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STUDY OF SOLAR THERMAL CAVITY RECEIVER FOR PARABOLIC CONCENTRATING COLLECTOR

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ABSTRACT

Energy is one of the building blocks of the country. The growth of the country has been fueled by cheap, abundant energy resources. Solar energy is a form of renewable energy which is available abundantly and collected unreservedly. The parabolic concentrator reflects the direct incident solar radiation onto a receiver mounted above the dish at its focal point. The conversion of concentrated solar radiation to heat takes place in receiver. The heat transfer characteristics of the receiver changes during the rotation of the receiver which affects thermal performance. The working temperature may also influence the thermal performance and overall efficiency of the system. Thermal as well as optical losses affect the performance of a solar parabolic dish-cavity receiver system. The thermal losses of a solar cavity receiver include convective and radiative losses to the air in the cavity and conductive heat loss through the insulation used behind the helical tube surface. Convective and radiative heat losses form the major constituents of the thermal losses. The convection heat loss from cavity receiver in parabolic dish solar thermal power system can significantly reduce the efficiency and consequently the cost effectiveness of the system. It is important to assess this heat loss and subsequently improve the thermal performance of the receiver.

KEYWORDS: Energy, Cavity receiver, Parabolic collector,

INTRODUCTION

Since 1973, the word "energy" has been continuously in the news. There have been shortage of oil in many parts of the world and the price of this commodity has increased steeply. It is by now clear that the fossil fuel era of non-renewable resources is gradually coming to an end. Oil and natural gases will be depleted first, followed eventually by coal. In India the energy problem is very serious. In spite of discoveries of oil and gas off the west coast, the import of crude oil continues to increase and the price paid for it now dominates all other expenditure. Every year the country is spending more than thousand crores for the import of oil. This amount forms a major part of India's import bill. The need for developing energy alternatives is thus evident and considerable research and development work is needed in this direction.

One of the promising options is to make more extensive use of renewable sources of energy derived from the sun. Solar energy can be used both directly and indirectly. It can be used directly in a variety of thermal applications like heating of water or air, drying, distillation, and cooking. The heated fluids can in turn be used for applications like power generation or refrigeration. A second way in which solar energy can be used directly is through the photovoltaic effect in which it is converted to electrical energy. Indirectly, the sun causes winds to blow, plants to grow, rain to fall, and the temperature differences to occur from the surface to the bottom of the oceans. Useful energy can be obtained for commercial and noncommercial purposes through all these renewable sources.

Solar energy is very large, inexhaustible source of energy. The power from the sun intercepted by the earth is approximately 1.8×10^{11} MW which is many thousands of times larger than the present consumption rate on earth of all commercial energy sources. Thus, in principle, solar energy could supply all the present and future energy needs of the world on a continuing basis. This makes it one of the most promising of the unconventional energy sources. In addition to its size, solar energy has two other factors in its favour. First unlike fossil fuels and nuclear power, it is an environmentally clean source of energy. Second it is free and available in adequate quantities in almost all parts of the world where people live (Sukhatme and Nayak, 2009).

DEVICES FOR THERMAL COLLECTION

In any collection device, the principle usually followed is to expose a dark surface to solar radiation so that the radiation is absorbed. A part of the absorbed radiation is then transferred to a fluid like air or water. When no optical concentration is done, the device in which the collection is achieved is called flat plate collector (FPC). The flat plate collector is the most important type of solar collector because it is simple in design, has no moving parts and requires little maintenance. It can be used for a variety of applications in which temperature ranging from 40^0C to about 100^0C are required. A simple, small-capacity natural circulation system, suitable for domestic purposes, is shown in Fig. 1

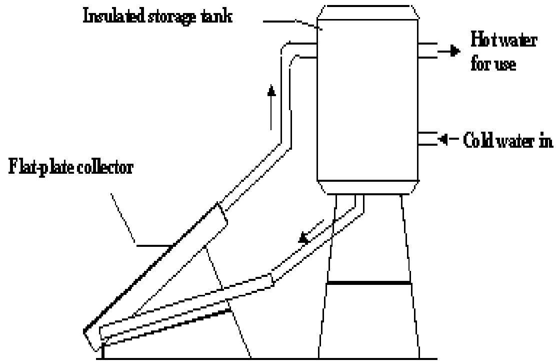

Fig. 1 Small capacity natural circulation water heating system.

When high temperatures are required, it becomes necessary to concentrate the radiation. This is achieved using focusing or concentrating collector. A typical line- focusing concentrating collector is shown in Fig. 2.The term concentrator will be used for the optical subsystem which directs the solar radiation on to the absorber, while the term receiver will normally be used to denote the subsystem consisting of the absorber, its cover and other accessories. The concentrator shown is a mirror reflector having the shape of a cylindrical parabola. It focuses the sunlight on to its axis, where it is absorbed on the surface of the absorber tube and transferred to the fluid flowing through it. Concentric glasses cover around the absorber tube help in reducing the convective and radiative losses to the surrounding. Fluid temperatures up to 400^0C can be achieved in cylindrical parabolic focusing collector systems.

