A Study on the Improvement of the Thermal Efficiency High Temperature High Pressure Washer with Waste Heat Recovery System

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1. Introduction

High-temperature and high-pressure washers spray hot water at temperatures in a range of 60~80°C at flow rates not lower than 10 L/min to clean various contaminated devices[1]. In order to operate washers having such a capacity, high-temperature and high-pressure hot water should be supplied from the wash gun. In leading high-temperature and high-pressure washers in the past, whereas high-pressure was secured through high-pressure pumps, hot water was obtained by burning diesel at the boiler to raise the temperature of water to 60-80 ° C[2].

In this study, a high - temperature high - pressure washer for energy saving intended to recover the exhaust gas at 270 ℃, which is discharged through the flue duct after warming the cold water in the boiler of the washer, through the waste heat recovery heat exchanger to drastically reduce the exhaust gas temperature was studied. In addition, a boiler unit and a high-temperature high-pressure pump that can be used at high temperatures were studied. By applying these improved devices, the boiler's self-load, which was required in existing systems due to the durability of the boiler for pressure resistance, can be reduced. In addition, because the washer proposed in this study is based on energy recovery, epoch-making study results in terms of energy saving will be derived with a technology that maximizes efficiency unlike existing technologies.

2. Experimental system and method

Fig. 1 shows a high-temperature high-pressure washer equipped with a waste heat recovery device. As shown in the figure, an experimental system was configured with a low-pressure boiler, a drive motor, a high-pressure pump, a spray nozzle, a hot water pressure, temperature, and flow rate control system, and a waste heat recovery system. The boiler as constructed so that the it can raise the temperature of cold water at room temperature by up to 90℃ using the heat of combustion of diesel. Pt 100Ω temperature sensors were to measure the temperature of cold water at the boiler inlet and that of hot water at the boiler outlet. In addition, a hot water flowmeter was installed at the boiler inlet to measure the flow rates. A temperature controller that can control water temperature was installed to control the temperature of water at the outlet of the boiler. The experimental equipment was configured so that the hot water heated at the low-pressure boiler is supplied to the compressor to increase the pressure of the water to make the water coming out from the outlet of the compressor into high temperature high pressure water, which can be sprayed from the spray nozzle for washing. A pressure controller was installed at the high-pressure compressor so that the water spray pressure can be adjusted in a range of 1~ 300 bar. As such, a high-temperature high-pressure washer equipped with a waste heat recovery system that heats low-pressure water to the temperature range of 70~80℃ at the boiler by supplying the combustion heat of diesel, sends the hot water to the compressor to increase the pressure up to 200 bar thereby making high-temperature high-pressure water, and sprays the water through the spray nozzle was configured, the performance of the high-temperature high-pressure washer in response to changes in water temperature was experimented, and the performance of the high-temperature high-pressure washer equipped with a waste heat recovery system in response to changes in the pressure of the compressor was experimented.

Fig.1 High-temperature high-pressure washer equipped with a waste heat recovery system

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3. Results and Discussion

Fig. 2 shows the temperature rise values of the hot water sprayed from the spray nozzle in relation to changes in the initial operation time of the high-temperature high-pressure washer equipped with a waste heat recovery system. Experiments were carried out under the conditions of three different spray pressures of the high-pressure pump at 100 bar, 150 bar and 200 bar. The quantity of fuel supplied to the boiler was 0.052 kg/min for all three conditions. As the spray pressure of the high-pressure pump increased, the spray quantity of water increased. Since the spray quantity of water increased as the spray pressure of the high-pressure pump increased while the quantity of fuel supplied to the boiler was the same under the three conditions, the spray temperature decreased. When the boiler was initially started and the pressure of the high-pressure pump was 100 bar, the temperature of hot water rose rapidly up to 69℃ as shown in Fig. 3. About 80 sec. was taken for the water temperature to rapidly rise to 69℃. After rapidly rising to 69℃, the temperature of hot water was maintained constant. When the pressure of the high-pressure pump was 150 bar, the temperature of hot water rapidly rose up to 71 ° C. About 95 seconds was taken for the water temperature to rapidly rise to 71°C. After rapidly rising to 71°C, the temperature of hot water was maintained constant. When the pressure of the high-pressure pump was 200 bar, the temperature of hot water rapidly rises up to 79 ° C and maintained constant thereafter. About 110 seconds was taken for the water temperature to rapidly rise to 79°C. As the pressure of the high pressure pump increased, the spray quantity of water increased. The time taken to reach the steady state increased as the pressure of the high-pressure pump increased due to increases in the spray quantity and temperature rises until the steady state is reached. As such, the spray temperature of the high pressure washer installed with a waste heat recovery system increased by 3 ~ 5°C than the spray temperature of high temperature and high pressure washer without the waste heat recovery system. In addition, the time to reach steady state also decreased by more than 10 seconds. Therefore, the thermal efficiency of the high-pressure washer increased because the exhaust gas waste heat recovery system was installed at the exhaust gas outlet of the high-pressure washer to recover the waste heat of the exhaust gas and preheat the combustion air before being supplied. Thanks to the results as such, the amount of kerosene used by the high-pressure washer decreased and energy saving was realized.

