IJCRT Publish Paper record is available at DOI: http://doi.one/10.1727/IJCRT.17140

Thermoelectric Generator System for Generation of Electric Power through Waste Heat Energy from Two Wheeler Silencer

Dr. D. S. Deshmukh[1] Mr. P. M. Solanki [2] Dr. V. R. Diware[3] Dr. S. P. Shekhawat[4]

([1]*Associate Professor, DBACER, YCCE Campus, Wanadongari, Nagpur, Nagpur, (M. S.), India,)*
([2]Research Scholar, Mechanical Engineering, SSBT`s COET, Bambhori, Jalgaon, (M. S.), India,)
([3] Associate Professor & Head, Chemical Engineering, SSBT`s COET, Bambhori, Jalgaon, (M. S.), India,)
([4] Professor & Head, Mechanical Engineering Dept., SSBT`s COET, Bambhori, Jalgaon, (M. S.), India,)

Abstract— **A number of irreversible processes in the engine limit its capability to achieve a highly balanced efficiency. These rapid successions of events happening in the cylinder create expanding exhaust gases with pressures that exceed the atmospheric level, and they must be released while the gases are still expanding to prepare the cylinder for the following processes. By doing so, the heated gases produced from the combustion process can be easily channelled through the exhaust valve and manifold. The large amount of energy from the stream of exhausted gases could potentially be used for waste heat energy recovery to generate power. Various methods to harness the waste heat to produce power effectively had ended up in vain. This paper proposes and implements a thermoelectric waste heat energy recovery system for internal combustion engine automobiles, including gasoline vehicles. The key is to directly convert the surface heat energy from automotive waste heat to electrical energy using a thermoelectric generator (TEG). The experimental results demonstrate that the proposed system can work well under different working conditions, and is promising for automotive industry.**

Keywords*— Thermoelectric Generator, *Waste heat from two wheeler silencer, TEG Module, heat source,

I. INTRODUCTION

There is no system which converts total input energy into output energy practically, there are some losses. In the universe there is no system which is 100% proficient, due to losses system effectiveness decreases in real practices. Automobile sector are an example of high energy usage with low competence. It has 30% efficiency and roughly 75% of the energy produced during combustion and roughly 75% of the energy produced during combustion is lost in the exhaust or engine coolant in the form of heat. If this energy is tapped and transformed into functional energy, the overall efficiency of an engine can be improved. Thermoelectric technology can be used to generate electrical power from waste heat. Thermoelectric generator utilizes the Seebeck effect which was first observed in 1821. Thermoelectric generator practically came into existence in 1960 which were developed appreciably and since then number of manufacturers are now marketing thermoelectric modules for power generation, heating and cooling applications. Constant research and advances in thermoelectric materials and manufacturing techniques, enables the technology to make an increasing efforts to address the growing low power energy sources typically used in energy harvesting and scavenging systems. Thermoelectric generator can be used to generate a small amount of electrical power, typically in the microwatt (μW) range, if a temperature difference is maintained between two terminals of a thermoelectric generator.

The hotness of exhaust gas pipe of an engine is very high when exhaust gases are flowing through it and that is around 200°C to 300°C. Thermoelectric generator is model for such applications as they are small, with no moving parts and relatively efficient at this temperature. Thermoelectric generator is basically solid state devices that are used to convert thermal energy from temperature gradient to electrical energy. By using waste thermal energy through IC engines exhaust to charge the battery instead of using an alternator the overall fuel economy can be increased by 10%.

II. PROBLEM STATEMENT

There is need of waste heat recovery because we are facing the problem of energy crisis in terms of conventional sources of energy. By using waste heat we can save not only conventional sources of energy but also we can enhance the efficiency of these sources of energy. By using waste heat we can go along with sustainable development in an easy way as it is the demand of today's world. It is better to have something rather than having nothing and in the case of heat recovery we are saving some amount of energy which we can use not only for our self but also for upcoming generation. In general we can say that by saving waste heat we are not only securing our self but also upcoming generation from facing the problem of energy crisis which is the current issue of today's world and it also play an important role in making India a developed country as energy plays an important role in other dimensions which are related to our economic zones.

