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Study of Advancements of Solar Furnace Technology to Find Out Best Suitable Solar Furnace for Indian Conditions

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Abstract:- As a way to lessen reliance on non-renewable energy sources, the utilisation of solar energy has gained importance. One of the methods developed to use solar energy is solar furnaces. Through the use of focused sunlight that may be used in numerous ways, these furnaces produce tremendous temperatures. This study will look at advances in solar boiler technology and identify the most suitable solar boiler for Indian conditions. The study includes an analysis of various solar furnace designs, their underlying operating principles, and the materials used to create them. This article reviews the most recent research on solar boiler technology and its potential applications. The climate and solar energy resources in India are also examined in this study. The study's conclusions can be used to promote India's adoption of solar furnace technology, reducing that country's dependency on non-renewable energy sources and advancing the development of a sustainable energy system. The publication ends with suggestions for additional study in this area.

Keywords:- *Solar Energy, Solar Furnace, Concentrated Sunlight, High Temperatures, Indian Conditions, Efficiency, Cost-Effectiveness, Sustainable Energy, Renewable Energy, Non-Renewable Energy, Climatic Conditions, Materials, Operating Principles, Potential Applications, Research, Technology.*

I. INTRODUCTION

New technologies that exploit renewable energy sources, including solar energy, have been developed as a result of the rising demand for energy and the ensuing depletion of non-renewable resources. One of these innovations is the solar boiler, which harnesses sunlight to concentrate high temperatures for a variety of uses. Solar furnaces are a viable alternative to conventional furnaces that rely on non-renewable resources because of their many benefits, including affordability, low environmental impact, and scalability.

The goal of this research paper is to examine solar boiler technology improvements and determine which solar boiler is best for Indian settings. India is the best place for the use of solar energy because it has high sun insolation throughout the year. Finding the best solar boiler for Indian circumstances can therefore have a big impact on creating a sustainable energy system. Analysing several solar furnace designs, their working theories, and the materials that went into making them is part of the study. The most recent findings on solar boiler technology and possible uses are reviewed in this publication. A review of India's climate and access to solar energy is also included in the report. The study's results will be used to determine which solar boiler is most appropriate for Indian conditions in terms of effectiveness, affordability, and practicality. The study's findings can be used to encourage India's adoption of solar furnace technology, which can help the nation lessen its reliance on non-renewable energy sources and advance the creation of a sustainable energy system. The publication ends with suggestions for additional study in this area.

II. HISTORY

Technology for solar furnaces has been developed for many years. The first solar furnace was created by French physicist Augustin Mouchot in the late 19th century. A small engine was powered by steam produced by the stove. Since then, the technology behind solar furnaces has undergone numerous modifications and advancements that have increased its effectiveness and usefulness in a variety of settings.

The potential application of solar furnace technology in high-temperature fields like chemistry and materials science attracted attention in the 1960s. During this time, one of the most important developments in solar furnace technology was the creation of the Scheffler reflector, a parabolic reflector that concentrates sunlight into a specific area. In India, rural populations employed the Scheffler reflector, which bears the name of its creator, Wolfgang Scheffler, to construct solar steam generators and cookers.

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Overall, the advancements in solar furnace technology have made it an attractive alternative to conventional furnaces, particularly for high-temperature applications that require clean and renewable energy sources.

III. LITERATURE REVIEW: STUDY OF PAST ADVANCEMENTS

(Hukuo et al. 1957) addressed a number of design issues with a solar furnaces during the early stages of advancements in solar furnaces. One of these problems was the mirror's accuracy. A solar image produced by a paraxial sunspot beam needs to be accurate enough to have a diameter of smaller than the scattering circle of the focus. Then it was proposed to use a 2-3 aperture ratio. Conclusions were reached demonstrating that a specimen's temperature is not always determined by the mirror's accuracy alone. It is closely related to the physical traits of the specimen as well.