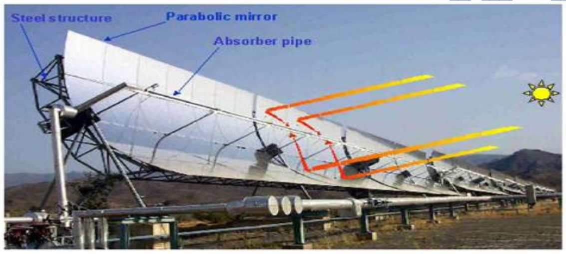

Fig. 2 Cylindrical parabolic concentrating collector

The generation of still higher working temperatures is possible by using paraboloid concentrating dish collector (Fig.3) which have a point focus. These require two-axis tracking so that the sun is in line with the focus and the vertex of paraboloid.

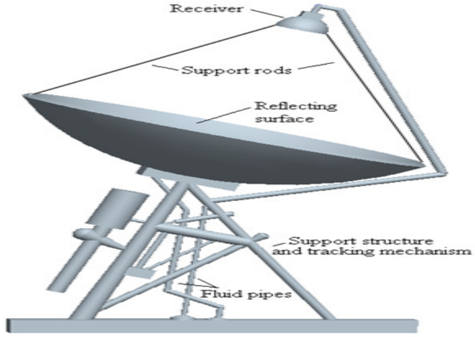

Fig. 3 Paraboloid concentrating collector

Among the various solar collectors, the parabolic dish concentrating collector is the most suitable system for meeting medium and high temperature process heat requirements. Generally, it consists of a reflector in the form of a dish and a receiver at the focus. The thermal and optical losses occurring from an open cavity solar receiver are less when compared to other types of receivers and hence, such receivers are preferred. Solar concentrators are used for many applications such as supplying process heat to industries, generating electricity, melting and processing of metals as in the case of solar furnaces, etc. Many varieties of concentrators are used in various parts of the world. Recently in India, Fresnel parabolic dish with a cavity receiver is being used for supplying low and medium temperature process heat (Kedare et al.,2002). It consists of a mirror assembly in the form of a dish and a cavity receiver with a helical metallic coil. Such a system does not need any evacuated tube construction and uses simple float glass mirrors as reflectors. This makes the system cheaper in Indian scenario and durable in industrial environments. Working fluids used in such systems are thermic oils, air or pressurized water.

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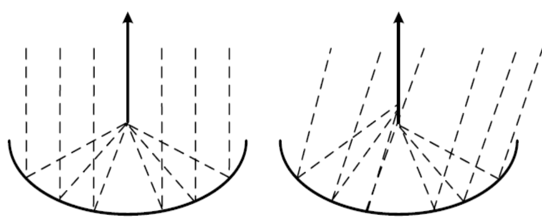
SOLAR COLLECTOR/CONCENTRATOR

The solar collector is the key element in a solar thermal energy system. The function of the collector is quite simple; it intercepts the incoming solar insolation and converts it into a useable form of energy that can be applied to meet a specific demand, such as generation of steam from water. Concentrating solar collectors are used to achieve high temperatures and accomplish this concentration of the solar radiation by reflecting or refracting the flux incident on the aperture area (reflective surface), Aa onto a smaller absorber (receiver) area, Ar. The receiver's surface area is smaller than that of the reflective surface capturing the energy, thus allowing for the same amount of radiation that would have been spread over a few square meters to be collected and concentrated over a much smaller area, allowing for higher temperatures to be obtained. These concentrating solar collectors have the advantage of higher concentration and are capable of much greater utilization of the solar intensity at off-noon hours than other types of solar concentrators. However, one of the major problems of using a 'dish-type' parabolic collector is that two-dimensional tracking is required. Most concentrating collectors can only concentrate the beam normal insolation (the parallel insolation coming directly from the sun), otherwise the focal region becomes scattered and off focus, as shown in Fig.4, therefore requiring the concentrator to follow the sun throughout the day for efficient energy collection. For the parabolic concentrator, continuous tracking is needed; if oriented east-west, the concentrator requires an approximate ± 30°/day motion; if north-south, an approximate 15°/hr motion. This tracking also must accommodate a ±23.5°/yr declination excursion (Newton Charles, 2006)



/Fig. 4 Concentration by parabolic concentrating reflector for a beam parallel to the axis of symmetry, and at an angle to the axis.

