A Survey of Solar Dish Cavity Receivers Geometries

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Abstract

Recent scholarly efforts have extensively explored the efficacy of solar dish concentrators through both numerical simulations and empirical investigations. These studies predominantly scrutinize the interplay between solar receiver geometry and the dual objectives of minimizing heat loss while amplifying thermal efficiency. This comprehensive review synthesizes the spectrum of research dedicated to examining various cavity receiver geometries, alongside their optimization techniques when integrated with parabolic dish collectors. We systematically assess configurations including flat-sided, cylindrical, conical, and hemispherical designs. Our findings highlight that for an inlet temperature set at 200°C, the conical cavity receiver is distinguished by an exergy efficiency of 30%, a thermal efficiency approximating 70%, and an optical efficiency nearing 87%, maintaining a working fluid temperature range of 650°C to 750°C. The elevated operational temperatures, coupled with the inherent geometry of the cavity, accentuate the significance of mitigating heat losses attributed to convection, conduction, and radiation, as these factors critically impinge on system performance. Additional variables such as cavity inclination angle, diameter-to-depth ratio, tubing contour, and material selection are identified as instrumental in influencing cavity heat losses. Consequently, the pursuit of an optimized cavity receiver geometry emerges as a pivotal area of study. Drawing upon the issues analyzed, we propose strategic recommendations and conclude with insightful remarks poised to guide future research endeavors.

Keywords: Cavity Receiver, Solar Dish Geometry, Parabolic Dish Collectors

مراجعة أشكال المستقبلات الشمسية المجوفة لصحن شمسي

سرمد سلام عبد الرسول ، رعد كاظم محمد الدليمي

الخلاصة:

لقد بينت الجهود العلمية الحديثة وعلى نطاق واسع فعالية مركزات الصحون الشمسية من خلال عمليات المحاكاة العددية والتحقيقات التجريبية. تقوم هذه الدراسات في الغالب بفحص التفاعل بين هندسة مستقبل الطاقة الشمسية والأهداف المزدوجة المتمثلة في تقليل فقدان الحرارة مع زيادة الكفاءة الحرارية. تقوم هذه المراجعة الشاملة بتجميع مجموعة من الأبحاث المخصصة لدراسة الأشكال الهندسية المختلفة لمستقبلات التجويف، جنبًا إلى جنب مع تقنيات التحسين الخاصة بها. نقوم بتقييم التكوينات بشكل منهجي بما في ذلك التصاميم المسطحة والأسطوانية والمخروطية ونصف الكروية. تسلط النتائج التي توصلنا إليها الضوء على أنه بالنسبة لدرجة حرارة المدخل المحددة عند 200 درجة مئوية، يتميز مستقبل التجويف المخروطي بكفاءة الطاقة بنسبة 30%، وكفاءة حرارية تقارب 70%، وكفاءة بصرية تقترب من 87%، مع الحفاظ على نطاق درجة حرارة سائل العمل 650 درجة مئوية إلى 750 درجة مئوية. تبرز درجات الحرارة التشغيلية المرتفعة، إلى جانب الهندسة المتأصلة للتجويف، أهمية تخفيف فقدان الحرارة المنسوب إلى الحمل الحراري والتوصيل والإشعاع، حيث تؤثر هذه العوامل بشكل خطير على أداء النظام. تم تحديد متغيرات إضافية مثل زاوية ميل التجويف، ونسبة القطر إلى العمق، وكفاف الأنابيب، واختيار المواد باعتبارها مفيدة في التأثير على فقدان حرارة التجويف. ونتيجة لذلك، فإن السعي وراء هندسة مستقبل التجويف الأمثل يظهر كمجال محوري للدراسة. وبالاعتماد على القضايا التي تم تحليلها، نقترح توصيات استراتيجية ونختتم بملاحظات ثاقبة تهدف إلى توجيه المساعي البحثية المستقبلية.

1. Introduction

Solar dish concentrators have been the subject of extensive experimental and numerical studies due to their potential for highly efficient solar energy conversion. These studies primarily emphasize enhancing thermal efficiency and minimizing heat losses, both of which are directly influenced by the design of the receiver. The cavity receiver, in particular, has garnered significant attention, as its geometry critically affects heat retention, energy capture, and overall performance.

This review provides a comprehensive examination of various cavity receiver geometries and their integration with parabolic dish collectors. We analyze past research on key designs, including cylindrical, hemispherical, conical, and flat-sided receivers, with a focus on optimization techniques. By synthesizing findings across studies, this review highlights advancements, challenges, and knowledge gaps, thereby setting a foundation for future innovations in solar dish concentrator technology.

1.1 The Geometries of Cavity Receivers

The effective parameters for heat distribution and transfer are the cavity receiver's geometries. As seen in Figure 1, there are four primary common geometries for cavity receivers: cylindrical, hemispherical, conical, and flat sides. The primary study on the geometry of the solar dish cavity receivers and improvements to their thermal performance is presented in this chapter [3].

