Design of Work System for Reducing Pollution and Forest Fire Smoke

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Abstract. Air quality has an impact on human life. The incidence of forest and land fires has caused many casualties. On the other hand, poor air quality as a result of forest and land fires also threatens human life directly. Therefore a Pollution and Smoke Reduction Tool was designed as a solution to the problems of pollution and smoke due to forest fires. The purpose of writing this article is to describe the design and manufacture of Pollution and Smoke Reducers as well as its working principles. The writing method used is descriptive qualitative, with data collection techniques in the form of literature studies to strengthen ideas. Pollution and Smoke Reducers are tools that can convert particulate CO (PM) PM10 and PM2.5 into CO₂ and burn particulates PM10 and PM2.5 until they disappear. Pollution and Smoke Reducers are the development of research on catalytic converters and diesel particulate filters by utilizing a fan/blower as a smoke suction agent and a heater to heat the smoke until it burns completely. Pollution and Smoke Reducers are also equipped with wire mesh and fiber to trap particulates and hold them until they burn entirely. Pollution and Smoke Reducers are designed with several materials and tools specifically designed to reduce the direct impact of forest and land fires by burning PM 10 and PM2.5 and lowering CO emissions. The smoke reduction capability based on the designed design has smoke and particulate reduction capacity of ±43,476.80184 ft³. The capacity of the smoke and particulate suction rate is 21500 ft³/minutes with the ability of the significant smoke suction rate so that smoke and particulates due to forest fires can enter the equipment and do not fly freely under the wind. Hence, the air that is inhaled by the community has better potential and safe for health.

Keywords - pollution; forest fire smoke; catalytic converter; wiremesh; reheater

1. Introduction

Forests are an essential factor in the ecology of the environment and human life. However, burning emissions from forest fires, namely smoke, have represented a global public health problem [1]. The potential for forest fires itself is quite high. It is also known that forest fires from tropical regions in South America, Africa, and Asia are global hotspots to produce fire emissions [2]. In the current situation and conditions, forest fires directly contribute to the most substantial pollution and climate change, which have an immediate and immediate impact on the lives of living things around them [3]. The pollution also affects the ecosystem and the economic activities of the community in the location of the forest fires [4]. Smoke haze pollution from forest fires that occurs contributes significantly to human health problems and carbon emissions / global warming problems [5]. This is because some of
the smoke content from forest burning is very dangerous. The smoke content varies with the type of fuel being burned and the stage of combustion [6] However, in general the smoke content from forest fires consists of SO₂, NOX, O₃, CO and small, very aerodynamic particulates [7].

The resulting high-temperature biomass fires such as forest fires also produce emissions and a large amount of smoldering soot [8,9]. Soot is also considered very dangerous, soot which is meant in the event of forest fires is dust particles (PM 10), and particulates (PM 2.5). Of these pollutants, particulate matter (PM) is the most concerning, given its very small size and ability to be inhaled deep into the lungs, which in turn hurts asthma [10]. Particles with an aerodynamic diameter of less than 10 μm were defined as PM10. Whereas PM2.5 has an aerodynamic diameter of less than 2.5μm [11].

Based on the problems caused by forest fire pollution, many studies have discussed related emissions and pollution such as [12][13] then fire risk and detection [14][15] and also fire impact assessment [16][17], according to research [18] the highest number of research articles were found on fire emissions and pollution (46%), followed by fire risk and detection (42%), and fire impact assessment (12%). However, from the many studies, there is still little research that discusses how to stop the effects of forest fires. Including the handling of smoke, which is currently an unresolved problem. As a result of the impact it has had long enough to stop. The high risk of the impact of forest fires, namely pollution and smoke, and there are still few ways to deal with them, is a problem that has not been resolved. One way that can be done to reduce levels of pollution and smoke is to reduce it with a tool. So that making smoke and pollution reduction tools due to forest fires is an absolute must.

Previously, research has been carried out related to the reduction of exhaust emissions by engineering the installation of a catalytic converter intended for diesel engines [19]. The results obtained are quite good because the catalytic converter can reduce harmful pollutants more efficiently and at a lower cost. Another similar study is a study entitled “Application of copper-zinc metal as a catalytic converter in the motorcycle muffler to reduce the exhaust emissions” [20]. Research shows the use of a catalyst can reduce exhaust emissions much more significantly than without a catalyst. Based on the problems and the results of previous research, the authors innovated a catalytic converter technology to reduce the impact of forest and land fires. It is hoped that the innovation in designing this tool can be realized to reduce smoke from forest and land fires quickly so that it does not endanger and harm the community.

