iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** X **Month of publication:** October 2016

DOI:

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Thermal Analysis of Exhaust Heat Exchanger in Automobile Thermo Electric Generator

B. Jagadeeshbabu[1], D. Lokanadham[2], P. P. Dhanunjayarao[3]
Mechanical Engg. Aditya Institute of Technology and Management, Tekkali

Abstract- By the view of increasing fuel costs and environmental issues, it is a requirement to manage the power utilization. In here it is mere focus on the automobile that, they take major contribution out of all power produced devices. in the view of power management it is here utilize the waste heat from exhaust of automobile. ideal heat exchangers recover as much heat as possible from an engine exhaust at the cost of an acceptable pressure drop .they provide primary heat for a thermoelectric generator (TEG) ,and their capacity and efficiency is dependent on the material ,shape and type of heat exchanger .three different exhaust heat exchanger were designed within the same shell ,of empty ,parallel plate serial plate exchanger and their ANSYS models were developed to compare heat transfer and pressure drop in typical driving cycles for a vehicle with 1.2L gasoline engine .The result showed that the serial plate structure enhanced heat transfer and transferred the maximum heat .it also produced a maximum pressure drop.
Keywords— Slag; ANSYS, Exhaust Heat Recovery, Thermo Electric Generator, Automobile Exhaust, Heat Transfer.

I. INTRODUCTION

Considering the climate change and the shortage of non-renewable energy resources,the interests in waste heat recovery has been growing remarkably, especially during the past decade. Waste heat recovery from internal combustion engines (ICE) is one of the opportunities for economizing of energy consumption. In an ICE, a great amount of fuel energy is wasted in form of heat due to thermal limitations. Roughly one-third of fuel energy is converted to mechanical power and the rest is released to the ambient in form of heat. Different methods have been recommended for waste heat recovery from ICE; such as thermoelectric, absorption refrigeration system, and organic Rankine cycle (ORC). The If only a part or even a minor amount of the large waste heat could be recovered and converted into electricity, a great sum of heat would be saved and the system efficiency of the vehicle would increase substantially.

Various thermodynamic cycles have been proposed and studied for low-grade waste heat recovery. An absorption cooling cycle in hybrid and electric vehicles transfers waste heat from the battery pack and exhaust gases into the boiler ofejector for cabin cooling [2]. The organic Rankine cycle system possesses the capability to convert low grade heat sources into electricity [3]. An open steam power cycle (open Rankine cycle) has greater waste heat recovery efficiency than other Rankine steam cycles [4]. A combined thermoelectric generator and organic Rankine cycle was proposed to increase the system performance of exhaust heat recovery [5]. Usually, the disadvantage of these cycles is the secondary fluid circuit composed of a pump, an evaporator, an expander and a condenser; the circuit increases vehicle weight and mechanical complexity and reduces available volume. Based on the Seebeck effect, the thermoelectric generator system takes the advantage of no moving parts, silent operation, and very reliable, therefore better suited waste heat recovery from automobile exhausts than the above cycles [6].With the development of advanced thermoelectric materials, the direct energy conversion of waste heat into electric The material, the shape and type of an exhaust heat exchanger have been studied previously. Two shapes of exhaust heat exchangers are generally used for an automobile exhaust TEGs: box and cylinder shells with internal fins. Early in the 1988, Birkholz et al. [10] proposed a 300 mm_300 mm_500 mm rectangular structure with internal fins made of the Hastelloy X alloy for the Porsche 944 engine. The box's height was high enough to prevent engine power deterioration. Bass et al. [11] designed a hexagonal cylinder that was 470 mm in length and 220 mm in diameter with a center hollow displacement conic heat-diffuser. Ikoma et al. developed a 160 mm_40 mm_455 mm rectangular box using SUS304 stainless steel [12]. Fins with different area ratios were set inside the inner shell, parallel to the gas flow, to transfer more heat [13,14] Thacher et al. [15] used a rectangular 1018 carbon steel compact heat exchanger with offset strip fins for a 1999 GMC Sierra pickup truck. Crane et al. [16] employed a cylindrical design with internal folded fins made of stainless steel–clad copper. As for the exhaust heat exchanger optimization and theoretical analyses, CFD simulations and geometry improvements were conducted to enhance turbulence and heat transfer. Crane et al. [17] used hot water as a heat source and air as a heat sink to simulate an exhaust thermoelectric generator. Martinez et al. [18,19] calculated the thermal resistance and pressure drop for a heat exchanger