Later, it was discovered that rather considerable modifications in design size could be required even for modest changes in a furnace's specified performance or overall efficiency. It was thought that the design of a furnace would benefit from an initial test programme of experimental calorimetric measurements. The essentials of such a program were described briefly by **(Bliss et al. 1957).**

(Baum et al. 1958) listed some fundamental optical factors in the selection of a design for a solar furnace while taking into account the physical architecture of a solar furnace. He contends that the aperture of a solar furnace, the size of the target, the angle of convergence, the maximum attainable concentration ratio, the overall efficiency, and the amount of spill light that surrounds the target are all directly correlated.

(Lim et al. 2009) discussed the flux distribution of a quasi-single-stage solar furnace which consists of a non-imaging focusing heliostat as the primary stage and a much smaller spherical concentrator as a secondary. A digital simulation strategy was used because the first stage heliostat cannot be imaged. Theoretically, a solar furnace using an 8 X 8 m non-imaging focusing heliostat with 289 mirrors and a spherical concentrator with a 0.7 m aperture and 27 cm focal length could produce a flux concentration of 25,000 suns, according to simulation data. A 6 X 6 m working prototype of the new solar furnace using a non-imaging focusing heliostat constructed in Ning Xia province, PR China, has been shown in Fig. 1.

A Non-Imaging Focusing Heliostat (NIFH) and a considerably smaller parabolic concentrator were presented as the components of an innovative, cost-effective solar furnace system by **(Chong et al. 2010).** The unique solar furnace system was designed using a constant geometry of the NIFH heliostat to prevent the need for year-round astigmatic correction with local controllers, simplifying the design and lowering the cost. The prototype of the novel solar furnace system consisting of the fixed geometry NIFH heliostat and the secondary parabolic concentrator on the campus of University Tunku Abdul Rahman has been shown in Fig. 2.

Fig. 1. A 6 X 6 m working prototype of the new solar furnace using nonimaging focusing heliostat constructed in NingXia province, PR China.

A group of academics has presented a number of potential solutions for the optical design of a concentration system for a solar boiler in a technical note **(Renewable Energy 63 (2014) 263-271)**. With the help of this note, the optical design and analysis of a concentration system for a solar furnace—a structure that employs concentrated sunlight as a direct source of heat—was completed, and many practical choices were recommended. It was discovered that the best approach to visually construct a solar furnace suitable for testing solar application components and procedures was to arrange spherical mirrors on a spherical envelope. When an acceptable beam enlargement is taken into account, the spherical mirrors on a spherical envelope system concentrate the sun's rays on the receiver in a manner similar to the heliostat-axis paraboloid.

Fig. 2. The prototype of novel solar furnace system consisted of the fixed geometry NIFH heliostat and the secondary parabolic concentrator in the campus of Universiti Tunku Abdul Rahman.

(Monreal et al. 2015) described the influence of the latitude and atmospheric conditions in the final design and energy cost of solar furnaces for their use in industrial applications. To carry out design optimisations for various geographical regions, several criteria have been applied. In order to explore this strategy step-by-step and screen out other potential elements connected to actual atmospheric conditions, Monreal's study solely took clear sky conditions into account. The key finding was that places with a low Linke turbidity index and medium latitude, around 27°, appeared to be suitable sites for a solar boiler.

In order to enhance the tracking of a time-varying temperature reference, active cooling was used in the control architecture for solar furnaces described by **(Costa et al. 2018)** in his paper. This capacity is crucial during the temperature reference's descending phase when heat loss must be accelerated.

IV. TYPES OF SOLAR FURNACE

A. Direct Solar Furnace

Direct Solar furnaces can be further divided into various types.

B. Single Lens Direct type

This type of solar boiler has no practical applications. This demonstrates how the solar boiler functions. The light is focused or condensed at the focal point using a single lens, which increases the warmth of the light.

C. Multiple Lens type

In this type, multiple lenses are used to focus light through the first series of lenses. This then converges to the focal point through the second row of lenses using plane mirrors as the means to direct the path towards the focal point, i.e., the furnace.

