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Analysis of Recoverable Exhaust Energy from a Light-duty Gasoline Engine by using Heat Pipe: A Review

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***Abstract:* - Heat pipe is a very effective heat transfer device. Due to high heat transfer capacity it becomes very effective device for absorbing heat from exhaust gases in the evaporator region and transported the heat to the condenser region where the vapor condenses to release the heat to cooling media. Heat pipe technology has found increasing application in enhancing the thermal performance of Internal Combustion Engine by utilizing the Waste Heat of Exhaust gases.**

***Keywords:* - Internal Combustion Engine, Waste heat recovery, Heat pipe, Exhaust Gas**.

I. INTRODUCTION

Efficient energy saving vehicle is needed for combating problems arising due to the increase in the exhaust emission and limited availability of gasoline. Now-a-days the sustainable vehicle developments are focused on four topics: emission legislation and control, new fuels, improved combustion and a range of advanced concepts for energy saving. [2]. Among various advanced concepts, Waste Heat Recovery System for Internal Combustion (IC) engines has been proved to not just bring measurable advantages for reducing fuel consumption but also increase engine power output (power density) or downsizing, further reducing CO2 and other harmful exhaust emissions correspondingly[3]. Vazaquez et al. predicted that if 6% of the heat contained in the exhaust gases were converted to electric power, 10% reduction of fuel consumption can be achieved [4]. Early researches on Waste Heat Recovery have investigated the basic concepts, problems and expected improvements for such a system. An example could be found from the research conducted by Chammas and Clodic [5], who presented the advantages offered by a Rankine Cycle (RC) system designed for hybrid vehicles. Up to 18% improvement in fuel economy could be achieved when water was used to recover the waste heat from exhaust gases. In Comparison to the conventional system of waste heat recovery of exhaust gases by turbocharger which is normally having 15% fuel saving and significant power increase, Rankine cycle can have more about 20% of fuel saving and similar power increase [6]. Although Rankine Cycle Waste Heat Recovery system has higher manufacturing cost, it does not increase the back pressure of exhaust gas and it can be installed after turbocharger to regenerate further exhaust energy which turbocharger is unable to absorb. Some reports show that how further investigation of the technology and architectures are possible [7]. For instance, Teng et al. carried out a series of experiments [8-10] on heavy-duty diesel engines to estimate the potential of Waste Heat Recovery, with hybrid energy systems combined the exhaust system with the charge air cooler and Exhaust energy recovery cooler(s). Their results show that up to 20% increase in the engine power and about 25% improvement in fuel savings over the ESC 13-mode test could be achieved by the Waste Heat Recovery system. Ringler et al. [11] selected two basic Waste Heat Recovery configurations: one just with exhaust gas only and another with exhaust gas plus coolant from various Rankine cycle layouts for a detailed evaluation of heat recovery based on a four-cylinder IC engine. Their experimental works indicate that waste heat recovery can produce an improvement in power output of about 10% at typical highway cruising speeds. Weerasinghe et al. [6] identified the substantial potential of Waste Heat Recovery for IC engines via two most promising and technically sound technologies: turbo-compounding and exhaust heat secondary fluid power cycles. Their results show that the two Waste Heat recovery technologies would contribute more power output in the order of 4.1%-7.8% and fuel savings by 2%-22%. Various researches suggest that over 20% improvement in fuel economy can be achieved from Waste Heat Recovery. In this paper, the study has been focused on the exhaust energy from a light-duty gasoline engine with the objective of exploring the available recoverable energy in exhaust gas. While the exhaust gas temperature and mass flow rate vary with engine operating conditions, the available exhaust energy for a steam Rankine cycle Waste Heat Recovery system and its characteristics under different engine operating conditions will be studied and then the optimal operating areas for utilizing the exhaust gas energy is identified.