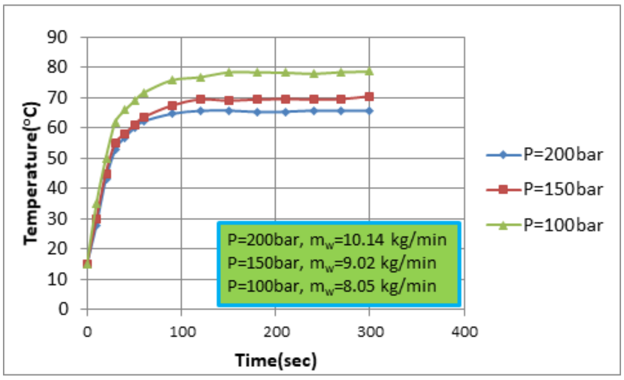

Fig.2 Discharge temperature of high-pressure washer in relation to hot water heating time (high-temperature high-pressure washer installed with a waste heat recovery system)

Fig. 3 shows the energy consumption rates of a high-pressure washer equipped with a waste heat recovery system and a high-pressure washer without any waste heat recovery system. The energy consumption rates were determined by measuring the amount of energy consumed in relation to the spray quantity of water. The amounts of energy consumed were measured at five different spray quantities of water, 8.05, 9.02, 10.14, 12.1, and 15.0 kg / min. As shown in Fig. 3, the energy consumption rate increased as the spray quantity of water increases. The energy consumption rates of the conventional high-pressure washer before development were 7.5 ~ 14.L / hr, and the energy consumption rates of the high pressure washer without any waste heat recovery system was shown to be 5.9 ~ 11.1 L / hr, and the energy consumption rates of the developed prototype was shown to be 4.07 ~ 7.48L / hrwhen the spray quantities of water were in a range of 8.05~15.0kg/minr. The target value of energy consumption rates of this study is 11L / hr when water spray quantity is 15kg / min. By the way, since the energy consumption rate of the prototype was 7.48L / hr when the injection quantity of water was 15kg / min, the target was exceeded. The reason why the energy consumption rate of the high-temperature high-pressure washer equipped with the waste heat recovery system was shown to be much lower than that of the conventional high-pressure washers is that the new technology of low-pressure boiler was developed in this task for the first time at home and overseas and the waste heat of exhaust gases was recovered and used to preheat cold water and combustion air to contribute to the great reduction of energy consumption rates. In addition, since the washer was developed to have U-shaped coils leading to the formation of two pass flows of combustion air and turbulent flows thereby greatly enhancing the thermal efficiency, the energy consumption rate was reduced a lot.

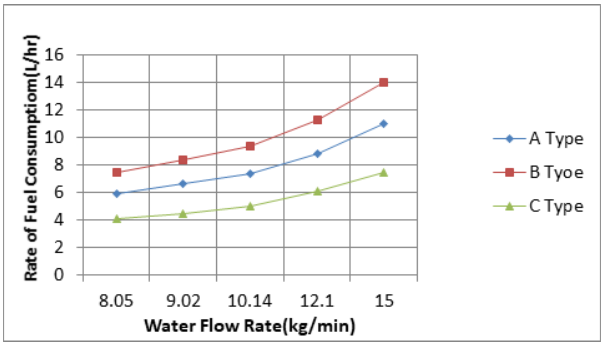

Fig.3 Fuel consumption rates of the high-pressure washer

4. Conclusion

In this study, a high-temperature high-pressure washer that heats low-pressure cold water in the low-pressure boiler by supplying the combustion heat of diesel to make hot water, sends the hot water to the compressor to increase the pressure thereby making high-temperature high-pressure water, and sprays the water through the spray nozzle was studied and the following results were derived.

The spray quantity of water increased as the pressure of the high-pressure pump increased. The time taken to reach the steady state also increased as the pressure of the high-pressure pump increased. Therefore, the thermal efficiency of the high-pressure washer increased because the exhaust gas waste heat recovery system was installed at the exhaust gas outlet of the high-pressure washer to recover the waste heat of the exhaust gas and preheat the combustion air before being supplied. Thanks to the results as such, the amount of kerosene used by the high-pressure washer decreased and energy saving was realized.

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