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Filter Cleaning System Modification to Improve Dust colletor

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Abstract: The filter cleaning system is a vital part of dust collectors, acting as a crucial barrier between dirty and clean air. Blockages in dust collectors often stem from insufficient maintenance affecting filter cleaning elements like valves, jetspray tubes, and bagcloth. Inadequate air pressure from the jetspray can worsen blockages by hindering dust removal from the bagcloth. Solving this issue requires a thorough reconditioning of filter cleaning components and optimizing jetspray pressure. To improve system efficiency, the capacity of the jetspray tube is carefully determined, following compressor specifications and complying with the ASME VIII Div I (Pressure Vessel) standard. The jetspray tube has dimensions of 1400mm x 8inch SCH20. A feasibility test evaluates the tube's allowable thickness and safety factor based on operational pressure. Precise calculations and adherence to industry standards ensure the structural integrity and safety of the jetspray tube. Using Solidworks 2020, stress simulations are conducted on the SCH20 pipe with a thickness of 6.35mm, operating under a pressure of 7 bar. The simulation results confirm the pipe's safety for use, validating its structural strength and compliance with safety standards. This comprehensive approach, involving both component reconfiguration and structural assessment, guarantees the dependable and secure operation of the filter cleaning system in dust collectors.

Keywords: Dustcollector; Filter cleaning system; Jet spray

1. Introduction

A dust collector is a system employed to enhance the air quality resulting from industrial processes, capturing dust and other contaminants in air or gas. Blockages in a dust collector pose significant issues, particularly when dealing with flammable dust, as they can potentially lead to explosions [1-2]. The operational concept involves creating a reduced pressure on the suction side below atmospheric pressure [3]. In this process, contaminated air near the suction hole is drawn in, and subsequently, a filter is employed to separate dust from clean air. Dust Collector P1 utilizes the jet pulse cleaning system for filter cleaning, and you can observe its mechanism in Figure 1.

The operational process involves a running fan generating suction to pull in air mixed with dust from the foundry process in the Plant 1 area. This contaminated air flows through the ducting inlet to reach the filtration room within the dust collector. Inside the dust collector, the air undergoes filtration using bagcloth. The bagcloth allows clean air to escape through its pores, while the dust particles get trapped on the exterior of the bagcloth. To clean the dust adhered to the bagcloth, a high-pressure air spray is employed through a nozzle aimed at the bagcloth. The pressurized air causes the bagcloth to expand and vibrate, leading to the detachment of the dust particles, which then fall into the hopper for collection. This process ensures the effective removal of dust from the bagcloth, maintaining the dust collector's efficiency [4].

