

Modernization of Eco-friendly Blacksmith Furnace to Fabricate Farms Equipment

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Abstract. Blacksmiths manufacture farm equipment that still uses conventional systems in their production. The fabrication process goes through the heating stage of steel to a temperature of 850°C as the primary raw material (carbon steel). Heating aims to make the steel easy to shape into farm tools. Conventional furnace designs, such as those at blacksmiths in the Pandak area, Bantul, still use an open system, causing air pollution around the workplace. This research modernizes a blacksmith furnace for iron with multi-air flow and dust filtration systems. Total dust testing uses SNI 7119-3:2017 standards. The results were that the burning stove has three variations of airflow, which can be adjusted to the type of work to save wood charcoal fuel by around 30%. A combustion furnace with an ash filtration system can minimize pollutant particles around the work environment from 3.99 mg/m³ to 0.024 mg/m³. Modernization of furnaces has reduced air pollution by up to 99%.

1 Introduction

Agricultural equipment and tools were primarily crafted through hand forging. In Indonesia, the artisans who specialize in forging work are known as Blacksmiths. There are approximately ten traditional blacksmiths still actively practicing their craft in the Pandak area of the Special Region of Yogyakarta [1]. The process of creating agricultural equipment (Figure 1), such as hoes, knives, and sickles, involves several stages, including selecting raw materials, heating, forging [2][3], shaping, and finishing [4]. The steel-heating process plays a crucial role, and therefore, the furnace must be designed for maximum efficiency [5]. Teak wood charcoal is used as the fuel for heating the metal due to its high calorific value [6]. Presently, blacksmiths use open systems for their furnaces (Figure 2), leading to air pollution in the surrounding environment, mainly in the form of charcoal burning dust. Prolonged exposure to this dust can result in health issues, particularly respiratory problems [7]. The safe concentration of dust in a work area is set at

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3 mg/m³ based on the circular letter of the Minister of Manpower number SE-01/MEN/1997, which establishes the threshold value for chemical factors in the air [8].



Fig. 1. Agricultural equipment resulting from the forging process by blacksmith craftsmen

The current design of heating furnaces uses gas fuel and G32 refractory brick that can withstand temperatures up to 1600°C [9]. It is imperative to upgrade blacksmith furnaces to minimize pollution caused by residual dust particles from combustion and to enhance heating efficiency with closed-system furnaces. This research is focused on modernization of furnace technology for blacksmiths by introducing a dust particle filtration system and adjusting the airflow entering the furnace to maximize the efficiency of charcoal fuel.



Fig. 2. An Open Furnace in the Djawadi blacksmith

2 Research method

The method used involves a redesigned furnace with three different inlet air flows and a dust filtration system (Figure 3). We simulated the air flow entering the pipe using Autodesk Inventor software. Dust testing in the blacksmith environment was conducted twice: 1) When using a furnace with an open system, and 2) After modernizing the furnace

with a filtration system. Total dust testing was performed according to the Indonesian National Standard number 7119-3:2017, which covers the Total Suspended Particulate (TSP) test using the ambient air gravimetric method [10, 11]. This involved using filter paper with a high-volume air sampler (HVAS). Test samples were taken using an average vacuum pump flow rate of 1.13 –1.70 m³/min to obtain suspended particles of less than 100 μm. The filter paper used is fiber-glass type with a porosity of <0.3 μm, made from microfiber-glass and with a collection efficiency of particulates with a diameter of 0.3 μm of 95%.

