Minto Wheel Based Heat Energy Recovery Systems

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Abstract: *According to The American Meteorological Society, anthropogenic heat (Heat released to the atmosphere as a result of human activities, from sources like industrial plants, space heating and cooling, human metabolism, and vehicle exhausts) typically contributes several hundred W/m² of wasted energy in major cities and industrial areas. This project involves using Minto wheel (heat engine with pairs of sealed chambers, one of each filled with low boiling point liquid such as propane or R-12) to tap anthropogenic heat from several sources and convert it into usable forms, viz., electricity, mechanical work, etc. Minto wheels operate even on small temperature gradients to produce large amount of torque and several horsepower. Waste heat of such low quality (temperature) is otherwise very difficult to efficiently utilize using conventional heat exchangers. For higher temperatures (large heat sources), the rotation of the wheel can be used to produce electricity in the conventional method. The applications of this technology are endless, from use in remote places with limited electricity supply, to efficient reconversion of waste heat from even small air conditioners, till large server farms, industrial furnaces and chilling towers.*

Keywords: Heat energy, convection, conservation of energy, Minto Wheel, Electrical energy.

1. Introduction to Heat Energy

Heat is defined as the form of energy that is transferred across boundary by virtue of a temperature difference. The temperature difference is the 'potential' or 'force' and heat transfer is the 'flux'. The transfer of heat between two bodies in direct contact is called conduction. Heat may be transferred between two bodies separated by empty space or gases by the mechanism of radiation. A third method of heat transfer is convection which refers to the transfer of heat between a wall and a fluid system in motion. Convection is usually the dominant form of heat transfer in liquids and gases. Although often discussed as a distinct method of heat transfer, convective heat transfer involves the combined processes of conduction (heat diffusion) and advection (heat transfer by bulk fluid flow).

Two types of convective heat transfer may be distinguished:

Free or natural convection: when fluid motion is caused by buoyancy forces that result from the density variations due to variations of thermal temperature in the fluid. In the absence of an external source, when the fluid is in contact with a hot surface, its molecules separate and scatter, causing the fluid to be less dense. As a consequence, the fluid is displaced while the cooler fluid gets denser and the fluid sinks. Thus, the hotter volume transfers heat towards the cooler volume of that fluid. Familiar examples are the upward flow of air due to a fire or hot object and the circulation of water in a pot that is heated from below.

- Forced convection: when a fluid is forced to flow over the surface by an external source such as fans, by stirring, and pumps, creating an artificially induced convection current.

The direction of heat transfer is taken from a high temperature system to the low temperature system. Heat is a form of energy in transit (like work transfer) i.e. they cannot be stored by the system. It is a boundary phenomenon, since it occurs only at the boundary of a system. Energy transfer by virtue of temperature difference is called heat transfer.

The transfer of heat and the performance of work may both cause the same effect in a system. Heat and work are different forms of the same entity, called energy, which is conserved. Energy which enters system as heat may leave the system as work, or energy which enters the system as work may leave as heat.

A heat engine cycle is a thermodynamic cycle in which there is a net heat transfer to the system and a net work transfer from the system. The system which executes a heat engine cycle is called a *heat engine.* A heat engine may be in the form of mass of gas confined in a cylinder and piston machine or a mass of water or any fluid moving in a steady flow through a steam power plant. In the cyclic heat engine, heat Q_1 transferred to the system, work W_E is done by the system, work W_C is done upon the system and then heat Q_2 is rejected from the system. The function of heat engine cycle is to produce work continuously at the expense of heat input to the system. So the net work W_{net} and heat input Q_1 referred to the cycle are of primary interest. The efficiency of heat engine cycle is defined as ratio of 'Net work output of the cycle' to the 'Total heat input to the cycle'. This is also known as *thermal efficiency* of a heat engine.

2. Sources of Heat

In the majority of energy applications, energy is required in multiple forms. These energy forms typically include some combination of: heating, ventilation and air conditioning, mechanical energy and electric power. Often, these additional forms of energy are produced by a heat engine, running on a source of high-temperature heat. A heat engine can never have perfect efficiency, according to the second law of thermodynamics, therefore a heat engine will always produce a surplus of low-temperature heat. This is commonly referred to as waste heat or "secondary heat", or "low-grade heat". This heat is useful for the majority of heating applications, however, it is sometimes not practical or viable to transport heat energy over long distances, unlike electricity or fuel energy. The largest proportions of total waste heat are from power stations and vehicle engines. The

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largest single sources are power stations and industrial plants such as oil refineries and steelmaking plants.

Power generation: The electrical efficiency of thermal power plants is defined as the ratio between the input and output energy. It is typically only 30%. The image shows cooling towers which allow power stations to maintain the low side of the temperature difference essential for conversion of heat differences to other forms of energy. Discarded or "Waste" heat that is lost to the environment may instead be used to advantage.