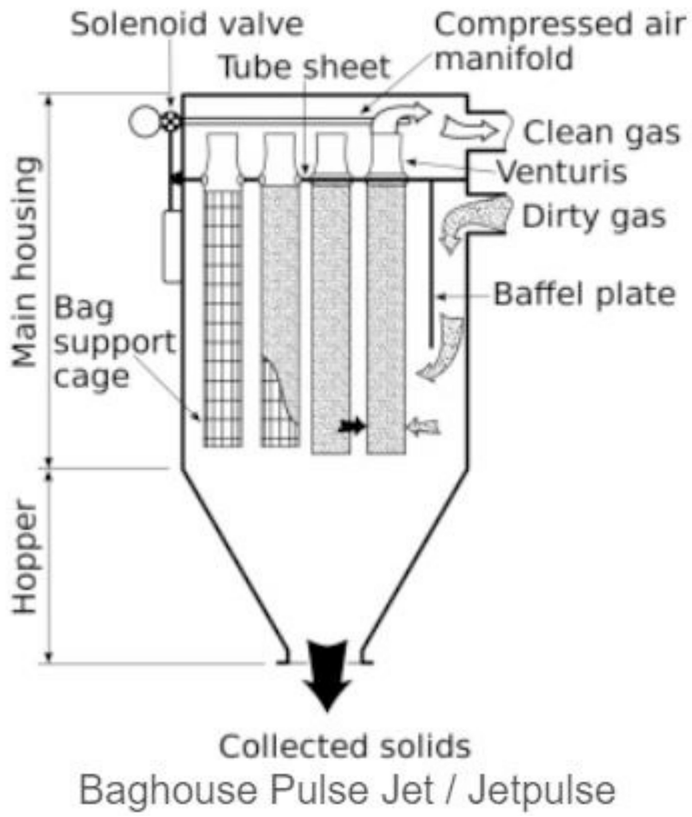

Figure 1. Working Principle of Jet Pulse Cleaning System

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The filter cleaning system components are situated within the baghousing in the clean air area directly above the tubesheet. Unfortunately, this placement poses a significant challenge for maintenance as it complicates the inspection and control of all filter-cleaning system components. The filter cleaning system relies on maintaining an ideal air pressure, as insufficient pressure, below the standard requirement of 7 bar, can lead to blockages. Blockages occur when dust fails to fall properly into the hopper, sticking instead to the bagcloth, thereby obstructing the filtration flow. To address this, it is essential to standardize the jetspray pressure, commonly set at 7 bar, based on both table data and actual requirements.

To optimize the filter cleaning system's performance, this study aimed at modifying the number of nozzles, resizing the pipe from the tube to the nozzle, and adapting the air volume in the jetspray tube. These measures aim to ensure the system operates at the specified air pressure, minimizing the risk of blockages and enhancing the overall efficiency of the dust collector in the Plant.

2. Materials and Experiment Methods

The jetspray tube, functioning as a pressure vessel, stores air from the compressor and directs it to the purging pipe through a valve with adjustable open and close times. To align the jetspray tube's capacity with the intended 7 bar pressure, adjustments in its dimensions are necessary. This adjustment is essential for optimal functionality [6]. The calculation of the jetspray tube's capacity involves considerations such as compressor specifications, the open-close time of the pulse jet valve, and the pressure drop occurring in the jetspray tube. This relationship is expressed mathematically in equation (1):

$$\boldsymbol{V} = \frac{\boldsymbol{t} \times \boldsymbol{C} \times \boldsymbol{pa}}{(\boldsymbol{p_1} - \boldsymbol{p_2})} \quad (1)$$

In the design of Jetspray Tubes, particularly high-pressure vessels, it is crucial to calculate and select the appropriate material to prevent potential failures such as leaks or explosions. To ensure safety and reliability, the initial step in the design process involves the careful determination of the material. In this case, we have chosen 304 stainless steel, aligning with the properties of the SCH20 ASME B36.10 pipe [7]. The selection of 304 stainless steel is based on considerations such as the design temperature of the pressure vessel. This material exhibits a maximum allowable stress of 30,000 psi and incorporates a corrosion allowance of 3 mm. The corrosion allowance assumes a growth of 3 mm every 20 years. The mechanical data sheet summarizing the design parameters for the jetspray tube is provided in Table 1. This meticulous selection of material ensures that the jetspray tube is well-suited for its intended application, promoting both safety and longevity.

Table 1. Mechanical Data Sheet (MDS) of Jetspray Tub

DESIGN CODE : ASME VIII Div.1	
Design Pressure	7 [bar] ≈ 101.526 [psi]
Thickness	0,25 [in] ≈ 6.35 [mm]
Internal Diameter (ID)	206.40 [mm]
Operating Pressure	7 [bar] ≈ 101.526 [psi]
Corrotion Allowance	0,13 [in] ≈ 3 [mm]
Design Temperature	122 [°F] ≈ 50 [°C]
Capacity	72.24[L/min]
Maximum Allowable Stress (304 Stainless Steel pipe)	16000 [psi] ≈110.3161 [Mpa]
Length (Panjang)	1400 [mm]
Radius (R)	4.0629 [in] ≈103.2 [mm]

Certainly, the calculation of shell and head thickness in pressure vessel design typically follows the guidelines provided by ASME VIII for shell thickness calculation as shown in Eq. 2.