The optical system directs the solar radiation on to an absorber of smaller area which is usually surrounded by a transparent cover. Because of the optical system, certain losses (in addition to those which occur while radiation is transmitted through the cover) are introduced. These include reflection or absorption losses in the mirrors or lenses, and losses due to geometrical imperfections in the optical system. The combined effect of all such losses is indicated through the introduction of a term called optical efficiency. The introduction of more optical losses is compensated for by the fact that the flux incident on the absorber surface is concentrated on a smaller area. As a result, the thermal loss terms do not dominate to the same extent as in flat plate collector and the collection efficiency is usually higher. Because of presence of an optical system, a concentrating collector usually has to follow or track the sun so that the beam radiation is directed on to the absorber surface. The method of tracking adopted and the precision with which it has to be done varies considerably. In collectors giving a low degree of concentration, it is often adequate to make one or two adjustments of the collector orientation every day. These can be made manually. On the other hand, with collectors giving a higher degree of concentration, it is necessary to make continuous adjustments of the collector orientation. The need for some form of tracking a certain amount of complexity in the design.

PARABOLOID DISH COLLECTOR RECEIVER/ABSORBER

The purpose of the receiver in the solar-thermal system is to intercept and absorb the concentrated solar radiation and convert it to usable energy. Once absorbed, this thermal energy is transferred as heat to a heat-transfer fluid, such as air, water, ethyl-glycol, or molten salt, to be stored and/or used in a power conversion cycle. There are two main types of receiver designs that are found to be used with parabolic solar concentrator systems: external receiver, and cavity receivers. As shown in Fig. 5 external receiver is usually cylindrical in shape.

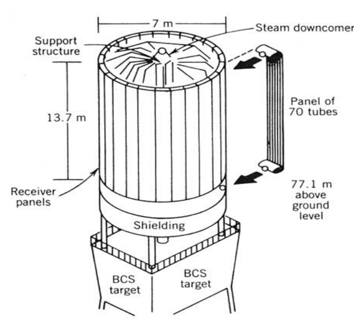


Fig. 5 External receiver

The solar flux is directed onto the outer surface of the cylinder consisting of number of panels and is absorbed by the receiver fluid flowing through closely spaced tubes fixed on the inner side. On the other hand, a cavity receiver has an aperture through which the reflected solar radiation passes. Once inside the cavity, internal reflections ensure that the majority of the radiation that has entered the cavity is absorbed on the internal absorbing surface as shown in Fig. 6. The cavity contains a suitable tube configuration through which the receiver fluid flows. In large scale solar concentrator projects, and commercially available solar concentrators, it is found that the cavity type receiver is most commonly used. This is due to the lower heat-loss rate compared to that of an external receiver; however, they are more expensive than external receivers. The concentrated solar radiation entering the aperture of the cavity spreads inside and is absorbed on the internal walls where the heat is then transferred to a working fluid. Any radiation that is reflected or re-radiated from the walls inside the cavity is also absorbed internally on the cavity walls resulting in a higher absorptance value of the receiver. This spreading of the solar radiation causes a reduction in the incident flux within the cavity, thus helping to prevent thermal cracking or smelting of the internal walls. Also, because of the design of the cavity receiver, it is easier to insulate to aid in avoiding radiant and convective heat loss to the environment.

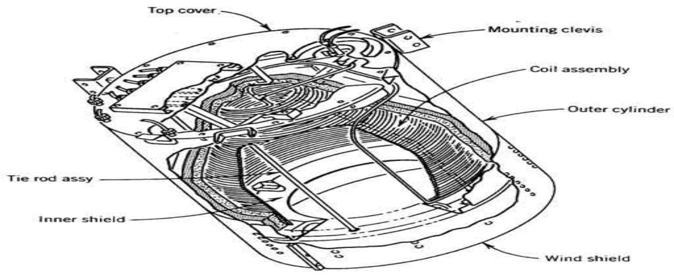


Fig. 6 Cavity Type Receiver

ENERGY LOSSES FROM SOLAR THERMAL CAVITY RECEIVER

Thermal as well as optical losses affect the performance of a solar parabolic dish-cavity receiver system (M. Prakash et al, 2009). The thermal losses of a solar cavity receiver include convective and radiative losses to the air in the cavity and conductive heat loss through the insulation used behind the helical tube surface. Convective and radiative heat losses form the major constituents of the thermal losses. The radiative loss is dependent on the cavity wall temperature, the shape factors and emissivity/absorptivity of the receiver walls while conduction is dependent on the receiver temperature and the insulation material. The radiative and conductive losses are independent of the cavity inclination. The convective heat loss depends on the air temperature within the cavity, the inclination of the cavity and the external wind conditions, thus making the phenomenon complex.

CONCLUSION

Solar thermal cavity receiver is important component in paraboloidal concentrating collector power system and subject to detailed research. The efficiency of the whole system depends on various parameters viz., type of cavity receiver, geometry of cavity receiver, the orientation of cavity, the size and position of cavity receiver etc. It is important to study each parameter in detail and investigate the influence of these parameters on the efficiency of the system. The detailed investigation in the field of non conventional energy is necessary to cope up with the requirement of energy for today and future also.

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