II. LITERATURE REVIEW

In 2012, Tianyou Wang used the EER system based on Rankine cycle. The schematic diagram is shown in figure1 [1]. And the observation reveals following facts:

- The flow rate of working fluid plays vital role for controlling the steam outlet pressure and overheat degree. For achieving required overheat and steam pressure, the flow rate must be carefully adjusted in case the working condition of engine changes.
- The flow rate has also significant influence on the heat exchanger efficiency. For achieving better heat transfer efficiency, the flow rate should be as high as possible.
- It was found that EER system based on the light-duty test engine could increase the engine fuel conversion efficiency up to 14%, though under general vehicle operating conditions it was just between 3% and 8%.
- Although the heat exchanger can increase the exhaust back pressure slightly, the total fuel saving could be up to 34% under 2000 rpm and 75 Nm.

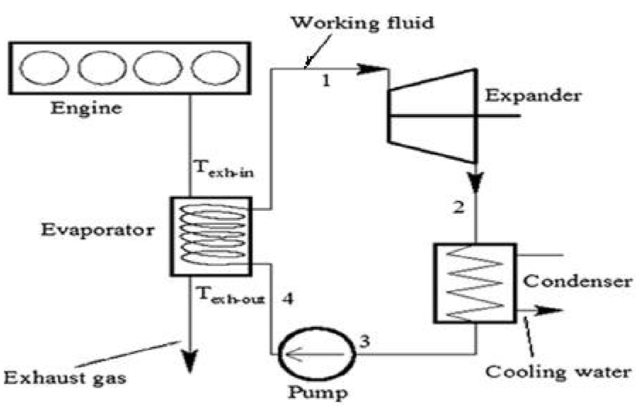

Figure 1 Schematic diagram of exhaust energy recovery system

In 2015, Tushar Tiwatane and Shivprakash Barve used heat pipe heat exchanger and different nano-fluids to recover waste heat from exhaust gases and suggested that [12]:

- The manufacture of lightweight heat pipes is a very important objective for current heat pipe industries and researchers.
- For developing nano-fluids for a wide range of heat transfer applications the understanding of the fundamentals of heat transfer and wall friction is very important.
- Heat transfer performance in a straight circular tube is amplified by suspension of hybrid nanoparticles in comparison with that of pure water. The average increase in Nusselt number for hybrid Nano fluid is 10.94% when compared to pure water.

In 2000, Ngy Srun AP used Exhaust gas heat recovery system for Exhaust Gas Recovery cooling and heating passenger compartment [13]. The schematic diagram is shown in figure 2. He observed that the exhaust heat exchange coefficient in a pipe of internal combustion engine expressed by the Nusselt-Reynolds correlation is

- Two times greater than the conventional Colburn correlation at the steady state conditions for low Reynolds number (Rd < 2 000).
- At high Reynolds number (20 000) both correlations have approximately the same values.
- This simple correlation allows calculating and designing the exhaust-coolant heat exchangers for NOx reduction and improvement of passenger compartment, heating for Turbo-Diesel with Direct Injection and Gasoline Direct Injection engines.

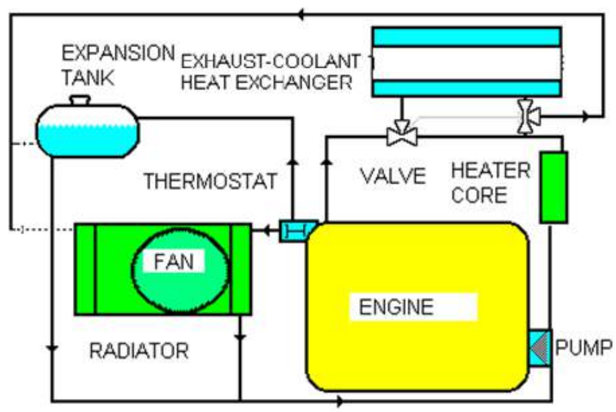

Figure 2 exhaust coolant heat exchanger on the coolant circuit for passenger compartment heating application

III. CONCLUSION

From the review it can be concluded that: It is proven beyond all doubts by researchers through their experiments that a considerable amount of heat is wasted in Internal Combustion (I.C.) Engines. More research is needed in Heat Recovery (HR) System design keeping practical aspects in view. Among all the available methods the Heat pipe heat recovery system is most efficient. The Heat pipe Waste Heat Recovery System should be implemented in different field such as chimney of food processing unit, locomotives etc.

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