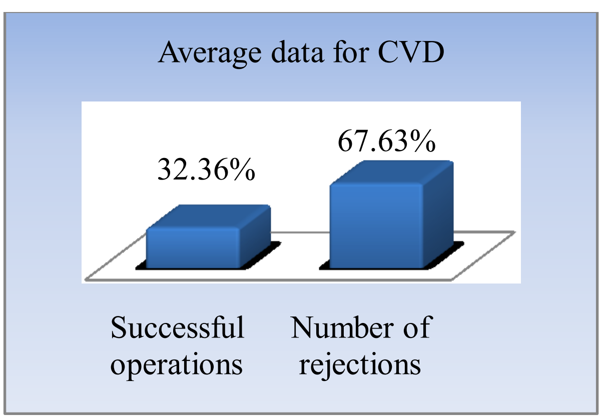
- The reactor is moved vertically up and down by the reactor handling system to ensure thorough cleaning of the inner walls of the reactor throughout its length.

5. RESULTS

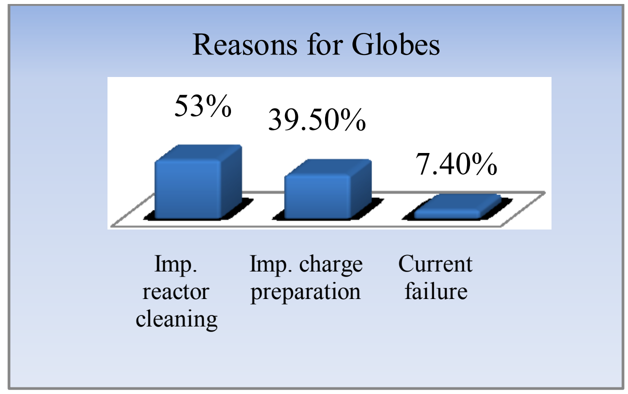
The implementation of the project has successfully resulted in the reduction of globes formation on the components. The globes on components are formed due to improper reactor cleaning or improper charge preparation or current failure.

The implementation of the automated CVD reactor cleaning system has eliminated the problem of improper reactor cleaning and hence led to the reduction of globes formation, thereby minimizing the rejection rate of components due to globes formation. Thus the implementation of the project has increased the overall efficiency of the CVD process.

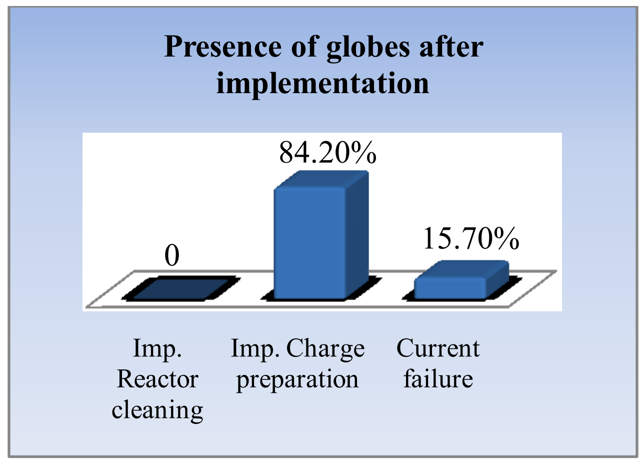
The data and graphs explained below indicate the effects of implementation of Automated CVD reactor cleaning machine.



Graph 1: CVD data before implementation

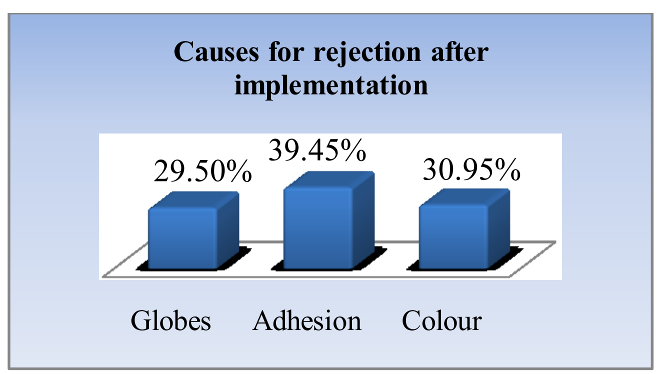


Graph 2: Reasons for globes before implementation

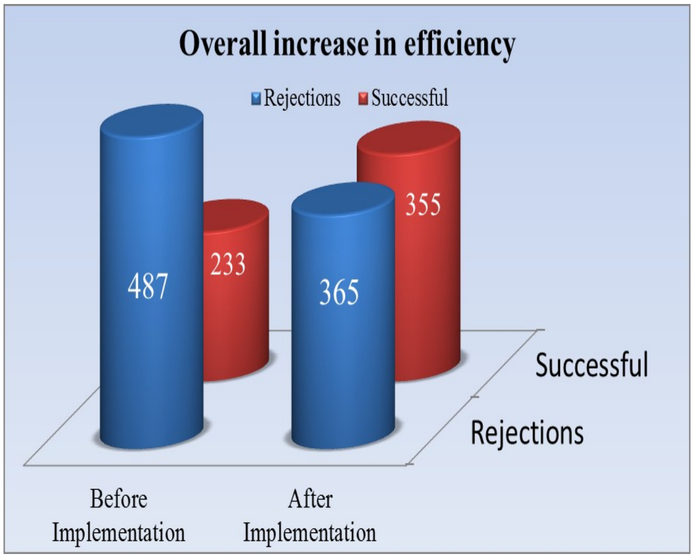


Graph 3: Reasons for globes after implementation

The presence of globes after the implementation of the project has been reduced due to the elimination of the problems caused by improper reactor cleaning.



Graph 4: Causes for rejection after implementation



Graph 4: Comparison of overall efficiency before and after implementation.

The above graph indicates the overall increase in efficiency obtained due to the implementation of the project. The implementation has led to an overall gain of 16.94% increase in efficiency.

6. CONCLUSION

As it is a known fact that in a competitive environment, the key way to success is to maximize output and minimize input i.e. to improve the overall efficiency of the process. This is done by minimizing the rate of rejections and wastage.

So in this paper, we propose an Automated CVD reactor cleaning system that can be used to clean the reactors thoroughly without any manual efforts. Thus effective cleaning is achieved and the rate of rejections of components due to improper reactor cleaning can be eliminated. Thus, an overall increase in efficiency can be achieved. Also the Automated reactor cleaning machine improves the ergonomic conditions of the operators by eliminating the manual tasks.

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