III. OBJECTIVES

The main focus of this paper is to develop experimental setup for conversion of waste heat energy (from Silencer of Two Wheeler) into electricity using thermoelectric generator (TEG). In this the conversion of waste heat directly into electricity by using thermoelectric generator. Waste from automobile exhaust heat, refrigerator heat, vehicle radiator heat, can be used as an input source as a waste heat to generate electricity .The objective of this paper is to study thermoelectric generator performance

IJCRT Publish Paper record is available at DOI: http://doi.one/10.1727/IJCRT.17140

analysis through experimentally investigate the performance of Thermoelectric Generator system i.e. with air source as cooling media and water source as cooling media.

IV. SCOPE

In present scenario, the communities are facing a major problem of energy crisis. The sources of renewable and clean energy are always welcomed. Thermoelectric technology is the source of such clean energy which generates energy by utilizing waste heat mainly from automobiles and very little research work is available therefore it is needed to contribute in setting up the appropriate experimental set up this Thermoelectric technology with the help of thermoelectric modules directly converts temperature gradient into electric energy.

V. METHODOLOGY

Methodology is the method that has been used from earlier project developed until the end product release. It consists of several stages of conducting this experimentation based on Literature Review. The next steps include study of automobile exhaust system on thermal basis. Then it was followed by identification and selection of component and fabrication.

1. Study of automobile exhaust system:

The temperature distribution of the exhaust exchanger was crucial for the TEG in three aspects: firstly, it determined the available thermoelectric material by maximum continuous operating temperature; secondly, it seriously affected the energy conversion efficiency of heat to electricity; thirdly, it dominated the uniformity of thermal stress in device level and module level. A non-uniform thermal stress made the contact between Thermo Electric module and heat exchanger rough, or even worse resulted in permanent damages to TEG modules.

The interface temperature of heat exchanger was just 210^{0}C on average when TEG used at the end of exhaust system . The highest temperature was 240 ^{0}C at the inlet and the minimum temperature was proximately 170 ^{0}C at the outlet. Considering that low-temperature thermoelectric modules (appropriate temperature 250 – 350 ^{0}C) are used in the TEG, the temperature of heat exchanger cannot meet the module's demand.

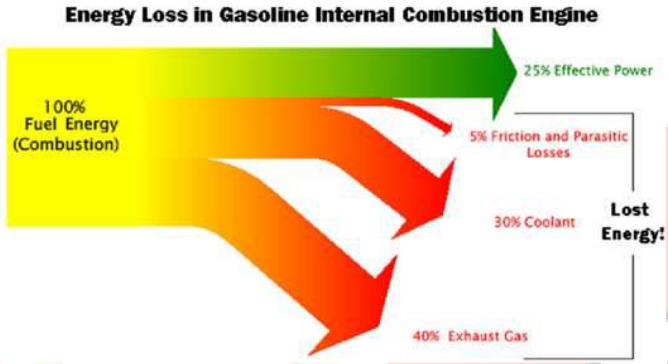


Fig. 1: Energy loss in Gasoline IC Engine [21]

2. Back pressure of an exhaust system:

The hot exhaust flowed into the exhaust gas system and transferred heat, which was bound to pressure drop for fluid. From the perspective of an automobile engine, this pressure drop was equivalent to a rise in the ambient pressure and naturally a drop in output power. In some cases, for the maximum power output, the pressure drop may be so high that the engine would stop working. It was necessary to test and evaluate pressure drop level of different cases under wide range of operating conditions. Corresponding to the different revolving methods of the engine in the three cases, there were 9 operating conditions for the exhaust gas system. It was general for each case: the more the revolving speeds, the larger the pressure drops.

VI. DEVELOPMENT OF EXPERIMENTAL SETUP

1. Accessories:

Sr. No.	Name Of Accessories	Specifications	Quantity
1	Thermoelectric Generator	TEG1-1268-4.3	1
2	Battery	12 V	1
3	Voltmeter	0-30 V	1
4	Ammeter	0-10 A	1
5	Thermo-Hygro Clock	0-100 0C	1
6	Thermocouple	0-1300 0C	2
7	Heat Sink	2*2*2 inch	2
8	Two Wheeler Silencer	Hero Honda Splender	1
9	Wiper Motor With Water Tank	Maruti 800, 12 V, wiper Motor, wiper tank	1

IJCRT Publish Paper record is available at DOI: http://doi.one/10.1727/IJCRT.17140

