Performance analysis of refrigeration system from exhaust gas waste heat of petrol engine

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Introduction

The vapor absorption system is one of the oldest techniques of producing refrigerating effect. This system can be used in both domestic and large industrial refrigerating plants. The vapor absorption system uses heat energy, rather than mechanical energy. In the vapor absorption system, the compressor is replaced by an absorber, pump, generator and a pressure reducing valve. In the system, the vapor refrigerant from the evaporator is drained into an absorption unit, wherever it is absorbed by the weak solution of the refrigerant founding a strong solution, which is pumped to the generator, wherever it is heated by some external source. During the heating process, the vapor refrigerant then flows into the evaporator and thus cycle is completed.

The vapor absorption refrigeration system uses at least two fluids. One fluid acts as a refrigerant even though the other as an absorber. The desirable properties of a refrigerant-solvent combinations are the absorber should have higher affinity to absorb the refrigerant, ideal absorbent should go on in liquid state under operating conditions, high boiling point, high specific heat for better heat transfer and low viscosity. However, ARS’s not hurtful inexpensive waste heat, solar, biomass or geothermal energy sources for which the cost of supply is

ABSTRACT

The Vapor Compression Refrigeration system (VCRS) currently used in the vehicles are exhibiting the main drawback of using power directly from the engine shaft to drive the compressor. This drawback leads compressor to consume more fuel to drive the engine. This issue can be overcome by vapor absorption refrigeration system. The energy loss from the vehicle can be utilized by the Vapor Absorption Refrigeration System (VARS), and thereby reducing the excessive work done by the engine. In this method, engine exhaust pipe line is coupled with the refrigeration system. The tests like performance, heat balance and emission test are conducted on an internal combustion petrol engine with and without absorption refrigeration system. The results such as performance of the engine, heat balance, emission from the engine are monitored. Significant observations are made utilizing waste heat by VAR system.

KEYWORDS: Refrigeration, VARS, Waste Heat, Petrol Engine.
small in many cases. Additionally, the working fluids of these methods are environmentally friendly. The overall performance of the absorption cycle in relations of refrigerating effect per unit of energy input generally poor, however, waste heat such as that excluded from a power can be used to realize better overall energy utilization. Ammonia/water (NH$_3$/H$_2$O) systems are broadly used where lower temperature is required. However, water/lithium bromide (H$_2$O/LiBr) system is also broadly used where reasonable temperatures are required (e.g. air conditioning). Ammonia/water (NH$_3$/H$_2$O) refrigerant pair was used in this system.

**Experimental Setup:**

**Fig. 1:** Schematic diagram of experimental setup

**Engine specification:**

- No of cylinders: 3
- No of strokes: 4
- Fuel: Petrol
- Rated power: 27.6 @5000 RPM
- Cylinder Diameter: 66.5 mm
- Stroke length: 72 mm
- Compression ratio: 9:2:1
- Orifice Diameter: 35 mm
- Dynamometer arm length: 200 RPM

**Fig. 2:** Front view of vapor absorption refrigeration system
Fig. 3: Back view of vapor absorption refrigeration system

The experimental setup consisting of the engine coupled to the refrigeration unit put to running mode. Vapor absorption refrigeration system consists of absorber pipe, Condenser, Generator, Evaporator and Generator pipe. The machine is to provide 60 w capacity of refrigerator with the components. The refrigeration system obtained was modified in order to put up the waste heat setting the generator tube to the exhaust pipe. The pipe coming from engine exhaust is coupled to the one end of the generator tube and the other end of the generator tube is free to atmosphere. When the engine starts working the exhaust gases are made to pass through the generator where the heat is recovered, which later discharges in to atmosphere. Aqua-ammonia refrigerant pair was used in this system.

Performance Of Petrol Engine (Maruti 800 Engine Setup):

Fig. 4: Performance of TFC (with and without absorption system)

Figure 4 shows the performance of multi cylinder petrol engine with increasing speed for various load conditions with and without absorption refrigeration system. TFC is almost same in both conditions.