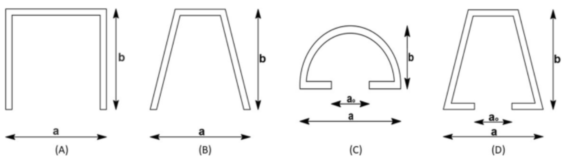

Figure (1): Cavity Receivers' Primary Common Geometries

2. Cylindrical Cavity Receivers

The cylindrical shape is one of the most prevalent geometries in solar cavity receivers that are generally built for limited system capacities. Typically, headers, valves, receiving tubes, and shells make up a cylindrical cavity receiver. Because the cylindrical form was designed without sharp corners, there was the least amount of pressure drop. Furthermore, it would be advantageous if the aperture-to-absorber area ratio was minimal.

2.1 Thermodynamic Researches on Cylindrical Cavity Receiver

One of the most crucial aspects of cylindrical receivers is the research of thermal performance, with convective heat losses serving as the main focus.

The performance of cavity receivers and the impact of cavity aperture diameter were examined by Garrido et al. [4]. They discovered that, at a temperature of 1020 K, an aperture diameter of 190 mm produces a greater electric output than aperture sizes of 170 mm and 150 mm. Energy and exergy are two important parameters for evaluating a cylindrical cavity's thermal performance. It yields the maximum exergy factor for high solar radiation and cavity operating temperature.

By changing the number of tube loops, Zou et al. [5] examine the thermal efficiency of cylindrical cavities. When there were five tubes, the maximum thermal efficiency of roughly 71.41% was attained. The ideal cavity length was 0.403 meters, and the ideal aperture was 0.184 meters.

Mawire and Taole's study [6] found that there was a high energy and energy efficiency of roughly 45% and 10%, respectively. Energy efficiency may be influenced by the type of working fluid.

Loni et al. [7] investigated TiO_2/thermal oil, Cu/thermal oil, Al_2O_3/thermal oil, and SiO_2/thermal oil in relation to this matter. They found that SiO_2/thermal oil produced the highest exergy efficiencies, while Cu/thermal oil produced the lowest. Furthermore, in a different study, the ideal cavity depth was 1 m, and R141b was tested as a working fluid in ORC. 94% of the optical efficiency was achieved [8]. However, R141b was more effective than R123 in the thermodynamic analysis of a simple organic Rankine cycle, and it raised the thermal efficiency to 22.83% [9].

2.2 Experimental Researches on Cylindrical Cavity Receivers

Cylindrical cavity receivers were the subject of extensive experimental research. Heat losses in cylindrical cavities were investigated experimentally by Prakash et al. [10]. Around the hollow aperture, they employed wind skirts with a diameter of 0.5 meters. They discovered that when the receiver was at zero tilt and facing head-on wind, the greatest heat losses were seen. In other receiver inclinations, the cavity heat losses might not be significantly impacted by the wind.

Three types of cavity coatings have been empirically identified: Pyro-paint 634-20, Pyromark 2500, and Fiberfrax 140. These coatings were tested on a cylindrical cavity. At 770o operating temperature, the receiver efficiency was 91.5% overall [11].

Azzouzi et al.'s work [12] aimed to improve the thermal efficiency of the cavity. Thermal efficiency rose by roughly 10% when the inclination angle was changed from 36 to 60 degrees (with respect to the horizontal line and cavity looking downward). However, when the depth to aperture diameter ratio (L/D) increased, the thermal efficiency declined.

After conducting an indoor experiment, Li et al. [13] discovered that, depending on how the optical energy was distributed, the cavity receiver thermal efficiency may reach 60.7%. A flux pattern akin to the sun's was applied to the receiver aperture by applying an incident radiation power of 12,554 W. The 12 7 kW Xe-arc lights that make up the solar simulator.

In 2018 an empirical investigation on the impact of nano fluid on cavity receiver thermal efficiency by Loni et al. [14]. For a solar dish collector, the researchers used MWCNT/thermal oil nano fluid. About 13.12% of the thermal efficiency was optimized. Instead of applying pure thermal oil, they employed SiO_2/oi, Al_2O_3/oil, MWCNT/oil, and nano fluids at high temperatures in further research. At an intake temperature of 1500C, the results showed that the cavity's receiver thermal efficiency increased by roughly 2.54% when compared to the other thermal oil application [15].

2.3 Design and Modeling

In order to get a consistent flux distribution in the cavity receiver, Yan et al. (2018) [16] combined a solar dish concentrator (DSDC) with a discrete cylindrical cavity. Additionally, they used evolutionary algorithms and ray tracing to optimize solar dishes. As a result, the local concentration ratio was significantly reduced using these techniques, while the optical efficiency was maintained at 88.93% to 92.19%. For the parabolic dish collector to be thermally efficient, the receiver aspect ratio is a crucial requirement. The highest levels of thermal efficiency and working fluid outlet temperature were attained by reducing the aspect ratio [17].