2. Forest Fire Smoke

Forest fire smoke has several pollutants released, such as PM 10 and PM 2.5, which are very dangerous to the environment, forest ecosystem, and human health. PM 10 and PM2.5 are of significant concern at the moment, as they are small enough to penetrate deep into the lungs and pose significant health risks. PM10 is a particle small enough to pass through the nose and throat and can enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects. At the same time, PM2.5 can be associated with several types of cardiovascular problems, such as hypertension [21], acute myocardial infarction [22], heart failure [23], and inflammation and blood clots [24] PM2.5 has even increased mortality associated with cardiovascular and ischemic heart disease [25]. Besides, PM2.5 has associated with susceptibility to pulmonary metastases [26] and breast cancer survival [27].

The main fuel in forest fires is wood. When wood is burnt smoldering, it releases most of CO, CH₄, and other organic compounds such as particulates [28]. Based on research simulations on the burning of eight main tree species in subtropical China, the total emission factors that have been calculated and analyzed with a burning flame equal to 230.49 ± 17.61 (smoldering) vs 154.35 ± 15.61 (burning, g/kg) for CO: 1018.23 ± 48.77 vs 1307.86 ± 76.99 (g/kg) for CO₂; 1.16 ± 0.16 vs 1.42 ± 0.23 (g/kg) for NOX; dan 18.62 ± 4.30 vs 9.51 ± 2.75 (g/kg) for PM2.5. These results are similar to those of other experiments conducted under the same conditions [29][30][31][32][33][34][35]. However, the differences between this study and other studies can be influenced by regional tree growth and experimental tools [36]. CO, PM10, and PM2.5 are the largest amounts contained in fire pollution.
CO, PM10, and PM2.5, which are currently considered dangerous for human health, are one of the urgent issues to be resolved.

3. Material selection

3.1 Metallic Catalytic Converter
Pollution reducers and forest fire smoke have designs and materials that can reduce smoke, supported by catalytic converters that are proven to reduce pollution well [37][38]. The reaction of exhaust gases in the exhaust using a catalytic converter, exhaust gas from CO to CO$_2$, and HC to H$_2$O. The process is when CO emission can change to CO$_2$ and it takes one molecule of O meanwhile, for the emission of HC to H$_2$O, two adjacent H molecules receive an additional one molecule of O from CO$_2$ [39]. Several metals that are known to be useful as oxide and reduction catalysts ranging from large to small are Pt, Pd, Ru > Mn, Cu > Ni > Fe > Cr > Zn and oxides of metals [40].

3.2 Diesel Particulate filters
The addition of a particulate filter, like the working concept of diesel particulate filters, functions to reduce PM10 and PM2.5 pollutants by filtering them and holding them for a while until they burn themselves and disappear [41]. This method is considered to be the most effective [42] and is capable of filtering particles from the fuel combustion residue [43]. The addition of ceramic fiber has the potential to filter out very small particulates. Also, they also have the potential to be used as diesel particulate filters because of their rigidity, thermal expansion, good thermal conductivity, and fracture toughness [44].

4. Design Tools
A means of reducing pollution and forest fire smoke is a tool that can convert pollutants (especially CO, PM10, and PM2.5) into CO$_2$ and PM10 and PM2.5, which will burn until they disappear. The design of the tool is composed of several essential components in it, starting from a stainless-steel-based tool frame, as shown in Figure 1, which has been designed using the Solidworks 2013 application. There is a fan/blower inside, which is used to suck smoke into the tool. In the framework, there is a bulkhead and space which will be filled with a copper-based catalytic converter. The partitions in the wire mesh frame or stainless-steel filter are used to lock the ceramic fibers, which are used as PM10 and PM2.5 filters to trap and burn themselves in the appliance. The design concept is taken from the combination of the idea of a diesel particulate filter and a catalytic converter. The stages of designing tools are carried out based on the following.

4.1. Create designs
They are making designs using Solidworks 2013 Student Version software. The stages that must be carried out in this stage include designing the machine frame design, the design of the tool head frame with a diameter of 2 m with an overall length of 6 m. Creating a catalytic converter with a diameter of 1.04 m with a range of 0.33 m and having a copper plate thickness of 1 mm, for the height of the catalytic converter curve measuring 3 mm, with this measure the reduction and suction capacity of the tool will be higher.
4.2 Design Analysis

The design was obtained based on literature studies, and a design that was able to increase the pressure in reducing pollution, and forest fire smoke was chosen [45]. The flue fluid flow pressure will be increased in the chamber containing the catalytic converter and fiberglass. The room was arranged because the emission reduction process and CO, PM10, and PM2.5 were mostly located in that room [46]. An increase in pressure will affect increasing the temperature in the appliance so that with an increase in temperature, the emission reduction performance of CO, PM10, and PM2.5 also increases [47]. The minimum temperature increase must be reached at the catalyst working temperature to convert the hazardous emissions, which generally occur at 250-300°C [48].