10	Thermal Grease	Heat Sink Compound	1

Table 1: List of Accessories

VII. BLOCK DIAGRAM OF PROTOTYPE

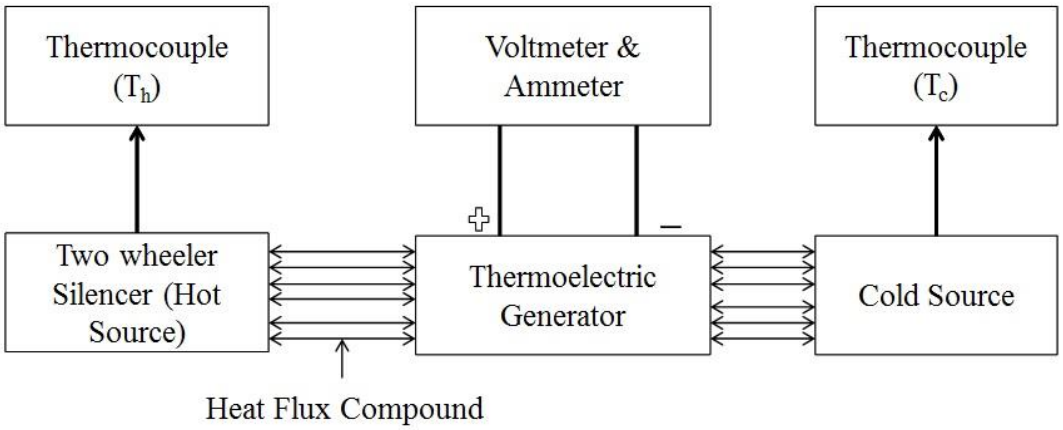


Figure 2: Block Diagram of Prototype

As shown in figure 2 thermoelectric module placed between two wheeler silencer as hot source and heat sink as cold source. Heat flux compound is applied on hot side of TEG module to increase thermal conductivity. Two thermocouples T_1 and T_2 are connect to two wheeler silencer and heat sink to measure respective temperature and their temperature gradient. The output from TEG module is measured by voltmeter and ammeter which is connected to two terminal of TEG module as the temperature of silencer increases it act as the hot source to the TEG module through the heat is provided to other side i.e. cold side of the TEG module. Temperature gradient across the TEG is developed thermoelectric module which works on the seebeck effect, which generates electric energy when there is temperature gradient across TEG module.

VIII. WORKING PROCEDURE

The vehicle is started and the acceleration is to be given, so that the amount of heat leaving the exhaust will be increased. Due to this heat, the surface of the exhaust pipe and the silencer will be heated to very high temperatures. These hot surfaces will try to liberate the heat to the atmosphere, which acts as a heat sink. Since the atmospheric temperature is less than that of the silencer surface, a temperature difference is created and hence the surface tries to attain the equilibrium state through the heat transformation process. But this will take much longer time. Hence in order to increase the rate of heat transfer the thermal grease is used. The thermal grease is coated on the hot surface of the silencers and also in the inner surface of the fins which are present in the upper part. The fins are also used to increase the heat transfer rate. As the vehicle moves, the air flow will take place between the fins and it acts as the sink. As the surface of the silencer gets more and more heated the heat transfer rate will increase due to the increase in the temperature difference. The TEG module is placed between the Heat Source (Hot Silencer Surface) and the Heat Sink (atmosphere) and the fins are placed above the module. The module is made of semiconducting materials. Hence by the principle of Seebeck Effect, the temperature difference can be directly converted into voltage by using some thermoelectric materials. Based on this effect, when the surface heat of the silencer is passed on to the atmosphere, the electrons and holes of the thermo electric semiconductors will try to move towards the junction and make the flow of electric current to be possible, then voltage develops. Hence this voltage can be connected to some battery and stored, or else it can be given directly to some electric appliances which uses DC. If we need AC voltage, it can be converted using the rectifier. The voltage generated can be increased by placing more number of modules and connecting them with one another to meet the demand of the required voltage. This voltage can then be supplied to the suitable electrical appliances.

IX. EXPERIMENTAL TESTING OF THE PROTOTYPE

Two tests were performed as follows:
1. Using Air Source as Cooling Media
2. Using Cold Water Source as Cooling Media

1. Using Air Source as Cooling Medi**a**

IJCRT Publish Paper record is available at DOI: http://doi.one/10.1727/IJCRT.17140

Figure 3: Air Cooling Setup

The prototype of air cooled model is made which contain heat sink as cooling media. Also prototype consists of TEG module, heat sink, voltmeter & ammeter, thermocouples etc. The prototype is mounted on the vehicle with the help of clamping. The vehicle is started and acceleration is given to increase the amount of flue gases flowing through exhaust as the surface of exhaust pipe increases the temperature difference between the surfaces of exhaust pipe and surrounding also increases. This temperature difference is converted into voltage output with the help of thermoelectric module by Seebeck effect.

2. Using Cold Water Source as Cooling Media:

Figure 4: Water Cooling System

In this test cold water used as cooling media of TEG setup in the heat exchanger. This prototype consists of, TEG module, heat exchanger, water tank, water pump, battery, water tubes, voltmeter, ammeter, thermocouples, clamping devices etc. The setup is assembled as the air cooled setup only difference was that heat sink replaced by the water heat exchanger. The prototype was mounted on the silencer of vehicle. The vehicle and the water circulation were started simultaneously and acceleration was given to the vehicle. The silencer gets heated with hot flue gases which act as hot side for the TEG module. On the cold side of the TEG module where the heat exchanger was attached, due to the water circulation it acts as the cold side for the TEG module. And as stated earlier the temperature difference was developed and output voltage obtained which were measured by the measuring devices i.e. voltmeter and ammeter.

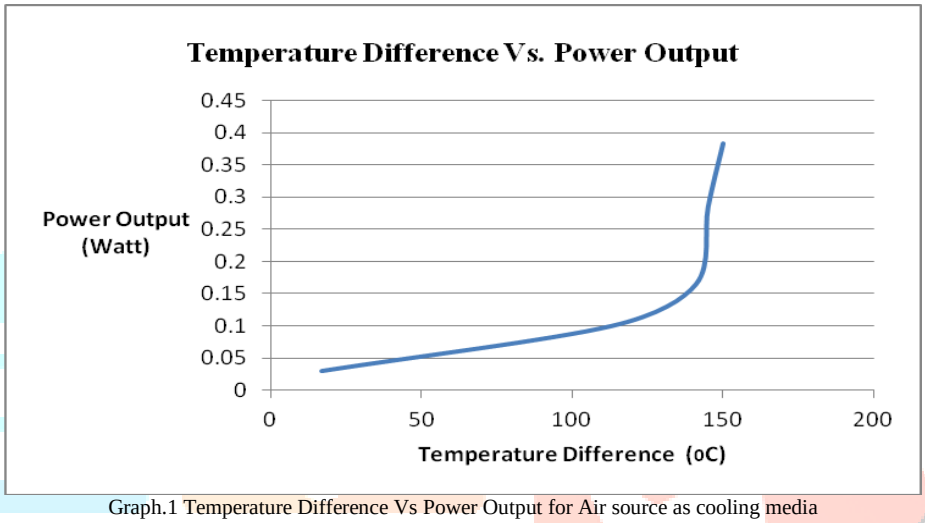
X. OBSERVATIONS

1. Using Air Source as Cooling Media:

Sr. No.	Hot Side Temperature T_h (^{0}C)	Cold Side Temperature T_c(^{0}C)	Temperature Difference $\Delta T=T_h-T_c$(^{0}C)	Voltage V (Volt)	Current I (Amp)	Power P (Watt)

1	50	33	17	0.6	0.05	0.03
2	100	34	66	0.8	0.10	0.08
3	150	37	113	1.0	0.10	0.1
4	180	39	141	1.5	0.11	0.165
5	185	40	145	1.9	0.15	0.285
6	190	40	150	2.4	0.16	0.384