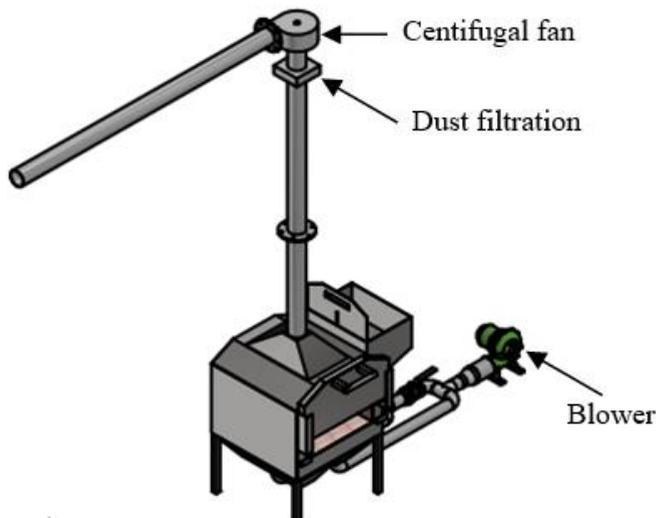


Fig. 3. Design of a modern blacksmith furnace

3 Results and discussion

The results of the modernization of the blacksmith's furnace are shown in Figure 4. Technological changes were made by adding a filtration system, supported by a centrifugal fan to remove the remaining dust from combustion. Additionally, the airflow in the furnace is adjustable through the inlet air pipe (Figure 4).

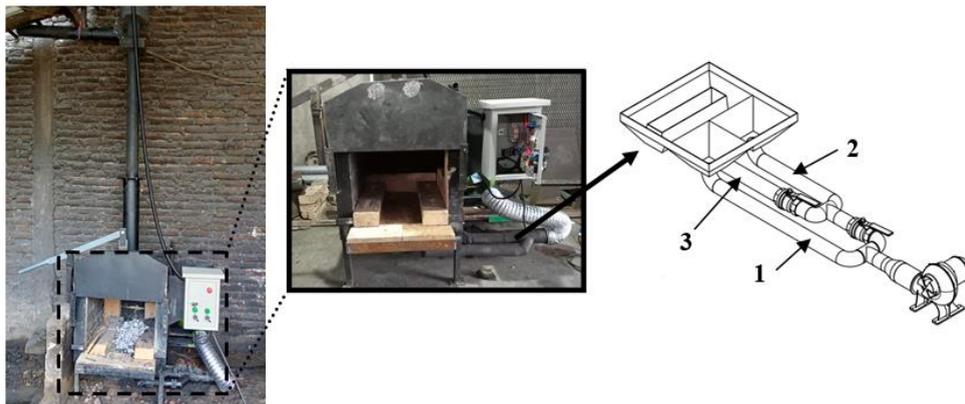


Fig. 4. Modernization of furnace with three variations airflow

The simulation results of the airflow entering the stove are depicted in Figure 5. The goal is to divide the airflow into three parts to accommodate different types of work and forging materials. Air pipe flow 1 is the primary flow with an airflow speed of 12 m/s, suitable for small tasks such as making knives. Pipe 2 creates a medium flow with an air speed of 8 m/s, used for medium types of work like making machetes. On the other hand, pipe 3 generates a large incoming airflow with an air speed of 6 m/s, suitable for tasks such as making hoes. The charcoal burning time in this closed furnace has been reduced by 50%, from 10 minutes to 5 minutes, compared to traditional furnaces.

