Waste Heat Recovery Using Thermoelectric Generator From An Engine

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I. INTRODUCTION

In the conventional method for generating electricity is converting thermal energy into mechanical energy then to electrical energy. In recent years, due to environmental issues like global warming, emissions, etc., are the limiting factor for the energy resources are required to generate electric power. Thermoelectric generators have emerged as a promising another green technology due to their diverse advantages. Thermo Electric Generator directly converts Thermal energy into Electrical energy. The application of this green technology in converting waste heat energy directly into electrical energy can too improve the overall efficiencies of energy conversion systems. In this paper we attempt to extract the waste heat energy from an automobile IC engine and then convert it into useful electrical energy

Fig 3.1 Shaft

Shaft is a common and important machine element. It is a rotating member, in general, has a circular cross-section and is used to transmit power. The shaft may be hollow or solid. The shaft is supported on bearings and it rotates a set of gears or pulleys for the purpose of power transmission. The shaft is generally acted upon by bending moment, torsion and axial force. Design of shaft primarily involves in determining stresses at critical point in the shaft that is arising due to aforementioned loading. Other two similar forms of a shaft are axle and spindle. Axle is a nonrotating member used for supporting rotating wheels etc. and do not transmit any torque. Spindle is simply defined as a short shaft. However, design method remains the same for axle and spindle as that for a shaft. 8.1.2 Standard sizes of Shafts Typical sizes of solid shaft that are available in the market are, Up to 25 mm 0.5 mm increments 25 to 50 mm 1.0 mm increments 50 to 100 mm 2.0 mm increments 100 to 200 mm 5.0 mm increments 8.1.3 Material for Shafts

The ferrous, non-ferrous materials and non metals are used as shaft material depending on the application. Some of the common ferrous materials used for shaft are discussed below. Hot-rolled plain carbon steel. These materials are least expensive.it is hot rolled, scaling is always present on the surface and machining is required to make the surface smooth. Since it is cold drawn it has got its inherent characteristics of smooth bright finish. Amount of machining therefore is minimal. Better yield strength is also obtained. This is widely used for general purpose transmission shaft.

Alloy steels:

Alloy steel as one can understand is a mixture of various elements with the parent steel to improve certain physical properties. To retain the total advantage of alloying materials one requires heat treatment of the machine components after it has been manufactured. Nickel, chromium and vanadium are some of the common alloying materials. However, alloy steel is expensive. These materials are used for relatively severe service conditions. When the situation demands great strength then alloy steels are used. They have fewer tendencies to crack, warp or distort in heat treatment. Residual stresses are also less compared to CS (Carbon Steel). In certain cases the shaft needs to be wear resistant, and then more attention has to be paid to make the surface of the shaft to be wear resistant. The common types of surface hardening methods are,

- Hardening of surface
- Case hardening and carburizing
- Cyaniding and nitriding

Design considerations for shaft:

For the design of shaft following two methods are adopted, Design based on Strength In this method, design is carried out so that stress at any location of the shaft should not exceed the material yield stress. However, no consideration for shaft deflection and shaft twist is included. Design based on Stiffness Basic idea of design in such case depends on the allowable deflection and twist of the shaft.

Design based on Strength:

The stress at any point on the shaft depends on the nature of load acting on it.

The stresses which may be present are as follows.

Bending stress:

$$\sigma_b = \frac{32M}{\pi d_0^3(1-k^4)}$$

Where,

M: Bending moment at the point of interest do: Outer diameter of the shaft k: Ratio of inner to outer diameters of the shaft (k = 0 for a solid shaft because inner diameter is zero)

Axial Stress:

$$\sigma_a = \frac{4\alpha F}{\pi d_0^2(1-k^2)}$$

σyc = yield stress in compression
Stress due to torsion

$$\tau_{xy} = \frac{16T}{\pi d_0^3(1-k^4)}$$

Combined Bending and Axial stress:

Both bending and axial stresses are normal stresses, hence the net normal stress is given by,

$$\sigma_x = [\frac{32M}{\pi d_0^3(1-k^4)} \pm \frac{4\alpha F}{\pi d_0^2(1-k^2)}]$$

The net normal stress can be either positive or negative. Normally, shear stress due to torsion is only considered in a shaft and shear stress due to load on the shaft is neglected.