Figure 1: Smoke and steam sent out from chimneys of industries have high amounts of heat

Coal-fired power station that transform chemical energy into 36%-48% electricity and remaining 52%-64% to waste heat. Industrial processes: Industrial processes, such as oil refining, steel making or glass making are major sources of waste heat. Electronics: Although small in terms of power, the disposal of waste heat from microchips and other electronic components, represents a significant engineering challenge as these necessitate the use of fans, heat sinks, etc. to dispose of the heat. Biological: Animals, including humans, create heat as a result of metabolism. In warm conditions, this heat exceeds a level required for homeostasis in warm-blooded animals, and is disposed of by various thermoregulation methods such as sweating and panting.

3. What is a Minto Wheel?

Our forefathers used waterwheel to produce power, power which changed man's way of life and increased productivity. Today, when we know that our supply of energy from fossil fuels (including uranium) is exhaustible, every consideration should be given to tapping renewable energy sources.
\Wallace Minto, a scientist known for his development of a pollution-free automobile engine, developed a practical version of an engine that runs on small temperature gradients to produce useful power. Such small temperature gradients are plentiful almost everywhere on earth, or can easily be produced from solar energy.

4. Working of Minto Wheel

The engine consists of a set of sealed chambers arranged in a circle, with each chamber connected to the one opposite to it by means of tubes. One chamber of each connected pair is filled with a low boiling point liquid like propane, butane or Freon. When the lower chamber is subjected to heat, the liquid begins to vaporize, producing a pressure on the surface of the remaining liquid generally known as vapor pressure, which forces the remaining fluid to spill in to the upper chamber. This fluid transfer to the upper chamber causes weight imbalance which ultimately leads to the wheel rotation.

As it rotates, the chamber next to one previously heated nears the bottom of the wheel, where it is subjected to heat causing the fluid in it to vaporize and eventually travel in to the chamber connected diametrically opposite to it. This cycle is repeated, thus causing the wheel to rotate and produce power as long as the temperature gradient is available. Most notable feature is that the working liquid only undergoes state change and is never lost as the chambers are sealed tightly.

The minto wheel starts operating at a small temperature gradient, and generates a large amount of torque, but at very low rotational speed. Although the rotation of wheel is relatively slow, it produces enormous torque or twisting effect on a shaft, that is high enough to be geared up through gears or belting to produce any desired speed at the final output shaft. The speed of rotation is directly proportional to the surface area of the containers used, the volume, and the height of the wheel. The greater the ratio of surface area to volume, the greater the rate of revolution.

The shaft power increases with the increase in amount of torque and number of revolutions. Hence, the proper design of Minto wheel can produce immense power which in turn is used to generate electricity.
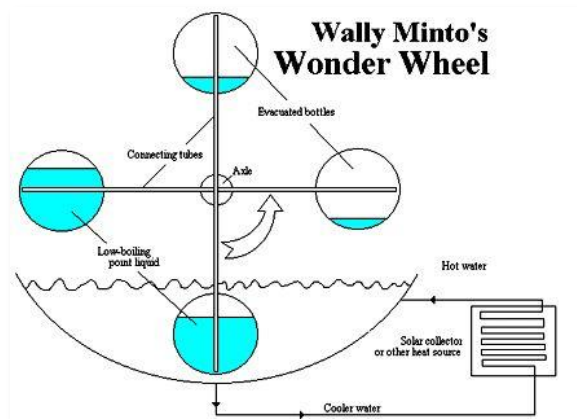

Figure 2: A simple four chambered Minto wheel

No significant power can be produced from ordinary fluids that have relatively high boiling points, such as water or alcohol. Their vapor pressures are too low at temperatures near ambient. In addition, it takes too much heat energy to vaporize a pound of their liquid. However, today we have available liquids that vaporize to produce high differential pressures at very modest temperature differences. The use of these fluids is what makes the Minto wheel practical as a power source. Units of modest size could perform such tasks as pumping water for irrigation, grinding food grains and generating small amounts of machine power on a farm-by-farm basis.

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A temperature gradient of as little as two degrees Celsius (about 3½° F.) will drive a wheel ten meters (33 feet) in diameter. Such small temperature differences are abundant almost everywhere in nature: such as the temperature difference between water and cooler air, or even the difference between direct sunshine and shade.

5. Design Issues

The Minto wheel is simple and inexpensive to build and is virtually maintenance free. When constructed of suitable materials and supplied with heat, a single unit can keep grinding out power for generations.

For Minto wheel to be highly efficient, it completely depends on the design unlike other heat engines depending on fuels. Minto wheel require cheaper fuel with low boiling point that produces a greater amount of energy. This saves lot of other non-renewable resources.

Certain basic considerations in the design of a wheel are:
1) The main body of the working liquid should be heated as little as possible. Side arm tubes, for example, could be used to heat and vaporize only that portion required to pressurize the chamber.
2) The power output capability of the wheel depends upon the temperature differential available to drive it.
3) Extended surfaces should be employed to facilitate heat transfer.
4) Electro – mechanical brakes can be used to reduce uneven torque and rotation in opposite direction.
5) Heat transfer to structural parts, particularly main container walls, should be minimized. Minimize the weight of the structural parts heated.
6) Higher density liquids maximize horsepower output from a given wheel operating at a given RPM.
7) Dual liquid fillings can be employed for special purposes. For example, using mercury as the shifting mass, powered by propane as the volatile fluid, tremendous torque can be generated with a relatively small diameter wheel.
8) The choice of working fluid is governed by optimum compromise among these factors, at the temperature range to be used.