$$\boldsymbol{t_{design}} = \frac{\boldsymbol{P} \times \boldsymbol{R}}{\boldsymbol{S} \times \boldsymbol{E} - \boldsymbol{0.6\,P}} \quad (2)$$

$$\boldsymbol{t_{design}} = \frac{\boldsymbol{P} \times \boldsymbol{D}}{\boldsymbol{2} \times \boldsymbol{S} \times \boldsymbol{E} - \boldsymbol{0.2\,P}} \quad (3)$$

Validate the selected thickness using the following formula:

$$MAWP = \frac{2 \times S \times E \times (t\,use - CA)}{D + 0.2\,(t\,use - CA)} \tag{4}$$

The Factor of Safety (*FOS*) is a measure that indicates the material's capability to withstand external loads, whether in the form of compressive or tensile forces. The determination of the Factor of Safety is typically done using the following formula:

$$FOS = \frac{S_{yield\ strength}}{\sigma_{equivalent\ stress\ Von-mises}} \geq 1.5 \tag{5}$$

Simulation analysis using structural loading operated on jetspray tube components with the help of Solidworks 2020 software using the static simulation method. [9]. This stress analysis simulation process aims to determine the resistance of the jetspray tube design results that have been made to the provision of 7 bar air pressure stored in the jetspray tube.

3. Results and Discussion

Final Results

The design steps to overcome the above problems are as follows:

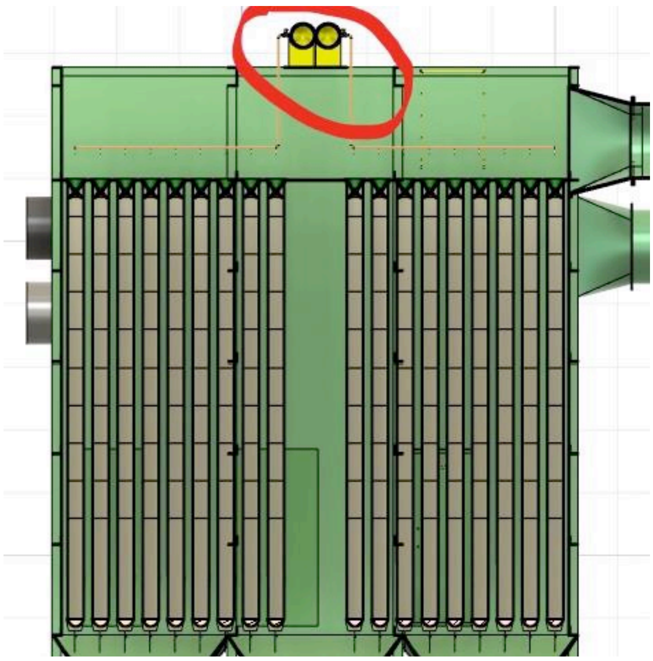

Figure 2. Filter Cleaning design before reconditioning

Adjustment of Filter Cleaning System Location

The adjustment of the location of the filter cleaning component is based on the previous location inside the bagfilter, which is a challenge as well as a difficulty for operators to perform maintenance or control the filter cleaning components, such as checking valve conditions, jet pulse tube pressure, and the condition of the PLC circuit inside. The actual layout of the filter cleaning system before adjustment can be seen in Figure 2.