Maximum shear stress theory:

Design of the shaft mostly uses maximum shear stress theory. It states that a machine member fails when the maximum shear stress at a point exceeds the maximum allowable shear stress for the shaft material. Therefore,

$$\tau_{max} = \tau_{allowable} = \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau_{xy}^2}$$

Substituting the values of σx and τxy in the above equation, the final form is,

$$\tau_{allowable} = \frac{16}{\pi d_0^3(1-k^4)}\sqrt{\left\{M + \frac{\alpha F d_0(1+k^2)}{8}\right\}^2 + T^2}$$

Therefore, the shaft diameter can be calculated in terms of external loads and material properties. However, the above equation is further standardized for steel shafting in terms of allowable design stress and load factors in ASME design code for shaft.

Specifications

Shaft diameter: 12mm
Inner Diameter: 10mm
Material: mild steel

Fig 3.1.2 Shaft

SPROCKET:

Chain drive is a way of transmitting mechanical power from one place to another. It is often used to convey power to the wheels of a vehicle, particularly bicycles and motorcycles. It is also used in a wide variety of machines besides vehicles.

Most often, the power is conveyed by a roller chain, known as the **drive chain** or **transmission chain**, passing over a sprocketgear, with the teeth of the gear meshing with the holes in the links of the chain. The gear is turned, and this pulls the chain putting mechanical force into the system.

Sometimes the power is output by simply rotating the chain, which can be used to lift or drag objects. In other situations, a second gear is placed, and the power is recovered by attaching shafts or hubs to this gear. Though drive chains are often simple oval loops, they can also go around corners by placing more than two gears along the chain; gears that do not put power into the system or transmit it out are generally known as idler-wheels. By varying the diameter of the input and output gears with respect to each other, the gear ratio can be altered. For example, when the bicycle pedals' gear rotates once, it causes the gear that drives the wheels to rotate more than one revolution.

Characteristics:

- High axial stiffness
- Low bending stiffness
- High efficiency
- Relatively cheap

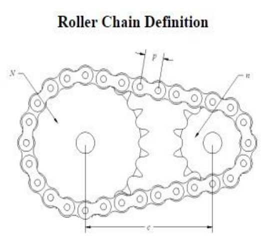

Fig 3.2.1 Roller Chain

Table 3.2.1 SPECIFICATION OF AXLE

Material	**Mild Steel**
Shape	Cylindrical rod
Length	50mm
Diameter	13mm
Inner diameter of supporting axle	15 mm
Outer diameter of supporting axle	17mm
Length	30mm
Thickness	3mm

Material	High Carbon Steel
Pitch	12.7mm
Width	30mm
Teeth	16
Balls	High carbon high chromium steel balls

Chain drives design calculation:

Chain length and centre distance

- Chain must contain even integer number of links
- Hence cannot pick an arbitrary centre distance and chain pitch
- Nearest chain lengths (in pitches) for a contemplated Centre distance, C_C, are calculated by empirical formulae like (for a two-**3.6**

TEG(THERMO ELECTRIC GENERATOR)