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

and used computational fluid dynamics to optimize the thermoelectric generator for a domestic gas boiler. Ming Pan [20] conducted thermal and hydraulic calculations on the intensification combinations. Gou [21] studied the dynamic characteristics of heat reservoir and heat sink for thermoelectric generators.

The present work reviews existing exhaust heat exchangers and proposes several internal structures: an empty cavity, a parallel plate structure, a serial plate structure. ANSYS models were developed with solid domains, liquid domains and fluid solid interfaces to compare the heat transfer and pressure drop for the 3 structures under the same working conditions. The numerical results suggest that the serial plate structure offers the highest heat transfer, while its pressure drop is excessively large under the maximum power output condition.

II. MODELLING

THREE internal structures of exhaust heat exchangers have been modeled for the purpose of comparison. All the three structures were made with the same dimensions, with a shell of 120mm *40mm of elliptical structure with the inlet and outlet of 40 mm in diameter for 3 of the structures. The pipe structure was reduced to 26 mm in diameter because the shell body was 30 mm thick. At both ends of the box, there were gradual enlargements andcontractions of approximately 90 mm in length to buffer and distribute exhaust flow. Each exhaust exchanger had a different internal structure: an empty cavity, a parallel plate structure, a serial plate structure. To reduce mesh quantity and promote the robustness and precision, only half of the whole body was used, and the model was obtained using a symmetrical plane. The number of mesh elements increased with complexity. An empty cavitystructure had the fewest elements with 108, 174, and the serial plate with holes structure had the most elements with 271, 340, 71% more than the former. The quality and quantity of a mesh for a certain physical body determines the robustness, accuracy and scale of the simulation computation. Skewness is one of the primary quality measures for a mesh. A value of skewness in the range of 0.1–0.3 indicates that the corresponding mesh quality is good. The mesh quality for the three structures was in the range given in Table 1.

Table 1: Mesh of Each Scheme

Scheme	Empty cavity	Parallel plate	Serial plate
Nodes	750,227	134,029	130,306
Elements	108,174	274,084	271,340
Skewness	0.10424	0.21426	0.28173

III. SIMULATION AND OPERATING CONDITIONS

The exhaust mass flow, exhaust temperature and hot side temperature of thermo electric generators are three key variables, and they depend on the automotive configuration, operation conditions and available thermo electric materials.

A. Exhaust State

Exhaust is a mixture of multiple compositions andisthermodynamicallysimilartoair.Exhaustisapproximately300–500kPainpressureand500–700^{0}Cin temperature when discharged from the engine cylinder. After passing through the catalytic converter and several connecting pipes, the pressure drop nears the atmospheric pressure and the temperature decreasesto300-600^{0}C because of local and frictional losses and heat leaks. The initial state of the exhaust gas at the inlet is important as a heat source for two reasons: first, it determines the maximum available heat in reference to the atmosphere state; second, it determines the upper temperature limit to exposed and which it must survive.