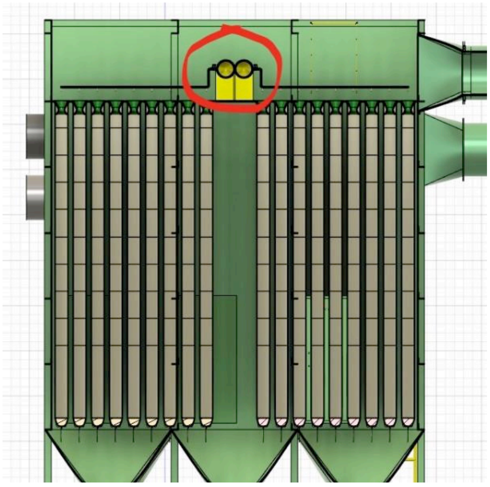

Figure 3. After adjusting the location of filter cleaning components

In the process of layout adjustment, a pivotal step involves relocating the filter cleaning component to a conveniently accessible area for both inspection and maintenance. This strategic placement involves situating the component on the external side of the upper door of the bag filter. The decision to position the filter cleaning component at the apex of the bag filter door is motivated by a noteworthy consideration—specifically, the cost reduction associated with minimizing the need for extending or modifying the Programmable Logic Controller (PLC) circuit and pipe arrangement during the installation phase [5]. The post-adjustment status of the filter cleaning component is visually represented in Figure 3.

Jetspray Tube Capacity Calculation

In determining the capacity of the jetspray tube, we use equation (1) in measuring the ideal air receiver tank for the compressor system with a jetspray volume of 36.12 liters. Where these results are the substitution of equation (1) with the data in Table 1.

Structure Analysis of Jetspray Tube

Pressure vessels, subjected to pressures higher than atmospheric, are categorized based on wall thickness into two main types: thin-walled and thick-walled vessels. Thin-walled vessels experience stress primarily in the circumferential and longitudinal directions. Conversely, thick-walled pressure vessels undergo stress in the circumferential, longitudinal, and radial directions. The stress distribution in the radial collar of thick-walled pressure vessels is particularly pronounced due to the substantial thickness of the vessel wall. Consequently, radial direction stress becomes a critical consideration in thick-walled vessels, in contrast to thin-walled vessels where radial stress is assumed to be uniform due to its less distinct nature.

These pressure vessels typically consist of four main components: shell, head, nozzle, and support. Together, they form a container designed to contain pressurized fluid. The nozzle serves as both the inlet and outlet for pressurized fluid, while the support functions to uphold the pressure vessel. The design parameters for the jetspray tube adhere to the standards outlined in the ASME VIII Div.1 Boiler and Pressure Vessel Code.

Calculation of shell thickness,

Calculation of shell thickness using the substitution of formula (2) with the data in Table 1.

$$t_{design} = \frac{\mathbf{101.526}\ [psi]\ \times\ \mathbf{4.0629}[in]}{\mathbf{16000}\ [psi]\ \times\ \mathbf{1}\ -\mathbf{0.6}\ \mathbf{101.526}\ [psi]}$$

$$t_{design} = \mathbf{0.02587}[in] = \mathbf{0.657}[mm]$$

$$t_{design} + CA\ = \mathbf{0.657}\ [\mathrm{mm}] + \mathbf{3}\ [\mathrm{mm}]\quad = \mathbf{3.657}[\mathrm{mm}](\mathbf{minimum})$$

Because a shell made from SCH20 pipe with a thickness of 6.35 mm is used, the shell design is categorized as safe.

Select Thickness by using formula (4) as follows:

Shell MAWP Calculation:

$$MAWP = \frac{\mathbf{2} \times \mathbf{16000} \times\ \mathbf{1} \times\ (\mathbf{0.25}\ -\mathbf{0.13})}{\mathbf{8.1259} + \mathbf{0.2}\ (\mathbf{0.25}\ -\mathbf{0.13})}$$

$$MAWP = \mathbf{471.1714}\ [psi] = \mathbf{32.4861}\ [bar]$$

MAW$\mathbf{471.1714}\ [psi]$ =P = → $\mathbf{32.4861}\ [bar]$

$P_{max.\ allowable\ working\ presure} > P\ design$

$\mathbf{32.4861}\ [bar] > \mathbf{32.4861}\ [bar]$ ⋙ $safe$

Head thickness calculation:

Calculation of head thickness using the substitution of formula (3) with the data in Table 2.1.