D. Single Parabolic Direct type

This is also one of the simplest types where instead of a lens, a parabolic mirror is used to reflect the light towards the focal point.

E. Lens-type furnace

Sunlight is focused using a configuration of several lenses and mirrors in a solar furnace of the lens type. The incident rays are refracted from the first lens and go towards the second lens to describe the fundamental process. The mirrors are situated to reflect any incident rays that may be travelling outdoors. The rays are refracted by the second lens after passing through the first one, focusing at a single point or focal point for the entire apparatus.

These solar furnaces were employed in the very early stages of scientific discovery. This sort of solar boiler cannot adjust its position or follow the sun throughout the day, which is a significant drawback. As a result, heliostats were created and put into use, rendering them obsolete. Heliostats can be used in heavy industrial applications involving high temperatures because they are used in sun furnaces. The high upfront cost of this kind of solar boiler is offset by its low ongoing costs.

F. Heliostat Solar Furnace

Heliostat Solar furnaces are further divided into multiple types depending upon the orientation of the optical axis.

- *Heliostat Optical Axis Horizontal*

In a Horizontal axis heliostat solar furnace, a plane mirror acting as a heliostat reflects the solar rays coming from the sun to a parabolic mirror. The reflection from the mirror makes the rays parallel and horizontal to each other.

The rays reflect from the parabolic mirror and converge at the focal point, which acts as the receiver. Odeillo solar furnace uses this principle for solar concentration.

- *Heliostat Optical Axis Vertical*

In a vertical axis heliostat solar furnace, the heliostat reflects the sun rays directly falling on it to the parabolic mirror in such a way that the rays become vertical after reflection and converge to the focal point, acting as the receiver.

- *Heliostat Optical Axis Horizontal and Vertical*

This is a hybrid version of the horizontal and vertical optical axis heliostat and can be used for customized design and applications.

G. Parabolic Concentrator

The parabolic concentrator's job is to focus or divert solar energy towards a specific area known as the focal point. The concentrator helps direct sunlight to a specific area by employing a number of curved mirrors. It is not practical or cost-effective to build an entire parabolic mirror. As a result, the concentrator requires a large number of planar or parabolic mirrors to function. The incoming reflection can be directed on the collector, which is often housed in a tower, by using a number of mirrors. The focus region can be thought of as a circle or an ellipse even if the concentrator may not be able to focus sunlight on a single location. The parabolic concentrator concentrates the sun's rays after they have been reflected off the heliostat. There are two types of compound parabolic concentrators: symmetric and asymmetric. The absorbers used in concentrators are typically pipe absorbers that are tubular and finned.

V. DESIGN AND CONSTRUCTION OF A HYBRID SOLAR FURNACE

A hybrid solar boiler is a solar thermal energy system that produces heat by combining solar energy with other fuel sources. It can be used for a variety of tasks, including material production, chemical processing, and power generation. The design of a hybrid solar furnace is dependent on the application, but the main elements are a heat exchanger, a combustion chamber, and a parabolic dish or trough concentrator. The combustion chamber, which

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burns fuel (such as natural gas or biomass) to produce heat, is where the concentrator directs solar energy. The heat is subsequently transferred through a heat exchanger, which can heat a substance, spin a turbine, or make steam.

Fig. 3. Structure of Solar Hybrid Furnace for commercial use.

A hybrid solar boiler requires expert technicians and engineers to build because of its complexity. Site preparation, component manufacture, assembly, testing, and commissioning are the procedures required. A suitable location must be chosen that receives enough solar radiation and has easy access to water and fuel supplies.

The concentrator, combustion chamber, heat exchanger, and other auxiliary systems are built during component fabrication. Connecting the parts and checking their functionality is known as assembly.

During commissioning, the system is adjusted and its performance is checked under various operating circumstances.

The potential of hybrid solar furnaces to offer sustainable energy solutions for various applications is demonstrated by a number of case studies. For instance, the Solar Hybrid Furnace for Industrial Applications (SHFIA) was created at the Indian Institute of Technology Bombay. Solar energy is focused into a combustion chamber using a parabolic dish concentrator, where biomass is burned to produce hot gases that heat water in a heat exchanger. The SHFIA is intended for industrial uses like steam production and drying and has a maximum thermal energy output of 3 kW.

