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Enhancement of louver dust collector efficiency using modified dust container

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ABSTRACT

External air injected into a gas turbine contains many solid particles, which can reduce the performance and life of the turbine. In this study, a louver dust collector, which is a type of inertial dust collector, was used to remove solid particles from air, and the shape of the dust container, which is part of the louver dust collector, was modified to improve dust collection efficiency. As existing dust containers have a structure for isolating particles, the inflow of the air into the dust containers is limited and effective removal of particles is difficult. In this study, slits were drilled in the dust container, baffle plates were used, and raised spots were added to improve particle collection efficiency through improved air flow in the dust container and increased inertia effect of the particles. The trajectory of the particles and the collection efficiency for each dust container shape were predicted using numerical analysis and the numerical analysis results were verified using a wind tunnel test. Results indicate that for an air flow rate of 3 m^3/min, the collection efficiencies of the louver dust collectors with the one-slit model dust container and two-slit model dust container improved by 40.1% and 43.5%, respectively compared with that of the louver dust collector with the existing dust container. Furthermore, for an air flow rate of 6 m^3/min, the collection efficiencies of the louver dust collectors with the one-slit model dust container and two-slit model dust container improved by 32.9% and 37.6%, respectively, compared with that of the louver dust collector with the existing dust container. Therefore, it is expected that the particle collection efficiency of the existing louver dust collector can be effectively increased by utilizing the shape of the dust container proposed in this study.

1. Introduction

A gas turbine is a heat engine that drives a turbine using high-temperature and high-pressure combustion gas, and for its operation, external air is usually injected into the gas turbine. However, as external air contains many solid particles, its continuous inflow may cause corrosion of the compressor blades and damage to the engine, and possibly may lower the performance of the gas turbine [1–3]. Various studies have been conducted to prevent performance degradation due to various solid particles contained in the external air introduced into the gas turbine. The particle collection efficiency was evaluated through the fixed valve tray column for the removal of fly ash particles entering the gas turbine [4]. Coating treatment was performed to improve the erosion resistance and prevent gas turbine compressor blades from being eroded by solid particles [5,6]. A computational fluid dynamics (CFD) analysis was performed to identify the impact adhesion properties of particles and guidelines for filtration systems were prepared to prevent blade sediments and compressor performance degradation [7]. Several types of inertial separators were studied to protect gas turbines from dust and sand [8]. The use conditions of an electrostatic precipitator for separating solid particles from combustion gas were investigated [9].

In this study, an inertial dust collector was considered to be installed in the secondary flow path of a gas turbine engine, to remove various solid particles floating in the external air entering the gas turbine. Inertial dust collectors collect dust using the inertia of the particles and can have a high dust collection efficiency under the condition that the gas moves at a high speed as in a gas turbine. Among them, the louver dust collector can effectively separate and remove solid particles using the louver blade in the flowing gas [10]. A louver refers to long plates, regardless of the material, continuously placed at a regular interval. There have been many studies to improve ambient air flow and to separate and remove particles in air using louvers. Dust particles in the combustion gas were removed through the circulating granular bed filter (CGBF) using louver plates [11]. The size distribution of dust particles was measured by the centrifugal separation method using a louver media filter, and particle collection efficiency was analyzed [12]. A fixed louver was installed in the burner duct of a pulverized coal power plant to separate solid particles from gas [13]. A louver-sublouver system was developed to remove fine dust particles and fugitive dust [14,15]. A device using a louver was installed on the

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upper wall of a factory to improve indoor air ventilation efficiency [16]. The natural ventilation efficiency of the wind tower system was improved using louvers [17]. The angle of the louver was a factor that significantly influenced the dust collection efficiency of the CGBF [18]. Analytical, numerical, and experimental investigations of louvered classifiers demonstrated the influences of louver shape, louver angle, number of louvers, inlet velocity, powder feed-rate, and blowdown on fractional collection efficiency [19–21]. These parameters were also examined in an extensive literature on louvered classifiers in both rectilinear and cylindrical geometries. A partial review of that literature is provided in [22] together with a correlation of fractional collection efficiency, showing the influences of gas and particle dynamics and array geometry. Particularly relevant to the present study is the work of [23,24]. In that study, a louvered classifier with a dust container, analogous to the "original model" herein, was applied to dust removal in the secondary flow path of a gas turbine engine. The present study uses and improves upon the results of [24].