A thermoelectric generator (TEG), also called a See beck generator, is a solid state device that converts heat flux (temperature differences) directly into electrical energy through a phenomenon called the See beck effect(a form of thermoelectric effect). Thermoelectric generators function like heat engines, but are less bulky and have no moving parts. However, TEGs are typically more expensive and less efficient. Thermoelectric generators could be used in power plants in order to convertwaste heatinto additional electrical power and in automobiles as automotive thermoelectric generators(ATGs) to increase fuel efficiency. 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. Thermoelectric materials generate electricity while in a temperature gradient. In order to be a good thermoelectric, materials must have the unique combination of both high electrical conductivity and low thermal conductivity: a rare set of properties for one material to hold. Nanotechnology can now be used to lower the thermal conductivity of semiconductors whose electrical properties are excellent, but manufacturing nanomaterials is not trivial. Anything—steam, for instance—will flow from hot to cold in a temperature gradient. In a thermoelectric material, electrons do the same thing. The extent to which electrons flow from hot to cold in an applied temperature gradient is governed by the Seebeck coefficient, also known as the thermopower. In order for a thermoelectric to establish a large voltage while in a temperature gradient, its thermal conductivity must be low. This ensures that when one side is made hot, the other side stays cold. For many decades, the only semiconductors known to have both low thermal conductivity and high power factor were bismuth telluride (Bi2Te3), lead telluride (PbTe), and silicon germanium (SiGe): three expensive compounds using rare elements. Today, low thermal conductivity can be achieved by creating nanoscale features such as particles, wires or interfaces in bulk semiconductor materials. These nanoscale features lower the thermal conductivity of the semiconductor and do not affect their strong electrical properties.

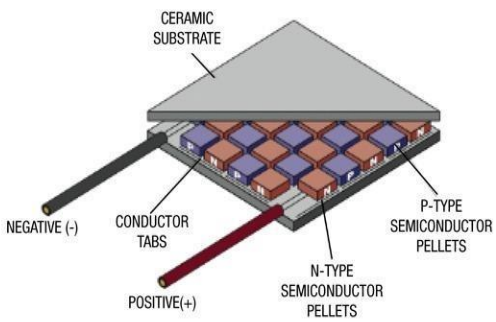

Fig 3.6.1 TEG Table no.2: Specification of TEG

Hot Side Temperature (℃)	300
Cold Side Temperature (℃)	30
Open Circuit Voltage (V)	8.4
Matched Load Resistance (ohms)	1.2
Matched load output voltage (V)	4.2
Matched load output current (A)	3.4
Matched load output power (W)	14.6
Heat flow across the module(W)	≈ 365
Heat flow density(Wcm^{-2})	≈ 11.6
AC Resistance(ohms) Measured under 27℃ at 1000Hz	0.5~0.7

THERMOELECTRIC MATERIALS:

Thermoelectric materials generate power directly from heat by converting temperature differences into electric voltage. These materials must have both high electrical conductivity (σ) and low thermal conductivity (κ) to be good thermoelectric materials. Having low thermal conductivity ensures that when one side is made hot, the other side stays cold, which helps to generate a large voltage while in a temperature gradient. The measure of the magnitude of electrons flow in response to a temperature difference across that material is given by the Seebeck coefficient (S). The efficiency of a given material to produce a thermoelectric power is governed by its "figure of merit" $zT = S^2\sigma T/\kappa$.

THERMOELECTRIC MODULE:

A thermoelectric module is a circuit containing thermoelectric materials which generates electricity from heat directly. A thermoelectric module consists of two dissimilar thermoelectric materials joined at their ends: an n-type (negatively charged), and a p-type (positively charged) semiconductor. A direct electric current will flow in the circuit when there is a temperature difference between the two materials. Generally, the current magnitude is directly proportional to the temperature difference.

In application, thermoelectric modules in power generation work in very tough mechanical and thermal conditions. Because they operate in a very high temperature gradient, the modules are subject to large thermally induced stresses and strains for long periods of time. They also are subject to mechanical fatigue caused by large number of thermal cycles.

Thus, the junctions and materials must be selected so that they survive these tough mechanical and thermal conditions. Also, the module must be designed such that the two thermoelectric materials are thermally in parallel, but electrically in series. The efficiency of a thermoelectric module is greatly affected by the geometry of its design.