B. Hot side temperature of a hermoelectric generator

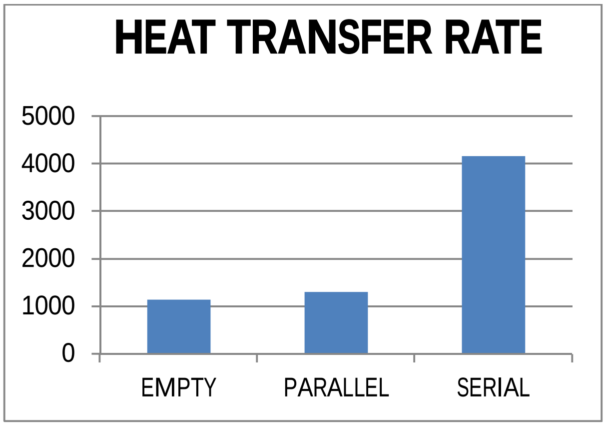
The hot side of the thermo electric generator absorbs heat from the shell and transfers it to the cold side. Its upper temperature limit is subjected to the maximum continued temperature the thermo electric material can be exposed to, for instance, 150–250^{0}C is acceptable for Bi_2Te_3. According to the range of the above variables, three typical operation conditions were considered in Table4: urban and suburban driving cycles and maximum power output.

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

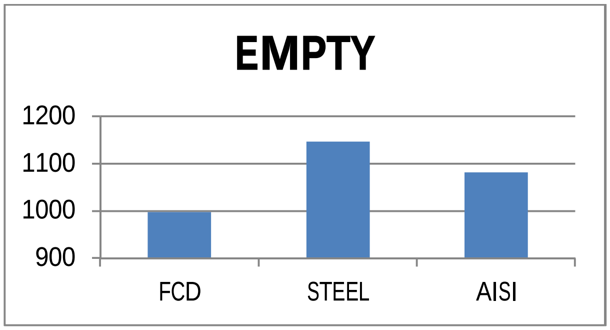
IV. RESULTS AND DISCUSSION

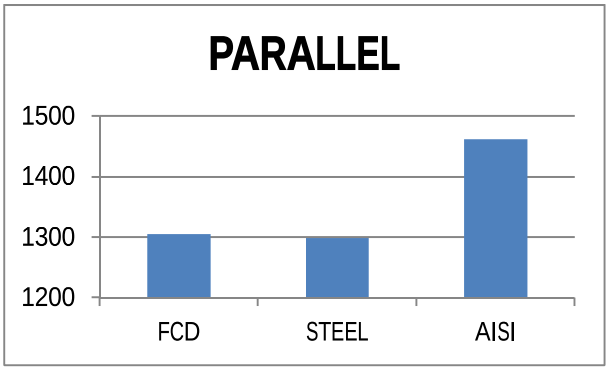
A. Heat transfer rate

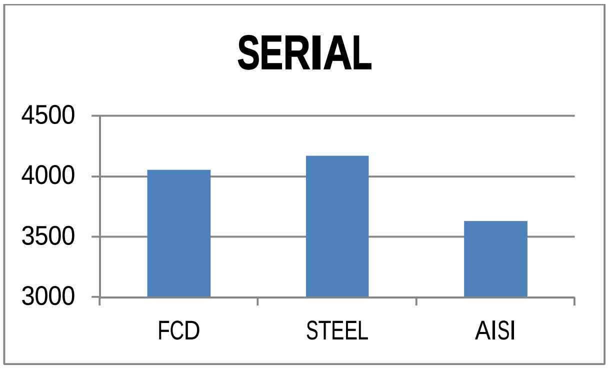
For the same material, serial plate structured TEG has highest heat transfer rate compared to the empty and parallel types.



For same type of structure



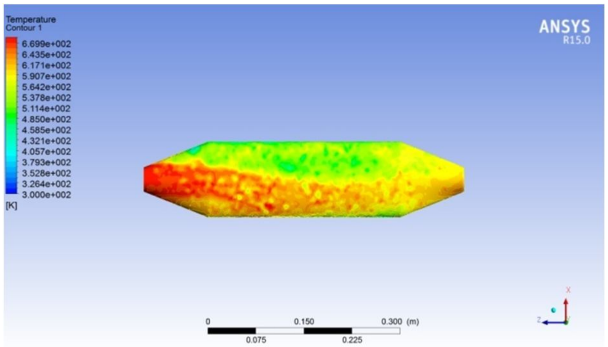




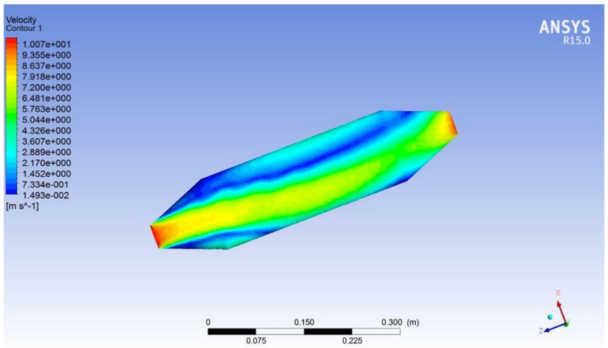
B. Temperature field and velocity field analysis

