Gas engine CGS that generates high-pressure steam utilizing waste heat from cooling water

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1. Introduction

The growing importance of distributed power and energy-saving systems has reignited the interest in gas engine cogeneration systems (CGS). High-efficiency gas engines were recently developed that could achieve the power generating efficiency nearly up to 50%, and they have already appeared on the market. Their spread is expected to contribute to stabilization of power supplies and the creation of a low-carbon society.

In addition to their high power generating efficiency, a recognized benefit of gas engine CGSs is that they permit waste heat to be utilized, allowing overall system efficiency to be further improved by making effective use of hot water and the steam obtained from exhaust gas. Conventionally the use of waste hot water was limited mainly to applications such as the heating of boiler feed water, air heating, hot-water supply, and air conditioning. But now we are developing a system to generate versatile steam from waste hot water.

In this paper, we explain a "Gas engine CGS that generates high-pressure steam utilizing waste heat from cooling water." It combines a steam generator that recovers waste heat by converting waste hot water to steam (MIURA's VS-400M, referred to below as "VS") and a screw compressor for boosting the pressure of low-pressure steam (Kobe Steel's MSRC160L, referred to below as "MSRC") with a high-efficiency gas engine (Mitsubishi Heavy Industries' 5750 kW 18KU30GSI, referred to below as "MACH").

2. System configuration

The system configuration is as shown in Figure 1. The temperature of the engine cooling water used by MACH is raised from 90°C (standard temp.) to 120°C. A standard system consists of one MACH combined with two VS+MSRC paired sets.

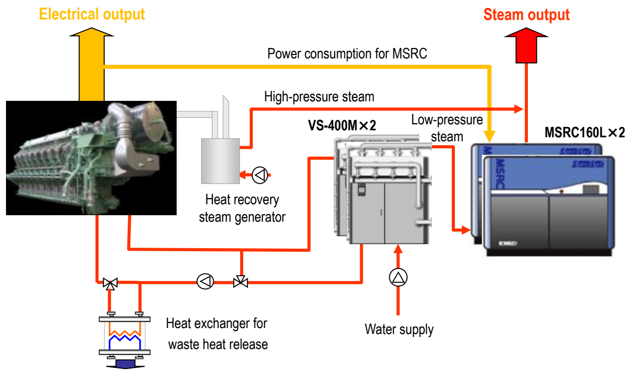

Figure 1 System configuration

The MACH engine cooling water (120°C) is supplied to VS and VS generates low-pressure steam (0.05 MPaG) by heat exchange. MSRC boosts the pressure of this low-pressure steam to a general-purpose pressure of approximately 0.7 MPaG, allowing it to merge with the heat recovery steam generator steam and be fed to steam processes.

3. Raising temperature of MACH engine cooling water

Figure 2 shows the pressure characteristics of suction steam pressure (=low-pressure steam). "Power consumption per steam generation" is an indicator of the power needed by MSRC to discharge 1 t/h of steam, and smaller value means high efficiency.

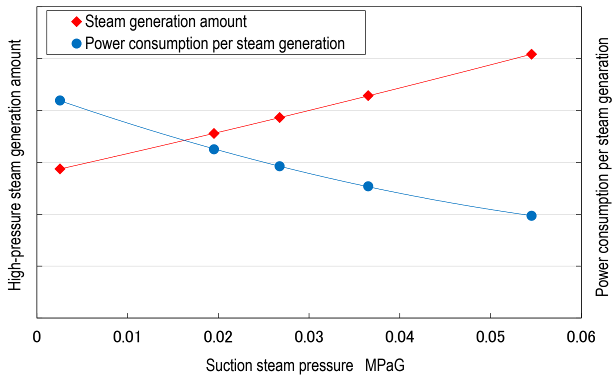

Figure 2 Characteristic of suction steam pressure for MSRC

For MSRC to run efficiently (i.e., with a low power consumption per steam generation), it is important that suction steam pressure should be high, and low-pressure steam depends heavily on the temperature of the engine cooling water supplied to VS. Development work was therefore carried out to raise the temperature of the MACH engine cooling water and so raise the temperature of hot water supplied to VS.

The parts and elements anticipated to be affected by higher engine cooling water temperature are as follows:

- O-rings in engine
- Combustion chamber parts
- Engine cooling water system components
- Lubricating oil and cooling water properties

Trials up to last year proved that engine cooling water temperature could be raised to 120°C without harming reliability or durability. Combustion was also optimized (limiting knocking and optimizing the air-fuel ratio). Power output, generating efficiency, and exhaust gas steam recovery efficiency were found to be equivalent to standard temperature specifications, and seasonal data on the amount of heat recoverable from hot water (air cooler and jacket) were also obtained (Figure 3). The amount of heat recoverable from hot water depends heavily on gas engine intake air temperature.