ENGINE:

A two-stroke (or two-cycle) engine is a type of internal combustion enginewhich completes a power cycle with two strokes (up and down movements) of thepistonduring only one crankshaft revolution. This is in contrast to a "fourstroke engine", which requires four strokes of the piston to complete a power cycle during two crankshaft revolutions. In a two-stroke engine, the end of the combustion stroke and the beginning of the compression stroke happen simultaneously, with the intake and exhaust (or scavenging) functions occurring at the same time.

Two-stroke engines often have a high power-to-weight ratio, power being available in a narrow range of rotational speeds called the "power band". Compared to four-stroke engines, two-stroke engines have a greatly reduced number of moving parts, and so can be more compact and significantly lighter.

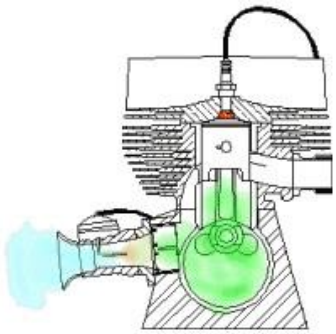

Fig 3.7.1 Engine

Specification of Two Stroke Petrol Engine:

Type	:	Two stroke
Cooling System	:	Air Cooled
Bore/Stroke	:	50 x 50 mm
Piston Displacement	:	98.2 cc
Compression Ratio	:	6.6: 1
Maximum Torque	:	0.98 kg-m
Brake Power	:	563.153Kw.

History:

The first commercial two-stroke engine involving in-cylinder compression is attributed to Scottish engineer Dugald Clerk, who patented his design in 1881. However, unlike most later two-stroke engines, his had a separate charging cylinder. The crankcase-scavenged engine, employing the area below the piston as a charging pump, is generally credited to Englishman Joseph Day. The first truly practical two-stroke engine is attributed to Yorkshireman Alfred Angas Scott, who started producingtwin-cylinder water-cooled motorcycles in 1908.

Application:

Two-stroke petrol engines are preferred when mechanical simplicity, light weight, and high power-to-weight ratioare design priorities. With the traditional lubrication technique of mixing oil into the fuel, they also have the advantage of working in any orientation, as there is no oil reservoir dependent on gravity; this is an essential property for hand-held power tools such aschainsaws.

ADVANTAGES AND APPLICATIONS

ADVANTAGES:

- Efficiency of the vehicle is improved
- Small modification is done in the vehicle
- Battery efficiency and lifetime also increased
- Simple in construction
- This system is noiseless in operation
- It is portable, so it can be transferred easily from one place to another place
- Power consumption is less
- Maintenance cost is low

APPLICATION:

- Use in automobiles as an alternate source of energy.
- Can supply power to any other electrical appliances.

II. CONCLUSION

A small-scale tri-generation system to provide heat, electrical power and cooling was investigated and a Making of production solar car will reduce forming pollutants. The first solar car on the market will reduce emissions of atmosphere pollutants by a third to a half at least or even more.

III. RESULTS

Fig 7.2.1 Results

We are producing voltage by sprocket wheel coupled with chain drive and using TEG is 22 voltage for every 15 minutes.

REFRENCES

[1] Review and trends of thermoelectric generator heat recovery in automotive applications – ieee paper(2019) James s.cotton and ali emadi

[2] Investigations of the thermoelectric-photoelectric integrated power generator with i-shaped thermocouple

structure and its test structures –ieee paper (2019) Sen zhang and xiaoping liao
[3] N.M Aggarwal S.K.Kataria & Sons - Automobile Engineering, K. K. Aggarwal, Yogesh Singh Publisher (2001)
[4] L.Escalin Tresa & Dr. M. Sundhararajan, An Intelligent repeated objects tracking on Video Sequences", Published in International Journal of Applied Engineering Research, Vol. 10 No.5 (2015).pp 11803-11810.
[5] S.Subramaniam, Advances in Automobile Engineering, Narosa Publisher.
[6] Gopalakrishnan, K., Prem Jeya Kumar, M., Sundeep Aanand, J., Udayakumar, R., Thermal properties of doped azopolyester and its application, Indian Journal of Science and Technology, v-6, i-SUPPL.6