1) Physical distribution in an empty cavity:

a) Temperature field

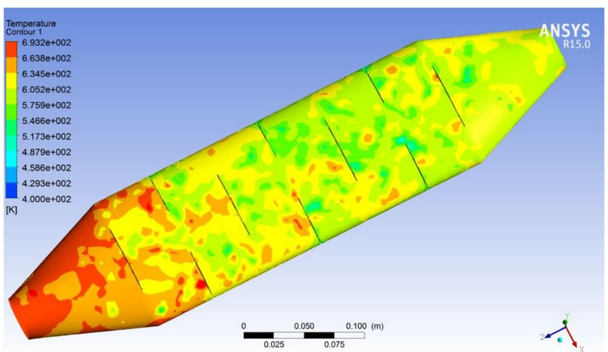


b) Velocity field

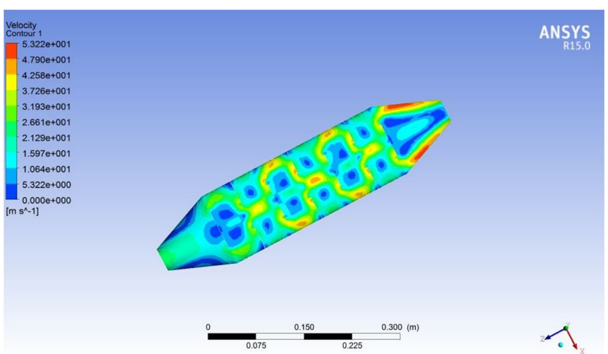


2) Physical distribution in an parallel cavity

a) Temperature field



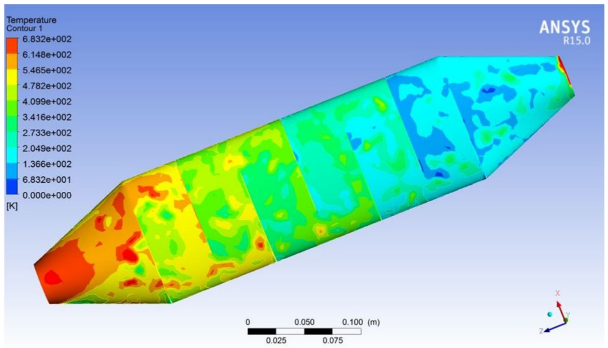
b) Velocity field



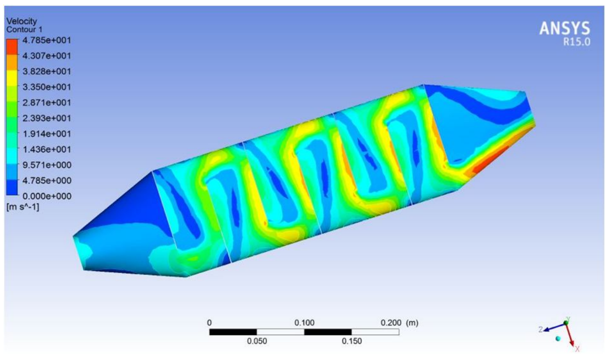
Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

3) Physical distribution in a serial cavity

a) Temperature field



b) Velocity field



A different thermal performance and aerodynamics originated from the temperature field and the velocity field of heat exchangers. It was necessary to analyze the physical field of the 3 structures under the same driving cycle. A symmetrical plane along the thickness of the shell was generated to obtain the temperature field and the velocity field of the exhaust. For the empty cavity, the exhaust expanded gradually at the inlet because it entered the body and left the shell wall with almost the same main flow area, as shown in Fig. In the absence of any structure or fin, some eddies with low temperature and low velocity appeared in the upper side of the empty cavity the most of the hot exhaust left directly from the structure. Compared with the empty cavity, the presence of anparallel fin, as shown in Fig, destroyed the large eddy and allowed the hot exhaust to disperse and collide with walls. Consequently, the heat transfer increased and the pressure drop also increased. To further enhance the turbulence and heat transfer, serial plate structure were proposed together.