As mentioned earlier, many studies have been conducted to improve particle collection efficiency by changing the properties of louver blades; however, only few studies have attempted to improve the collection efficiency by changing the shape of the dust container. The purpose of this study is to improve the particle collection efficiency of the louver dust collector by changing the shape of the dust container. The louver dust collector design considered in this study was based on that of the previous literature [23,24]. Slits were drilled and additional baffle plates were installed in the dust container to increase the amount of particles collected in the dust container through improved air flow inside the dust container and maximized inertia effect of the particles. The air flow through each dust container shape was predicted using CFD simulation, and the particle collection efficiency of each dust container shape was predicted through the analysis of the particle trajectory. The particle collection efficiency of the louver dust collector was measured through a wind tunnel test and compared with the predicted collection efficiency from simulation. Furthermore, changes in the collection efficiency due to the application of grease were evaluated and analyzed for each dust container model. Results indicate that changing the dust container shape could improve particle collection efficiency and suppress particle re-scattering. Therefore, the collection efficiencies of existing louver dust collectors can be significantly improved with low investment cost by replacing only their dust container shapes with those proposed in this study.

2. Numerical

Fig. 1a shows the two-dimensional (2D) model of the louver dust collector used for numerical analysis. It consists of continuous louver blades and one dust container downstream. The louver was constructed using five continuously arranged straight louver blades with louver blade lengths of 46 mm and gaps of 15 mm. In this study, to compare the collection performances of different dust container shapes, the collection efficiency of the louver dust collector was predicted by changing the dust container shape while the louver blade shape remained unchanged. Fig. 1b shows the grid system used for 2D simulation of flow field and particle trajectory. Triangular grids were created using the Gambit software. After performing grid independence test, the louver dust collector comprised approximately 70,000 triangular grid cells and the inside of the dust container comprised about 10,000 triangular grid cells.

Fig. 2a shows the existing dust container structure. It is a closed structure without gap except the entrance where dust is introduced through the louver blades (original model). The dust container of Fig. 2b has a slit in the left part of the original model (one-slit model). The width of the slit was 10 mm. A raised spot was added beneath the slit to prevent dust collected in the dust container from being re-scattered. The one-slit model is identical to the original model of Fig. 2a except for the slit and the raised spot. Fig. 2c shows a dust container with 10-mm-width slits in the left and right parts of the original model dust container and a 30-mm baffle plate at the center of the dust container (two-slit model). Raised spots were also added beneath the left and right slits and the baffle plate to prevent particles collected in the dust container and the baffle plate from being re-scattered.

ANSYS FLUENT *Release 16.1*, a commercial CFD software, was used for numerical analysis. The flow inside the louver dust collector was assumed to be two-dimensional, steady, incompressible, and turbulent. Turbulent flow analysis was conducted using the standard k-ω turbulence model based on the Reynolds-averaged Navier–Stokes (RANS) model [23–24]. The boundary conditions for flow analysis

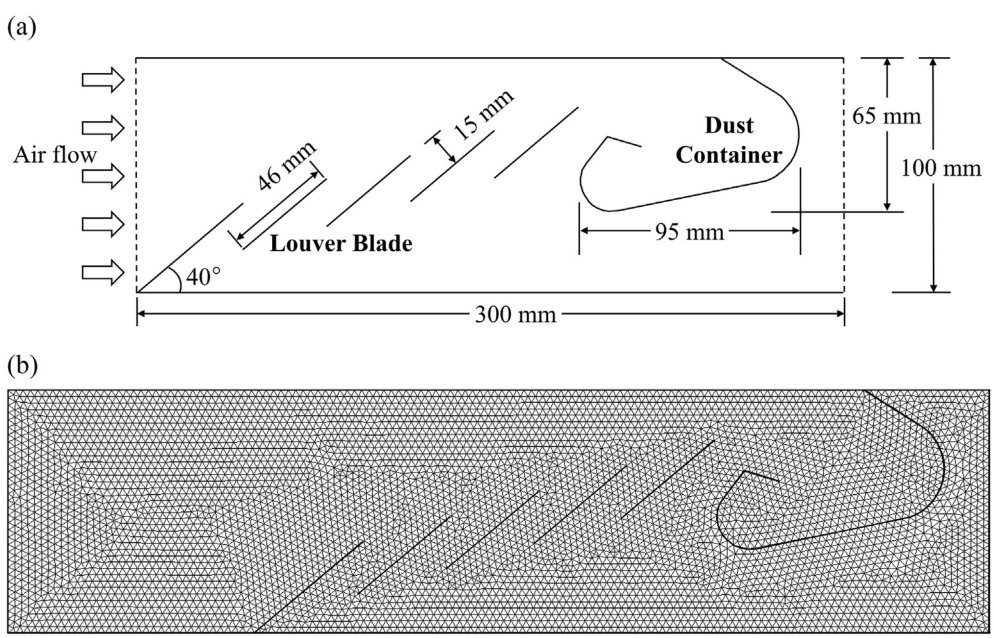

Fig. 1. Shape of louver dust collector: (a) Cross-sectional view; (b) Grid system for 2-dimensional simulation.