Increasing the pressure on pollution reducers and forest fire smoke is done by making designs that can increase the fluid flow rate. In this study, the increase in fluid flow rate and pressure and temperature was carried out by making the majority of the tool design circular in shape. This was done so that the fluid flow did not have obstacles due to surface angle curves. Besides, the design is made for a chamber with an increasingly tapered and smaller tilt angle. This is done so that the fluid flow is faster and then affects the pressure and temperature increase in the chamber containing the catalyst. Even though there is an additional heater in the appliance, it is necessary to maintain performance and optimize the reduction results.

To determine the design and determine the fluid flow performance in this tool, it is necessary to perform Computational Fluid Dynamics (CFD) analysis used to predict flow behavior, thermal characteristics and conversion efficiency of monolith substrates [49][50]. This analytical study also needs to be carried out for further research as a development to maximize the performance of the tool. Research on fluid flow analysis is mostly done to determine flow performance. Many researchers also investigate and simulate steady-state flow in flow conditions reacting to catalytic converters [51][52] [53][54] and other researchers investigated the unreacted steady-state flow in the catalytic converter [55][56].

4.3 Determination of Tool Material

The metals platinum (Pt), palladium (Pd), and rhodium (Rh) are precious metals as active components of catalytic converters to reduce emissions of hydrocarbons, carbon monoxide and nitrogen oxides [57]. Furthermore, some metals which are known to be effective as large to small oxidation and reduction catalysts are Pt, Pd, Ru > Mn, Cu > Ni > Fe > Cr > Zn and the oxides of these metals [38] In this study, the material used is stainless steel as a tool frame, the choice of this material is because stainless steel has good corrosion resistance and thermal conductivity. Besides, the choice of material
as a catalyst is Cu because the Cu emission reduction level is quite good [58][59][60], makes a temperature of 180-200°C which is a conversion curve of CO to a much lower reaction temperature [61]. Besides, the choice of Cu is due to its relatively low price compared to Pt, Pd, and Ru and is a material that is quite abundant and easy to find, so it is suitable for large-scale production [62]. The material used for the reduction of PM10 and PM25 is fiber glass fiber, fiber glass fiber has high heat resistance. As well as stainless-steel wire mesh to insulate, the fiber glass fiber is not felled.

4.4 Work Design Manufacturing tools
After analyzing the design and selection of the tool material, the next step is making a tool plan with the supporting equipment that has been determined. Making tools goes through several processing processes, including:
- Selection of the right materials
- Cutting material/raw materials
- Manufacture of catalytic converters
- Welding
- Series

4.5 Determination of Variable Testing Tools
After the tool is successfully made, the next stage is testing the tool. The parameter used to test the performance of the tool is a functional test on each component of the tool to determine the success of the tool being made. A performance test is carried out with an emission test using a gas analyzer to determine the content of the smoke reduction results in the pollution and smoke reducing device.

To improve the quality of the resulting equipment, several evaluations of each variable must be carried out, namely: a) Temperature in the emission reduction room, b) Speed of rotation of the exhaust fan/blower c) The number of glass wool / ceramic fibers d) The type of material for the tool frame and catalytic converter.

5. Result and Discussion

![Diagram](figure2.png)

**Figure 2.** Design Results

Information:
1) Suction fan/blower
2) Catalytic converter
3) Wire Mesh
The performance of the tool is directly proportional to the temperature of the smoke in the tool, the higher the temperature, the faster the reduction is made. The working principle of the tool starts from the rotating fan and then sucks the smoke into the tool. The smoke that has entered will be in the catalytic converter room which has been insulated by wire mesh and glass wool or ceramic fiber which is commonly used for high-temperature insulation and is stable up to a temperature of 1600°C [44]. The smoke will then filter and stick to the ceramic fibers. Another function of this ceramic fiber is to prevent the release of smoke and particulates that have not been completely burned or have not been reduced in the tool. So that PM10 and PM2.5 are filtered first and then will be reduced by themselves in the tool. Through this tool, PM10 and PM2.5 are reduced and safer for the environment. The working principle of PM reduction is like the working principle of diesel particulate filters which work as PM filtration [63]. Reducers with a catalytic converter will be assisted by a reheater that can heat up to a temperature of 800°C if the smoke temperature does not reach the reduction temperature. in this tool will be equipped with a temperature indikator [64]. The reaction that occurs in the catalytic converter.