V. CONCLUSIONS

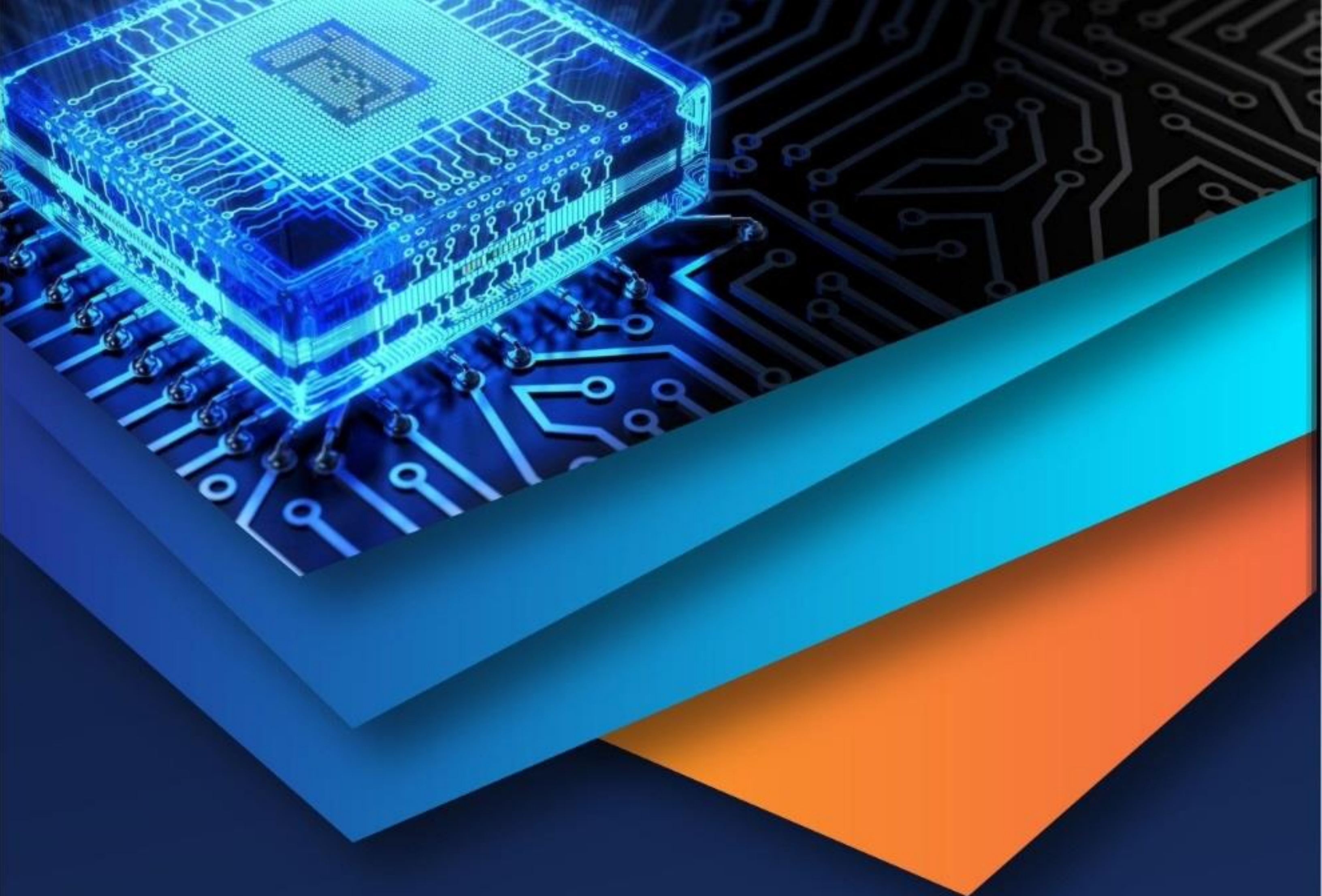
ANSYS models with a solid domain, liquid domain and fluid–solid interfaces were developed for 3 exhaust heat exchangers to simulate the temperature field and the velocity field Under same driving cycles, the descending order of pressure drop for 3 of the structures is the same as that for the descending magnitude of the heat transfer rate: serial plate structure, parallel plate structure, and empty cavity .Among the 3 heat exchangers, the pipe structure has the2ndgreatest pressure drop and the4thgreatest heat transfer rate. The serial plate structure forced the exhaust to flow back and for there by 7 baffles, enhanced the heat transfer with the shell wall and had the maximum heat transfer rate of all the structures.