The Hybrid Solar Thermal Power Plant (HSTPP), created by Abengoa Solar, is yet another illustration. It concentrates solar energy onto a heat transfer fluid using a parabolic trough concentrator, which is subsequently utilised to create steam in a typical power plant. The HSTPP has a 50 MW capacity with a backup natural gas burner for times when solar energy is not enough. It lies in the Spanish region of Andalusia.

The Hybrid Solar Gas Turbine Power Plant (HSGTPP), created by Siemens, concentrates solar energy onto a heat transfer fluid that produces steam in a gas turbine using a parabolic trough concentrator. The system can produce up to 400 MW of power and has a backup natural gas burner. The HSGTPP is a component of the 1.8 GW Benban Solar Park, which is situated in Egypt.

In conclusion, creating a hybrid solar boiler is a difficult procedure that needs to carefully take into account each application's requirements and integrate a number of different parts. Numerous case studies show how hybrid solar furnaces can offer cost-effective energy solutions for a range of applications.

VI. USE OF AI IN THE PANEL ADJUSTMENT SPACE FOR THE FURNACE

Various sectors employ artificial intelligence (AI) to streamline procedures, boost productivity, and cut costs. Similar to other industries, the solar boiler sector uses AI to enhance panel adjustment.

For the solar boiler to operate effectively, the panel needs to be adjusted. To capture the most solar energy and direct it towards the target area, panels must be precisely positioned. Incorrect panel adjusting might result in efficiency loss and energy loss.

Machine learning techniques are used by AI-powered panel adjustment systems to analyse sensor data and modify the panels in real-time. These systems are capable of detecting changes in the weather, the location of the sun, and other environmental elements that have an impact on solar energy harvesting. The AI algorithm may alter the panel in real-time using this information to provide the best possible energy capture.

The capability to optimise panel alignment for the exact requirements of a particular application is one of the major advantages of utilising AI in solar furnace panel adjustment. Different temperature ranges or target areas might be necessary for various purposes. With AI, the boiler may be tailored for the particular application, increasing efficiency and lowering costs.

The possibility to lower maintenance expenses is another advantage of AI-powered panel modification. For optimal alignment, traditional solar furnaces frequently require manual modifications. However, these modifications may now be made automatically thanks to AI, which eliminates the need for user intervention.

Overall, employing AI to modify solar furnace panels is a fascinating breakthrough for the sector. AI can increase effectiveness and cut costs by optimising panel alignment, making solar furnaces more useful for a wider range of applications. The solar boiler sector will see even more cutting-edge applications of AI as a result of the development of technology.

VII. CONCLUSION

The most suitable solar boiler design for India's climate The kind of solar boiler is most suited for India in light of the previous developments covered above. India would rely on a number of variables, including the amount of solar energy available, the temperature range needed, and the particular use.

India has a significant solar energy potential because the majority of the nation receives plenty of sunshine. Consequently, a solar boiler that effectively collects and concentrates sunlight would be a wise choice. The parabolic dish solar furnace is one sort of device that can work well in India. A big dish that directs sunlight onto a pinpoint focus point, where the heat is used to power an industrial operation, makes up a parabolic dish solar furnace. The dish is installed on a tracking system that moves with the sun throughout the day to catch as much solar energy as possible. Parabolic dish solar furnaces may reach temperatures of up to 3,000 degrees Celsius, making them ideal for high-temperature applications. They are also relatively compact and can be stored in small spaces, making them ideal for densely populated areas.

It is important to keep in mind that parabolic dish solar furnaces can be costly to construct and operate, particularly in poor weather circumstances like clouds and haze. Therefore, before choosing the finest kind of solar furnace for a specific site in India, it's imperative to carefully assess the specific requirements of the industrial process and the available solar resources.

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