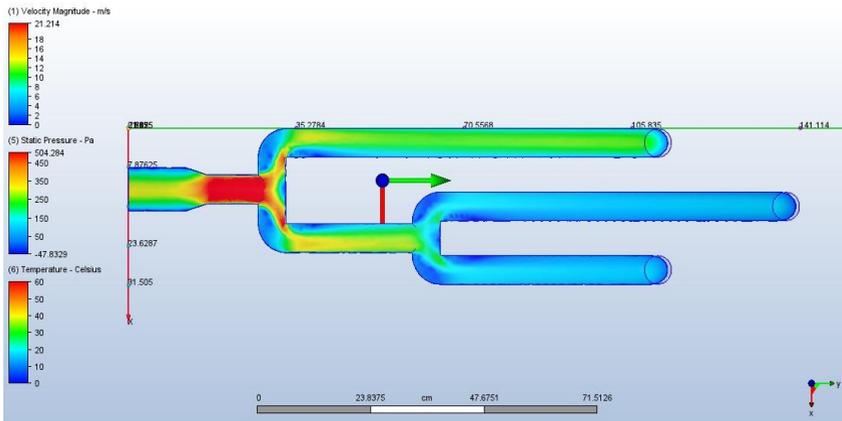


Fig. 5. Airflow simulation with three variation of pipe flow

The modernization of the blacksmith's furnace, as described in the findings, signifies a significant advancement in forging technology. The incorporation of a filtration system, powered by a centrifugal fan, not only improves air quality by effectively removing combustion dust but also optimizes the furnace's efficiency. This improvement is crucial in reducing health risks associated with inhaling particulate matter during the forging process. Furthermore, the adjustable airflow through the inlet air pipe allows for greater versatility in the types of tasks that can be performed. By dividing the airflow into three distinct channels, each tailored to specific forging requirements, the furnace can accommodate a wider range of materials and techniques. The high-speed flow (12 m/s) from pipe 1 is ideal for precision tasks, such as knife making, where a concentrated and intense flame is necessary to achieve the desired hardness and tempering of the metal. In contrast, pipe 2's medium flow (8 m/s) provides a balanced environment for crafting items like machetes, where moderate heating is required to maintain the integrity of the material without overheating. Lastly, the slower airflow (6 m/s) from pipe 3 is advantageous for larger tools, such as hoes, allowing for gradual heating, which is critical to prevent warping or damage to the metal.

The reduction in charcoal burning time from 10 minutes to 5 minutes is another remarkable benefit of this modernization. This efficiency not only saves fuel costs but also enhances productivity by minimizing downtime between forging tasks. This time savings can significantly impact the overall output of a blacksmithing operation, allowing artisans to focus more on crafting rather than on heating. The technological upgrades to the blacksmith's furnace not only elevate the quality of work produced but also contribute to a more sustainable and health-conscious forging environment. These advancements exemplify the critical role of innovation in traditional crafts, ensuring that they can thrive in a modern context while preserving their artistic and functional heritage.

The exposure of blacksmiths to high levels of respirable dust and crystalline silica has long been a concern, impacting both health and productivity in traditional forging environments [12, 13]. The modernization of the furnace with an environmentally friendly

air filtration system marks a crucial step towards mitigating these risks. The use of a 300 mesh stainless steel woven wire filter, as illustrated in Figure 6a, is particularly noteworthy for its ability to capture fine particulate matter while being durable enough for multiple reuses, like fibrous filters prevail for dust control in coal mines [14]. The primary goal of this filtration system is to minimize air pollution resulting from charcoal dust, which not only poses health hazards to workers but can also contribute to broader environmental issues. By effectively removing dust before air is released back into the workspace, this system enhances the overall safety and health of the blacksmithing environment. Regular maintenance, as indicated, is essential to ensure optimal performance of the filter. Cleaning the filter every few weeks helps prevent dust and ash accumulation, ensuring that the system remains effective in the long term (see Figure 6b).



Fig. 6. Dust filter components: a) before use and b) after use for 2 hours of production

The air quality tests conducted at Djawadi Pande Besi MSMEs reveal a remarkable transformation following the installation of modern furnace equipment. The reduction of Total Suspended Particles (TSP) from 3,999 mg/m³ to just 0.024 mg/m³ underscores the effectiveness of the filtration system, achieving a TSP removal efficiency of 99.39%. Such a dramatic improvement not only indicates successful dust control but also suggests a significant decrease in potential health risks associated with long-term exposure to airborne particles. Improving air quality is likely to have positive repercussions on worker comfort and productivity. Cleaner air can enhance concentration and reduce fatigue, factors that are essential in a demanding trade like blacksmithing [15, 16]. Furthermore, a healthier work environment can lead to lower rates of occupational illness, which in turn can reduce absenteeism and healthcare costs for both employees and employers. The implementation of an advanced air filtration system in blacksmithing furnaces represents a forward-thinking approach that harmonizes productivity with health and environmental concerns. This modernization not only safeguards the well-being of blacksmiths but also reflects a broader commitment to sustainable practices within the industry, paving the way for a healthier future in traditional crafts.

4 Conclusion and recommendation

The modernization of blacksmith furnaces with a closed system offers two main advantages. Firstly, there are three options for air flow variations to accommodate different types of agricultural equipment forging work. Secondly, increasing the burning time in the furnace by 50% can accelerate the heating of steel and save charcoal fuel. Additionally, the dust filtration system in the furnace can significantly reduce air pollution around the work area. For instance, the total suspension of particles of 3,999 mg/m³ has decreased to 0.024 mg/m³. Using a 300-mesh stainless steel woven wire dust filter can be highly effective in reducing dust particles, with a TSP removal efficiency of 99.39%.

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