REFERENCES

[1] YuC, Chau KT.Energy Convers Manag 2009; 50:1506–12.
[2] Javani N, Dincer I, Naterer GF.Energy 2012; 46:109–16.
[3] Wang D, Ling X,Peng H, Liu L,TaoL. Energy 2013; 50:343–52.
[4] Fu J, Liu J, Ren C, Wang L, Deng B, XuZ. Energy 2012; 44:544–54.
[5] Shu G, Zhao, Tian H, Liang X, Wei H. Energy2012; 45:806–16.
[6] Yang J. In: IEEE proceedings of the 24thinternationalconferenceonthermoelectrics; 2005ISBN0-7803-9552-2, ISSN1094-2734, p.170.
[7] Bell LonE.Science2008; 321(12):1457–61.

Volume 4 Issue X, October 2016
ISSN: 2321-9653

[8] http://chinaafc.miit.gov.cn/n2050/index.html.
[9] GB/T 19233-2008 Measurement methods of fuel consumption for light-duty vehicles.
[10] Birkholz U, Grob E, Stohre U, Voss K. In: Rao KR, editor. Proceedings of the 7th international conference on thermo electric energy conversion. Arlington, TX: University of TexasatArlington; 1988. p.124–8.
[11] Bass J, Elsner NB, Leavitt A .In: Mathiprakisam B, editor. Proceedings of 13 international conference on thermo electrics (AIP Conf.Proc., NewYork); 1995.(p.295–8.).
[12] KobayashiM,IkomaK,FuruyaK,ShinoharaK,TakaoH,ImanishiY,etal.In:FleurialJP,editor.Proceedingsofthe15thinternationalconferencenthermoelectric;1996.(p.373–7.).
[13] Ikoma K, Munekiyo M, Furuya K, Izumi T, Shinohara K. In: Koumoto K, editor. Proceedings of the 17th international conference on thermoelectric; 1998.(p.464–7).
[14] Ikoma K, Munekiyo M, FuruyaK, Kobayashi M, Kouatsu H, Shinohara K.J Jpn Inst Met1999;63:1457.
[15] Thacher EF, Helen brook BT, Karri MA, Richter CJ.JAutomobEng2007; 221:95–107.
[16] Crane DT, Lagrandeur JW.J Electron Mater 2010; 39:2142–8.
[17] Crane DT, Jackson GS. Energy Convers Manag 2004 ;45:1565–82.
[18] Martinez A, Vian JG, Astrain D, Rodriguez A, Berrio I. J Electron Mater 2010;39:1463–8.
[19] Rodriguez A, Vián JG, Astrain D, Martinez A. Energy Convers Manag 2009;50:1236–43.
[20] Pan M, Jamaliniya S, Smith R, Bulatov I, Gough M, Higley T, et al. Energy 2013;57:208–21.
[21] Gou X, Yang S, Xiao H, Ou Q. Energy 2013;52:201–9.



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY