DESIGN OF THERMOELECTRIC GENERATORS AS AN ALTERNATE ENERGY SOURCE IN HEATING SYSTEM

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***Abstract*:- The thermoelectric generators recover useful energy by the function of thermoelectric modules which can convert waste heat energy into electricity from automotive exhaust. In the actual operation, the electrical connected thermoelectric modules are operated under temperature mismatch conditions and then the problem of decreased power output causes due to the inhomogeneous temperature gradient distribution on heat exchanger surface. In this case study, an individual module test system and a test bench have been carried out to test and analyze the impact of thermal imbalance on the output electrical power at module and system level. Variability of the temperature difference and clamping pressure are also tested in the individual module measurement. The system level experimental results clearly describe the phenomenon of thermoelectric generator's decreased power output under mismatched temperature condition and limited working temperature. This situation is improved with thermal insulation on the modules and proved to be effective.**

***Keywords*:- Thermoelectric Module, Thermoelectric Generator, Thermal Insulation, Series connection.**

Introduction:-

Biomass burners and firewood furnaces are used in domestic and industrial heating and burning processes. Many of these systems require electric energy support for full performance. By applying thermoelectric generators to these heat sources it is possible to develop independent electric energy source, which start generation in the moment when there will be temperature difference on their sides. Thermoelectric generators are devices that use Seebeck effect – converting heat (temperature differences) directly into electrical energy. As the heat flows from hot side to cold side, free charge carriers – electrons or holes – in the material are also driven to the cold end. The resulting voltage is proportional to the temperature difference via the Seebeck coefficient. (Thomas Seebeck discovered the potential difference between two different metals caused by the temperature gradient, which give rise to the thermoelectric effect or converting temperature into current) One way to define the Seebeck coefficient is the voltage built up when a small temperature gradient is applied to a material, and when the material has come to a steady state where the current density is zero everywhere. If the temperature difference ΔT between the two ends of a material is small, then the Seebeck coefficient of a material is defined as:

$$S = -\frac{\Delta V}{\Delta T}$$

Where, ΔV is the Thermoelectric Voltage seen at the terminals.

The thermoelectric generator will generate DC electricity as long as there is a temperature difference across the module. The more electricity will be generated when the temperature difference across the module increases, and the efficiency of converting heat energy into electric energy will also increase.

Materials and methods:-

For research two thermoelectric generators TEP1-1264-1.5 were used (Fig. 1). One generator is a module consisting of 126 Bi2Te3 p-type and n-type semi-conductor couples. By connecting an electron conducting and hole conducting material in series, a net voltage is produced that can be driven through a load. Modules surface is flat plane with dimensions 40x40 mm and height 3.5 mm. Maximum working temperature on hot side is 280 ºC continuously and 380 ºC intermittently. For cold side it can't be more than 180 ºC. Heat flux across one module is about 140 W.

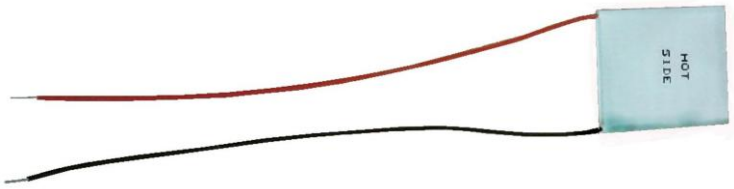

Fig. 1. **Thermoelectric module TEP1-1264-1.5**

For research experimental system (In Fig. 2 seen at below) was developed, consisting of thermoelectric generators 4, heat source – heater 1 with aluminum heat diffuser 2, heat sink 5, water supply 6, insulation 3. Cooling side is a specially made aluminum heat sink with internal water circulation as a heat carrier. Water flow in heat sink was 0.0137 $kg \cdot s^{-1}$.

For better heat transfer both sides of generators with thermo-paste covered. As module producer requires for better electricity generation modules have to be under pressure of 139.50 $kg \cdot cm^{-2}$, because of that bolt fastening 7 was applied Maximum temperature achieved on generators hot side with experimental system was 297 ºC, with temperature difference 267 ºC. Temperature on hot side was kept and adjusted with temperature regulator 9 and meanwhile necessary parameters were recorded. Values of temperature were determined with thermo-couples. Measurements were recorded with computer program PICO Recorder, afterwards data were processed in MS Excel and resulting graphs were developed.

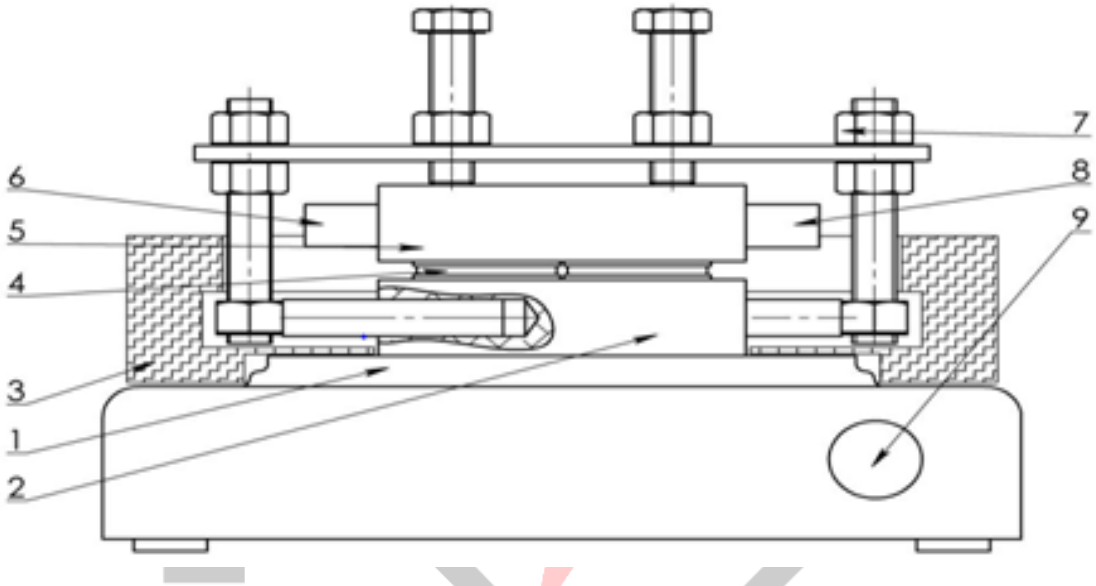

Fig. 2. **Experimental device:** 1 – heater; 2 – aluminum heat diffuser; 3 – heat insulation; 4 – thermoelectric generators; 5 – heat sink; 6 – heat carrier (water inlet); 7 – device fastening; 8 – heat carrier (water) outlet; 9 – temperature regulator

Results and discussion:-

Results of research are elaborated in graphs. Generated amount of electricity increases linearly with rise of temperature difference on module sides (Fig. 3). Offsets may be a cause of unsteady temperature at measuring moments.

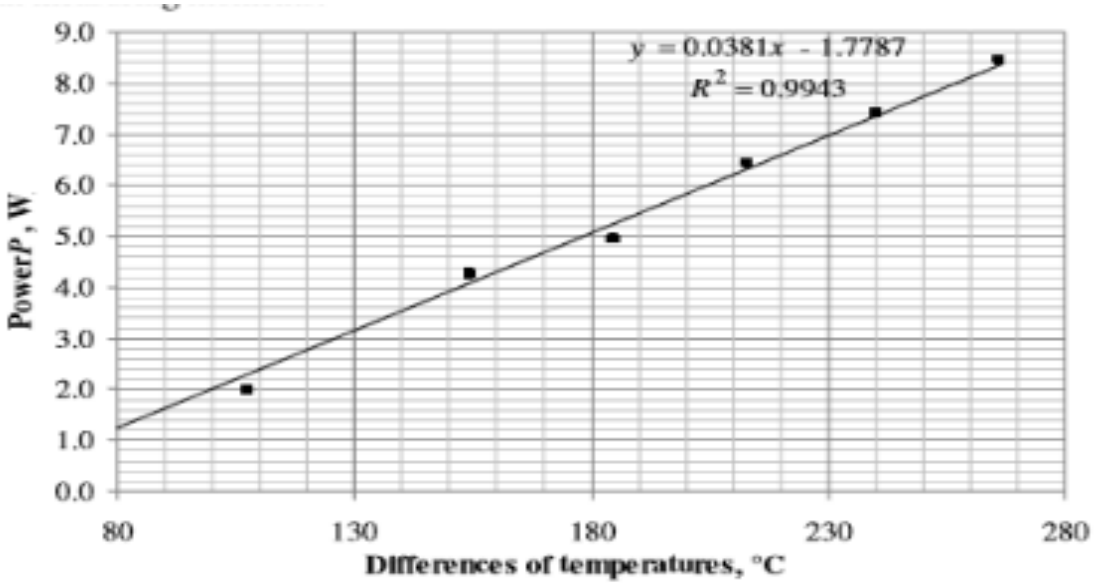

Fig. 3. Power of one TEG module depending on difference of temperatures

Efficiency of thermoelectric generators is increasing and stabilizing with temperature difference and reaches 4.36 % at t = 267.0 ºC (Fig. 4). If in system heated up water is necessary, then efficiency of whole heating or burning system will have higher value, than just thermoelectric generators.

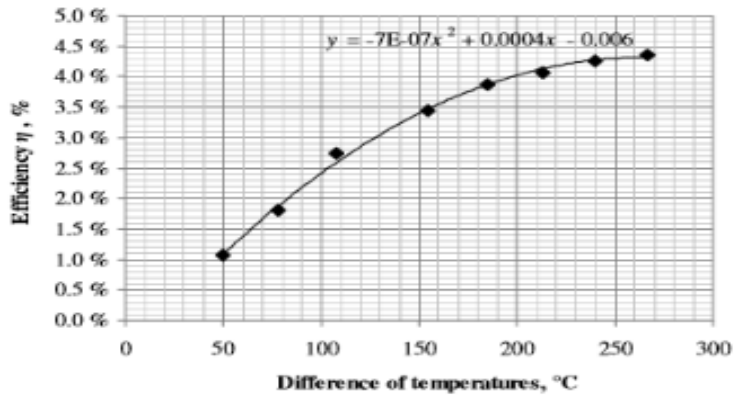

Fig.4 Efficiency depending on difference of temperatures

Advantages:-

Thermoelectric generators is Environmentally friendly, Recycles wasted heat energy, Scalability, meaning that the device can be applied to any size heat source from a water heater to a manufacturers equipment, Reliable source of energy, Lowers production cost.

Another application is radioisotope thermoelectric generators which are used in space probes, which has the same mechanism but use radioisotopes to generate the required heat difference.The thermoelectric generators recover useful energy by the function of thermoelectric modules which can convert waste heat energy into electricity from automotive exhaust

Conclusions:-

1. With current experimental system maximal generated power of thermoelectric module TEP11264-1.5 at temperature difference 267.0 ºC reaches 8.46 W per module.
2. Open circuit voltage for one module at temperature difference 267.0 ºC in current system is 19.8 V.
3. Efficiency of two thermoelectric modules in experimental system reaches 4.36 % at highest temperature.
4. By combining modules in heating or burning systems it is possible to develop independent alternate electric energy source, which would be sufficient to supply consumers with electric energy.
5. Before applying modules, it is necessary to measure temperature range in specific furnace or flue pipe, because of power high dependence on temperature difference.

References:-

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[3] Efficiency of two thermoelectric modules in experimental system reaches 4.36 % at highest temperature.
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