1. CO = CO₂
2. HC = H₂O + CO₂
3. NOx = N₂ + O₂

After the reduction reaction occurs, the smoke that comes out has a smaller potential and is safe for the environment.

The catalytic converter used has a design like a Figure 3 with copper as the base material. This catalytic converter is used as a reducer of smoke generated from forest fires [65]. The catalyst will decrease the activation energy so that it is oxidized CO + ½ O₂ becomes CO₂ Will be reached more quickly at lower temperatures (250°C – 300°C). Meanwhile, oxidation CO + ½ O₂ becomes CO₂ the phase without a catalyst will occur at the temperature 700°C [66].

![Catalytic Converter Design](image)

**Figure 3.** Catalytic Converter Design

The design and placement of the equipment during a fire will be arranged around the fire located in a safe position, the position that surrounds the smoke is carried out so that all the smoke can be absorbed in the tool. The arrangement of the tools is expected to provide excellent and safe reduction results for the surrounding environment.
5.1 Tool Reducing Capacity

The capacity of this tool is calculated in the space where the reduction process occurs, which includes a catalytic converter and fiber to reduce emissions CO, PM10 dan PM2.5. The reduction room has a height 1.45 m and in diameter 1.04 m by volume 1.2311312 m³ converted to 43,476,988,0184 ft³. The reduction capability of this tool is equal to 43,476,988,0184 ft³ Which is compressed in the reduction room together with the catalytic converter and fiber fibers. In the reduction room / middle body contains 3 catalytic converters sealed with stainless-steel wire mesh and glass wool with a thickness of 0.05m. There are 4 heaters that can be controlled to reach a temperature of 800°C. The last part of the fluid discharge, there is another catalytic converter which is 0.5 m long and 0.4 m in diameter. The addition of a catalytic converter at the end serves to maximize the reduction results because after it is compressed with the chamber body, the fluid rate will increase, and the pressure will also increase. So that the temperature carried by the fluid is also getting higher, the addition of catalytic is the right way to maximize the return of emissions reduction results.

![Figure 4. Tool Capacity Size](image)

Figure 4. Tool Capacity Size

The air intake fan/blower used has a high capacity to carry a lot of smoke and pollution from forest fires. The choice of high blower capacity is caused by forest fires that have a wide range, the spread of emissions is also extensive and irregular. The suction capacity of the blower is expected to be able to carry smoke and particulates that fly freely into the equipment and are not carried away freely by the wind. The determination of the fan has been carried out by studying the literature and looking at the types of fans and fan capabilities on the market. In this study, researchers chose fans in the BALAJI Fans and Blowers industry [67]. The fan used has a fan diameter of 40 inc or 1,016 m with a power input of 5 HP, 3 phases, a fan speed of 960 rpm, and a smoke/air intake rate of 21,500 Cubic Feet per Minute (CFM). So that the ability of the designed pollution reduction device and forest fire smoke has a smoke reduction capacity and compressed particulates of ±43,476,988,0184 ft³. The speed capacity

![Figure 5. Blowers that are planned to be used in reducing pollution and forest fire smoke](image)

Figure 5. Blowers that are planned to be used in reducing pollution and forest fire smoke [67]
of the smoke and particulate suction rate is $21500 \text{ft}^3/\text{minutes}$. Based on this capacity, the air that people breathe has the potential to be better and safer for health. The use of tools is recommended after a fire because the potential for smoke and emissions is most likely to occur after a fire. Besides, the installation of the tool will be safer after a fire so that the safety of the equipment operator is maintained.

6. Conclusion

Pollution and smoke reducers are designed with a design that can provide good reduction results. With additional supporting components such as fans, catalytic converters, reheaters, temperature indicators, and ceramic fibers, each part plays an active role in the process of reducing CO, PM10, and PM2.5 fumes in cases of forest and land fires.

Pollution and smoke reducers work when the fan is turned on and suck smoke into the appliance. After that, there is a reduction by the catalytic converter assisted by a reheater until it reaches a temperature of $250 \, ^{\circ}\text{C} – 300\, ^{\circ}\text{C}$. Unburned smoke, especially PM10 and PM2.5, will be filtered out on the wire mesh and filtered by ceramic fibers. Furthermore, the smoke will be stored, and then it will reduce itself. So, the output from the reduction in this tool is better and safer for the surrounding environment. The smoke capability based on the design that has been designed as smoke and particulate reduction capacity of $\pm 43,4769880184 \text{ft}^3$. The capacity of the smoke and particulate suction rate is $21500 \text{ft}^3/\text{minutes}$ with the ability of the significant smoke suction rate, the smoke and particulates due to forest fires can enter the equipment and do not fly freely under the wind, so the air that the community breathes has better potential and safe for health.

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