Table 2: Observation during Air Cooling Source as Cooling Media Test

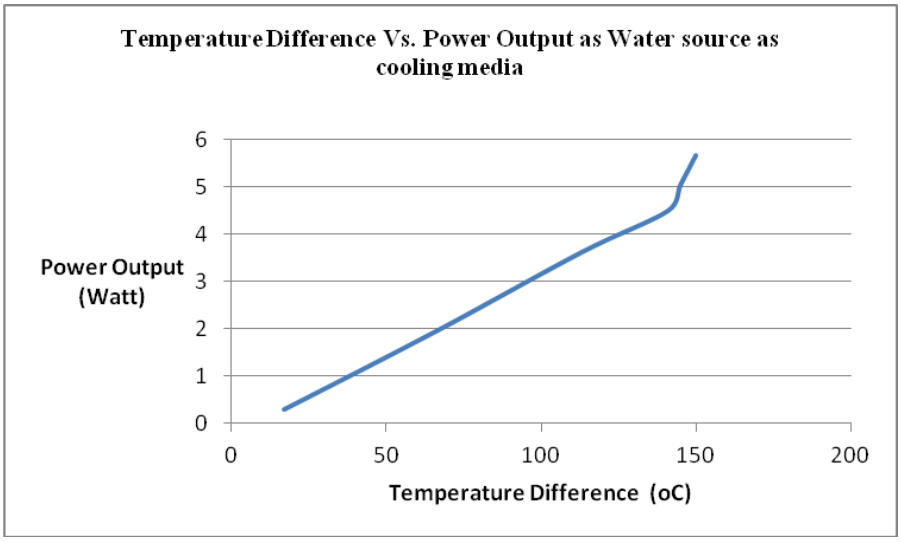


Graph.1 Temperature Difference Vs Power Output for Air source as cooling media

2. Using Cold Water Source as Cooling Media:

Sr. No.	Hot Side Temperature T_h (^{0}C)	Cold Side Temperature T_c (^{0}C)	Temperature Difference $\Delta T = T_h - T_c$ (^{0}C)	Voltage V (Volt)	Current I (Amp)	Power P (Watt)
1	50	33	17	1.2	0.25	0.3
2	100	34	66	3.25	0.60	1.95
3	150	37	113	4.7	0.77	3.62
4	180	39	141	5.3	0.85	4.5
5	185	40	145	5.8	0.87	5.04
6	190	40	150	6.3	0.9	5.67

Table 3: Observation during Cold Water Source as Cooling Media Test



Graph 2: Temperature Difference Vs Power Output for Water source as Cooling media

XI. CONCLUSION

It is concluded that the performance of thermoelectric generator is improved with water source as cooling media than the air source as per experimentation studied thermoelectric generator performance analysis experimentally with two cooling media. Thus the eco-friendly power generation method can be implemented for domestic and commercial use at an affordable cost. The efficiency of the engine will not be affected because only the surface heat of the silencer is drawn out. Further study can be extended increased output by connecting a number of TEGs in series and parallel.