$$t_{design} = \frac{\mathbf{101.526}\ [\mathrm{psi}] \times \mathbf{8.058}\ [\mathrm{in}]}{\mathbf{2}\ \times\ \mathbf{16000}\ [\mathrm{psi}]\ \times\ \mathbf{1} - \mathbf{0.2}\ (\mathbf{101.526})\ [\mathrm{psi}]}$$

$$t_{design} = \mathbf{0.02558}[\mathrm{in}] \approx \mathbf{0.6497}\ [\mathrm{mm}]\ (\mathbf{minimum})$$

$$t_{design} + CA = \mathbf{0.6497}\ [\mathrm{mm}] + \mathbf{3}\ [\mathrm{mm}] = \mathbf{3.6497}\ [\mathrm{mm}]\ (\mathbf{minimum})$$

Because a shell made from SCH20 pipe with a thickness of 6.35 mm is used, it means that the head design is categorized as safe.

Safety Factor Calculation

Based on ASME section VIII Div.1 for its safety factor ≥ 1,5 [8]. Calculation of factor of safety using formula (5) with substitution of yield strength and equivalent maximum stress.

$$SF = \frac{\mathbf{30000}[psi]}{\mathbf{12348.315}\ [psi]}\ \geq \mathbf{1.5}$$

$SF = 2.4294\ \geq 1.5$ (Simulasi Stress Solidworks 2020)

Since the Factor of Safety value is greater than 1.5 in accordance with the ASME section VIII Div.1 standard, the design used is categorized as safe.

Stress Analysis of Jetspray Tube Structure

Following the utilization of SolidWorks 2020 software for both 2D and 3D modeling, a simulation process was undertaken using 304 stainless steel material. The simulation aimed to analyze the structural behavior, with a specific focus on identifying the maximum stress within the purging pipe hole. The output of this simulation is presented in terms of the maximum stress distribution, visualized through a color map. The simulation results showcase a distinctive color gradient, transitioning from dark blue to yellow across the model. This color spectrum represents varying levels of von Mises stress, with dark blue indicating areas of low stress and yellow signaling regions of maximum stress concentration. The color diagram associated with this simulation serves as a valuable tool for interpreting stress distribution, providing a comprehensive understanding of the structural response in the purging pipe hole [8].

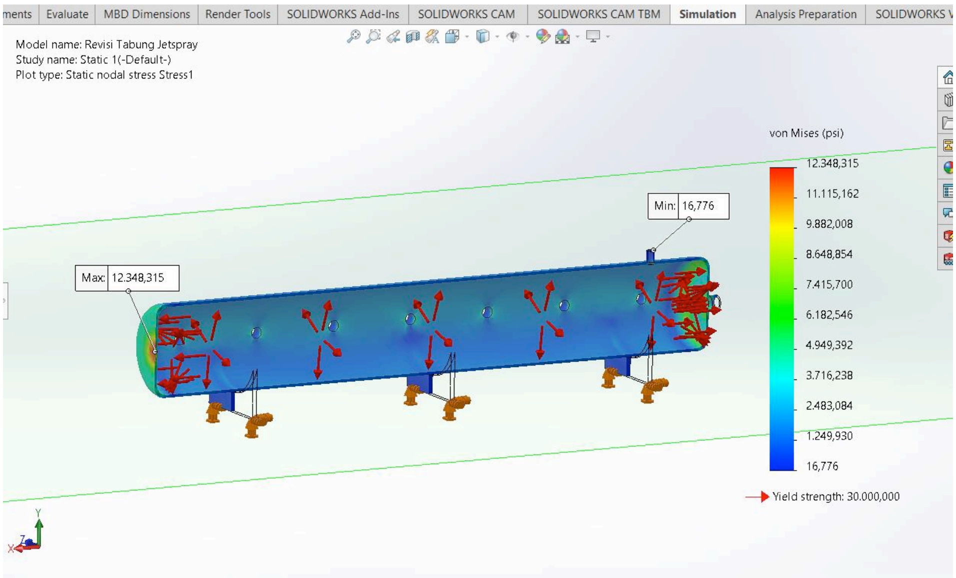

Figure 4. Stress simulation results using solidworks 2020

Working Image of Jetspray Tube

Once the design process has been conducted within the established safety limits, the subsequent phase involves creating a detailed working drawing or General Arrangement Drawing (GAD). The primary objective of this drawing is to articulate the outcomes of the design process while ensuring compliance with safety standards. In this context, the drawing specifically focuses on a 1400mmx8inch SCH20 Pipe featuring seven nozzles designated for purging purposes, as illustrated in Figure 5.