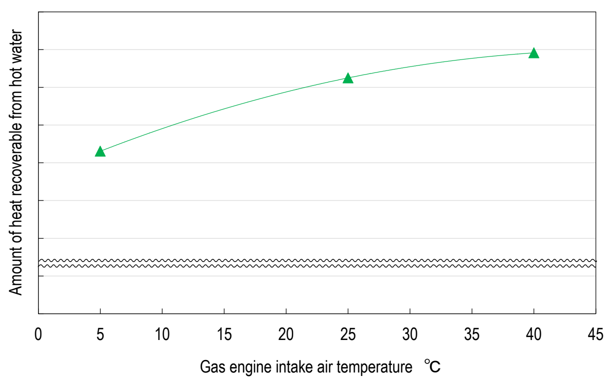

Figure 3 Relationship between intake air temperature and amount of heat recoverable from hot water in MACH engines

4. Development of VS+MSRC pairing

As the steam generated by VS can be fed to steam processes after pressurizing by MSRC, it is important that VS and MSRC should operate in tandem. If the combined control cannot be achieved, it could cause frequent start-stop or make the system less cost-effective to run.

To address this, a combined test system was set up at Tokyo Gas's Senju Techno Station in order to develop appropriate control specifications (including those for start-stop, shutdown, and emergencies). The control specifications were designed so that MSRC start-stop would be entirely controlled by commands from VS (except in the event of an emergency in MSRC), and as a result, the system was stably operated for more than 4,000 h. Assessment of the long-term performance of a combined VS+MSRC system is also underway. Development target performance is as shown in Table 1.

Table 1 VS+MSRC development target performance (with engine cooling water at 120°C and feed water at 60°C)

		VS+MSRC set x 1
0.6MPaG	VS steam output	810kg/h
	MSRC steam output	910kg/h
	MSRC power consumption	136kW
	Power consumption per steam generation	150kW/(t/h)
0.7MPaG	VS steam output	790kg/h
	MSRC steam output	900kg/h
	MSRC power consumption	151kW
	Power consumption per steam generation	168kW/(t/h)

Low-pressure steam generated by VS is compressed by MSRC to produce high-pressure steam. During the compressing process, water is injected to cool down the superheated compressed steam. As some of this water turns to steam due to the compression heat of the screw compressor, high-pressure steam output is approximately 10% points greater than low-pressure steam output.

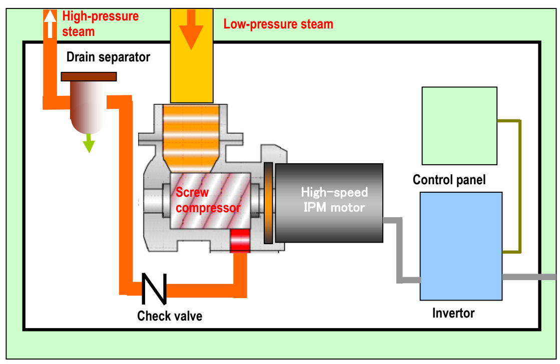

Figure 4 System configuration of MSRC

5. Performance of the gas engine CGS (that generates high-pressure steam utilizing waste heat from cooling water)

Based on the amount of heat recovered from hot water in MACH engines (Figure 3) and VS+MSRC development target performance (Table 1), it was determined that two VS+MSRC sets would be combined (used) per MACH to provide sufficient system capacity to operate at a high load year-round. Using this gas engine CGS makes it possible to raise steam recovery efficiency by approximately 10% points compared with a MACH of normal specifications, and overall efficiency can also be increased by 7%-8% points when power consumption by MSRC is also taken into consideration.

6. Future course of development

Various verification work will now be carried out to prepare the system for commercialization. And after this system is put on the market, following two points will be further developed to make the system more versatile.

(1) Development of steam compressor with improved negative pressure steam suction characteristics

The temperature of waste hot water from gas engines is normally around 90°C, and saturated steam pressure in this temperature range is negative. While a low suction steam pressure causes the power consumption per steam generation to worsen, as noted in section 3, still it may be better suited to a variety of engines as it requires fewer engine modifications.

(2) Raising of high-pressure steam

By increasing the pressure of high-pressure steam, it will be easier to supply the steam generated by this system more preferentially than the steam from the combustion boiler to the steam-using appliances (including steam absorption-type systems) which require pressure over 0.8 MPaG. Raising the pressure of high-pressure steam from this gas engine CGS will allow deployment of this technology without having to dramatically change existing process pressure, thus expanding the potential market.

7. Conclusion

The gas engine CGS that generates high-pressure steam utilizing waste heat from cooling water explained in this paper offers high power generating efficiency and allows waste heat to be recoverable in the form of steam of general-purpose pressure. As it has the potential to be widely deployed in factories, buildings, and other locations, we hope that it will soon see commercial release and contribute to further energy conservation as it enters widespread use.

8. Sources

(1) Kobe Steel website
http://www.steamstar.jp/msrc/index.html