Factors to minimize:

1. Cost:
The overall cost of construction of the wheel should be kept as low as possible. Even though it is a one-time expense, it augurs well to keep the costs low, in order to improve its reachability and widespread use.

2. Latent heat of vaporization of liquid:
It is the enthalpy change required to transform a given quantity of a substance from a liquid into a gas at a given pressure. This quantity has to be less as the liquid should be easily vaporizable at even low temperatures.

3. Specific heat of fluid:
The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius. Lower the specific heat, easier it is to increase or decrease the fluid temperature.

4. Viscosity of liquid:
The viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress. For liquids, it corresponds to the informal notion of "thickness". Higher the viscosity of the liquid, higher is the bond strength between its molecules. This affects its flow between the interconnected containers of the wheel and thus should be kept minimum.

Factors to maximize:
1. Vapor pressure:
Vapor pressure is defined as the pressure exerted by a vapor in thermodynamic equilibrium with its condensed phases (solid or liquid) at a given temperature in a closed system. This excess pressure causes an imbalance and thus makes the wheel to rotate.

2. Ratio of the specific volume of the vapor to that of the liquid:
This ratio has to be maximized in order to allow more vapor to flow into the upper chamber and deposit there. This, in turn, causes the wheel to rotate faster.

3. Liquid density:
Density of a liquid is defined as the ratio of the mass of the liquid to the volume it occupies. Pressure exerted by a liquid is directly proportional to its density and thus increases with increase in density.

6. Advantages

1) The Minto wheel can operate even at very low temperature gradients, producing several horsepower could pump irrigation water, grind grain, or saw wood.
2) At higher temperature gradients (larger heat sources), the rotational speed of the wheel is high enough to generate electricity.
3) The materials used to build the wheel could be scrap pipe, and no machining or skills are needed to build it.
4) The temperature difference required between the liquid on the bottom and the top occurs naturally in any weather condition.
5) Reduction in pollution.
6) High mechanical efficiency.
7) Increases efficiency of the original heat sourcesas it reuses the heat energy being wasted.
8) It is a greater source of alternative energy.
9) Highly reliable and require low maintenance.

7. Disadvantages

1) The design should be very accurate to give high efficiency. Hence great care should be taken while designing.
2) Low rotational speed at lower diameter of wheel, surface area and volume of containers. Hence it cannot perform better at wide ranges of size.
3) Under some conditions such as low temperatures and free rotation of the wheel, the output can be erratic as one vessel may get heated up more than the other. Or the

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wheel may rotate in opposite direction. All this can be removed simply by equipping the engine with electro-mechanical brakes.

4) When the design size is enough to produce greater RPM, even then it takes little amount of time to attain a higher RPM as maximum liquid has to vaporize.

8. Comparison with other heat engines

1) The main difference when compared to other engines is the piston of the Minto wheel comprises a liquid instead of a solid metal.

2) A major advantage of Minto wheel is that other conventional heat engines cannot tap low quality heat (low temperature) to generate any useful amount of electricity or torque, whereas Minto wheel uses such waste heat very efficiently.

3) It can carry out efficient reconversion of the waste heat produced from a wide range of heat sources, from small air conditioners, till large sources like industrial furnaces, unlike other heat engines which can produce output only with larger heat sources.

4) Since it deals with even small amounts of wasted heat, the output produced by the Minto wheel may not be constant. This, however, is not the case with other heat engines dealing with high temperature gradients.

5) The amount of heat energy rejected when work is done is very low compared to other heat engines. Hence, it is very efficient as Carnot's law states that efficiency of engine is constrained by the ratio of the temperature in to the temperature out.

9. Conclusion

Waste heat is by necessity produced both by machines that do work and in other processes that use energy, for example in a refrigerator warming the room air or a combustion engine releasing heat into the environment. In fact, the need for many systems to reject heat as a by-product of their operation is fundamental to the laws of thermodynamics. The American Meteorological Society estimates the quantity of this anthropogenic heat to be several hundred W/m2 in the center of large cities and industrial areas.

The development of the proposed technology will reduce themassive amounts of energy being wasted in the form of heat from several sources like large server farms, industrial furnaces and chilling towers in urban areas by efficiently tapping it. It also reduces the scarcity of electricity in remote areas and can also be used in performing a variety of tasks like pumping irrigation water, grinding grain, or sawing wood.

The design of the Minto wheel can be varied (i.e., the physical dimensions, materials used, etc.) to get the desired output at even low temperature gradients. Thus the heat engine can efficiently capture and reconvert heat of varying degrees of temperature, causing huge reduction in loss of energy, in turn reducing the need for more energy production. This directly leads to a reduction in burning of fossil fuels, the chief cause for production of greenhouse gases.

Also, it directly reduces the amount of heat and smog being released into the atmosphere, chief sources of thermal and air pollution. All this together, on the long run, will reduce global warming and make our planet a clean, green and energy efficient one.

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