Fig. 5: Performance of SFC (with and without absorption system)

Figure 5 shows the performance of multi cylinder petrol engine with increasing speed for various load conditions with and without absorption refrigeration system. SFC is almost same in both conditions.
Fig. 6: Performance of Thermal efficiency (with and without absorption system)

Figure 6 shows the performance of multi cylinder petrol engine for increasing speed with various load conditions with and without absorption refrigeration system. Thermal efficiency is almost same for both conditions.

Figure 7 shows the performance of multi cylinder petrol engine for increasing speed with various load conditions with and without absorption refrigeration system. Air fuel ratio shows not much difference in both conditions.

Fig. 7: Performance of air fuel ratio (with and without absorption system)

Fig. 8: Heat balance sheet without absorption system

Figure 8 shows the heat balance sheet of the engine. The percentage of waste heat from the multi-cylinder petrol engine without absorption system for increasing speed with various load conditions. Heat carried through brake power 10-20%. Heat carried away from exhaust gas 5-10%. Heat carried away from cooling water 40-50% and unaccounted heat losses 25-28%. Heat carried away from the cooling water is greater than the engine exhaust heat. In this experiment exhaust gas is the input source for refrigeration system. If cooling water as a heat source for the refrigeration system, it will produce more refrigeration effect.
Utilization Of Waste Heat With Absorption System:

**Fig. 9:** Exhaust heat Vs. Utilized heat from exhaust gas

Figure 9 represents the utilization of exhaust gas from engine. The utilized heat source is used to run the generator in absorption system. The amount of heat utilized is less. 60 W capacity of refrigeration system was used in this experiment. But it is also possible to run high capacity of refrigeration system using this amount of exhaust gas waste heat. The heat balance sheet of engine is analyzed with absorption system for increasing in speed and loading conditions.

Emission Test Comparison With And Without Absorption System:

The emission levels are compared with and without absorption system.

**Fig. 10:** Brake Power vs CO

Figure 10 shows carbon monoxide level with and without absorption system with different brake power levels. There is a slight increase in CO level with absorption system as compared to without absorption, but not significant.

Figure 11 shows hydrocarbon level with and without absorption system with different brake power levels. There is significant reduction in HC level in the presence of absorption system as compared to without absorption system.
Fig. 11: Brake Power Vs HC

Fig. 12: Brake Power Vs CO₂

Figure 12 shows carbon dioxide level with and without absorption system with different brake power levels. There is a slight reduction in CO₂ level in the presence of absorption system, but not significant.

Fig. 13: Brake power vs O₂

Figure 13 shows O₂ level with absorption and without absorption system. There is not much difference between with and without absorption system.
Fig. 14: Brake power vs NO\(_X\)

Figure 14 NO\(_X\) level with absorption and without absorption system with different brake power levels. There is a considerable increase in NO\(_X\) level in the presence of absorption system as compared to without absorption system.

Conclusion:

In the present study, the exhaust pipe line was coupled with vapor absorption refrigeration system. The results like TFC, SFC, Thermal efficiency, and air-fuel ratio show without much difference when comparing between with and without absorption system. Heat carried away from the cooling water is greater than the engine exhaust heat. In this study, exhaust gas is an input source for refrigeration system. If cooling water as a heat source for the refrigeration system, it will produce more refrigeration effect.

The amount of heat utilized was less in the present study. There was only 60 W capacity of refrigeration system was used in this study. But it is also possible to run high capacity refrigeration system utilizing the available exhaust gas waste heat. There is not much difference in the emission level of CO, O\(_2\), and CO\(_2\) with and without absorption systems. But there is a considerable reduction in HC emission with absorption system. Considerable increase in NO\(_X\) emission level is also observed with absorption system as compared to without absorption system. It is suggested that there is no harm using vapor absorption refrigeration system with the advantage of utilizing waste heat from engine exhaust gas.

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