The working drawing provides a comprehensive representation of the design, incorporating precise dimensions and specifications. It serves as a crucial document for communicating the intricacies of the design to various stakeholders involved in the manufacturing and implementation phases. By offering a detailed visual depiction, the working drawing facilitates a seamless transition from the design phase to the practical realization of the purging pipe system, maintaining alignment with safety considerations throughout the entire process.

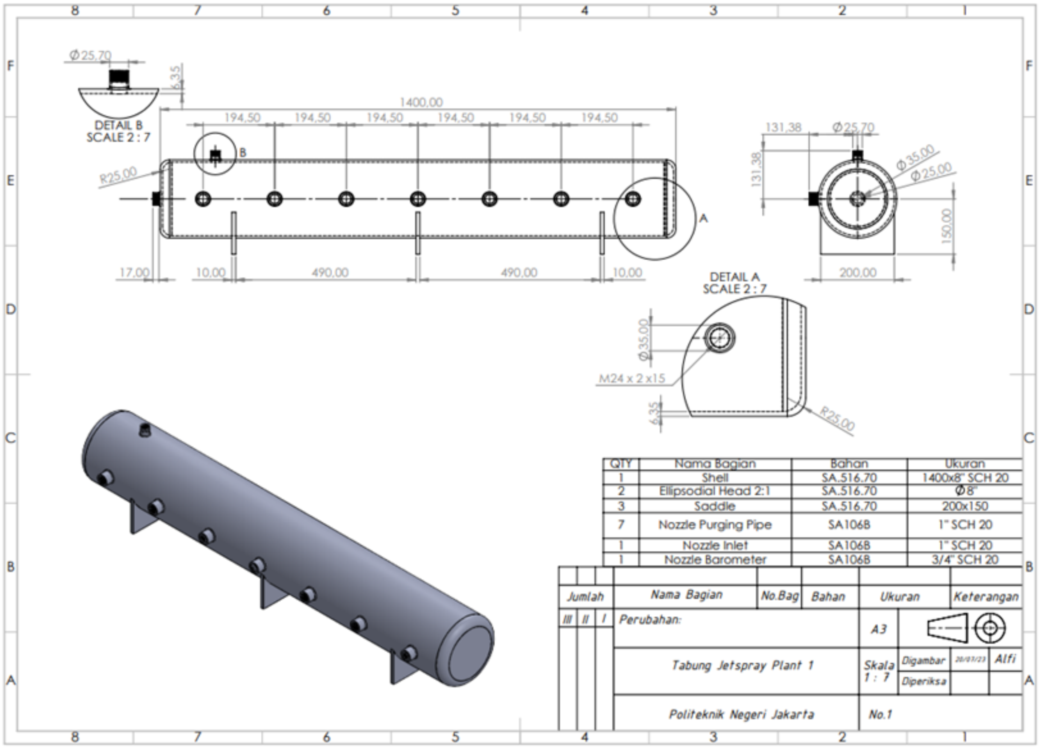

Figure 5. Jetspray Tube Working Diagram

4. Conclusions

The jet spray tube inside the filter bag was causing problems for operators during maintenance. To fix this, we moved the tube to the top of the filter bag, making it easier to reach. When the filter is clogged or blocked, it's because the jet spray tube doesn't have enough pressure. To solve this, we adjusted the tube's dimensions to handle a pressure of 5-7 bar and calculated that it should have a capacity of 40L. We then used SolidWorks 2020 and manual calculations to check the tube's safety. The tube, made of stainless steel 304 with dimensions 212.75 mm x 1400 mm and a thickness of 6.35 mm (SCH20 pipe), has been confirmed as safe. This whole process ensures that the filter system works well and meets safety standards.

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