XII. REFRENCES

[1] Ajay Chandravanshi, Dr. J. G. Suryavanshi, "Waste Heat Recovery from Exhaust Gases through I C Engine Using Thermoelectric Generator" (Research paper, volume: 3 | Issue: 7 | July 2013 | ISSN - 2249-555X), Visvesvaraya National Institute of Technology, Nagpur (440010) Maharashtra, INDIA.
[2] Baskar P, Seralathan S, Dipin D, Thangavel S, Norman Clifford Francis I, and Arnold C, "Experimental Analysis of Thermoelectric Waste Heat Recovery System Retrofitted to Two Stroke Petrol Engine",*International Journal of Advanced Mechanical Engineering.* ISSN 2250-3234 Volume 4, Number 1 (2014), pp. 9-14.
[3] Prathamesh Ramade, Prathamesh Patil, Manoj Shelar, Sameer Chaudhary, Prof. Shivaji Yadav, Prof. Santosh Trimbake-Automobile Exhaust Thermo-Electric Generator Design &Performance Analysis, *International Journal of Emerging Technology and Advanced Engineering,* (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 5, May 20140).
[4] Om Prakash, Mukesh Pandey, Savita Vyas, "Use of thermoelectric generator for heat recovery from an internal combustion engine", *International Journal of Advance Research In Science And Engineering IJARSE,* Vol. No.4, Issue 03,ISSN-2319-8354(E), March 2015.
[5] P. Mohamed Shameer1, D. Christopher,"Design of Exhaust Heat Recovery Power Generation System Using Thermo-Electric Generator"-*International Journal of Science and Research (IJSR),* ISSN (Online): 2319-7064 Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438, Volume 4, Issue 1, January 2015.
[6] Kumar, C. R., et al.: " Experimental study on waste heat recovery from an internal combustion engine using thermoelectric technology" Vol. 15, No. 4, pp. 1011-1022 1011, Year 2011.
[7] Rohini S. Mohite, Khan Owais Ayyub, Ansari Nadir Ajaz Ahmed, "Thermoelectric Heat Recovery from Four Stroke Engine*", International Journal of Innovative Research and Creative Technology (IJIRCT),*Volume 1,Issue 6, ISSN: 2454-5988.
[8] Aravind Karuppaiah.C, Ganesh.S, Dileepan.T, Jayabharathi.S, "Fabrication and Analysis of thermoelectric generator for power generation", *International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET),* Volume 3,Special Issue 1,ISSN(Online) : 2319-8753 , ISSN (Print) :2347-6710 , February 2014.
[9]Dipak Patil, Dr. R. R. Arakerimath "A Review of Thermoelectric Generator for Waste Heat Recovery from Engine Exhaust" Vol.1 Issue.8, December 2013.Pgs: 1-9
[10] P. M. Solanki, Dr. D. S. Deshmukh, Dr. V. R. Diware, "A Review on factors to be considered for a thermoelectric power Generation System Design",*International Conference on Global Trends in Engineering, Technology and Management (ICGTETM-2016),*ISSN: 2231-5381.
[11]Basel I. Ismail, Wael H. Ahmed, 2009, "Thermoelectric Power Generation Using Waste-Heat Energy as an Alternative Green Technology," Recent Patents on Electrical Engineering, 2, pp. 27-39.
[12]Adavbiele A.S. (2013), "Generation of Electricity from Gasoline Engine Waste Heat", *Journal of Energy Technologies and Policy* Vol.3 | Issue 3 | ISSN 2224-3232 (Paper) | ISSN 2225-0573 (Online)
[13]Sumeet Kumar, Stephen D. Heister, James R. Salvador and Gregory P. Meisner, General Motors Global R&D, Warren, MI, USA. (2013), "Thermoelectric Generators for Automotive Waste Heat Recovery Systems - Numerical Modeling and Baseline Model Analysis", *Journal of Electronic Materials* DI11664-013-2471-9_ 2013 TMS. (Journal)
[14]Jumade S R, Khond V W, (2012), "A Survey on Waste Heat Recovery from Internal Combustion Engine Using Thermoelectric Technology", *International Journal of Engineering Research & Technology* | Vol. 1 | Issue 10 | December- 2012| ISSN: 2278-0181. (Journal)
[15]Francis Stabler,"Automotive Applications for High Efficiency ThermoelectricWorkshop", San Diego, California. March, 2002.
[16] Richard H. Bauer ,"Auxiliary Electric Power for an Automobile through the Utilization of a Thermoelectric Generator"A Critical Examination. M of ME Thesis, Department of Mechanical Engineering, Clarkson College of Technology. 1963.
[17] Anthony Joseph Tomarchio,"A Feasibility Study of Replacing an Electrical Generator of a Standard American Automobile with a Thermoelectric Generator",M of ME Thesis, Department of Mechanical Engineering, Clarkson College of Technology.
[18]John C. Bass, Norbert B. Elsner, and Ralph Slone. Design Study and Experience with Thermoelectric Generators for Diesel Engines. Proc. Automotive Technology Development Contractors Coordination Meeting. Dearborn, USA. 1990.
[19] J. C. Bass, N. B. Elsner, and F. A. Leavitt. Performance of the 1kW Thermoelectric Generator. Proc. American Institute of Physiscs Conference, 1995.
[20]Jorge Vazquez, Miguel A. Sanz-Bobi, Rafael Palacios and Antonio Arenas. Stateof the Art of Thermoelectric Generators Based on Heat Recovered from the Exhaust Gases of Automobiles. Proceedings of the 7th European Workshop onThermoelectric. Pamplona, SPAIN. Oct, 2002.

[21] Kranthi Kumar Guduru, Yakoob Kol ipak, Shanker. B, N. Suresh, "Power Generation by Exhaust Gases On Diesel Engine", *Kranthi kumar G ,INDIA / International Journal of Research and Computational Technology, Vol.7 Issue.5 Page:06-13,*ISSN: 0975-5662, Dec, 2015, *Christu Jyoti Institute of Technology & Science,T.S state ,India*