Wang et al. investigated a hemispherical-bottomed cylindrical cavity receiver for an integrated hybrid gas turbine-receiver in 2014 [18]. The hemispherical bottom was used to counteract the elevated temperature and pressure.

a single ring-impinging array positioned for temperature storage throughout the upper flux-zone of the cylindrical surface. The absorber temperature difference was controlled and the temperature distribution on the cavity absorber surface became more uniform with the use of impinging jet cooling technology. An eight-nozzle impinging receiver with a single ring nozzle arrangement is a typical example. Two years later, the same researchers used a numerical study to examine single- and multi-row nozzle designs with different nozzle dimensions and number requirements. They discovered that the D320 L400 t3 d10 n12 impinging receiver design was an appropriate nozzle arrangement for managing the absorber's temperature variations. The D320 L400 t3 d10 n12 organization is made up of 12 single row nozzles surrounding the cylindrical surface, a 320 mm cavity diameter, 400 mm length, a 3 mm wall thickness, and a 10 mm nozzle diameter. According to the data, under 800 W/m^2 of radiation, the thermal efficiency reached 82.7% [19].

The total pressure drop in the solar dish system is an important parameter that needs to be acknowledged. The efficiency of the gas turbine decreased as the pressure dropped. The maximum allowable pressure drop in a power plant with a 5-kW micro gas turbine (MGT) is 3% [20], which can be attained by adjusting the jet velocity (Vj), fluid density (r), discharge coefficient (Cd) of the nozzle, and diameter ratio (b) between the plenum and nozzle. Thus, the pressure drop correlation can be expressed as follows:

The radiation flux distribution directly affects the cavity receivers' overall efficiency. The researchers look into a 260 mm-tall cavity receiver that receives different amounts of incident solar radiation—100, 300, 500, 800, and 1100 W/m^2. A critical shift in radiation flux was seen at 80 mm, with the highest shift recorded at 130 mm. Moreover, with a system error of 0 mrad, the radiation flux on the cavity receiver wall might be disregarded up to a height of 80 mm. The mirror tilt surface's solar dish concentrator error is shown by the system error. This modifies the direction in which the rays reflect [21].

A cylindrical cavity receiver using a Brayton heat engine is examined by Wang et al. [22]. Likewise, the impinging jet cooling method was proposed in order to raise the high transfer coefficient in the stagnation area. Moreover, one technique to enhance the performance of jet cooling was to increase the cavity diameter.

In order to study cavity heat losses, Beltran et al. [23] paired a Stirling engine with a solar dish system. Maximum heat transfer rate and highest concentration were reached with an aperture diameter of 130 mm and a rim angle of 45 ° in the cavity aperture.

Silicon carbide was employed in the cylindrical cavity receiver by Neber and Lee [24], which improved the thermal conductivity and absorptivity. As a result, the Bryton cycle power conversion (electrical efficiency) increased by more than 20% at a temperature of 1248 K.

By increasing the cavity depth to diameter (h/D) ratio, Xiao et al. [25] confirmed in 2012 that the cavity heat losses declination. Make a request to lower the height of the cavity convection zone and reduce heat loss. When compared to other angles, the inclination angle of 0o showed a more linear reduction trend. Additionally, in a different study conducted that same year, researchers found that at incidence angles of 0o, 60o, and 90o with wind speeds of 4 m/s, the least value of the combined convection heat with a high-temperature dish/engine was reached in the cylindrical cavity. where increasing the cavity inclination angle decreased the overall convection heat loss. When the wind speed was modest, this reduction was apparent [26]. Because of its simpler design and cheaper manufacturing costs, the cylindrical cavity is one of the most economical solar cavity receiver geometries. This may help to explain why, in comparison to other forms, the cylindrical cavity has been the subject of more experimental investigations concerning solar cavity receivers. Furthermore, some of the solar energy that was received was lost in a typical cylindrical cavity receiver because a coiled tube could not completely cover the cavity bottom. Several suggested approaches to this challenge include combining the cylindrical chamber with a convex or conical bottom. Table 1 briefly illustrates the related studies about the cylindrical cavity receiver.

Table (1): Survey of the Studies on Cylindrical Cavity Receivers

Author(s)	Type of Study	Brief Title	Highlights	Ref.
Xiao et al. (2012)	Numerical	Wind's Impact on Heat Loss in Cavities	lowering the receiver tilt angle to reduce convection heat loss when the wind incidence angle was between -90^o and -30^o.	[26]

Xiao et al. (2012)	Simulation	Cavity Aspect Ratio's Impact on Heat Losses	Convection heat losses decreased as the cavity aspect ratio (h/d) increased. With an inclination angle of 90 degrees and h/d = 4, the smallest cavity heat losses were achieved.	[25]
Neber and Lee (2012)	Experimental and simulation	Optimal Brayton Efficiency	The 0.06 m aperture diameter and the Brayton cycle temperature between 1500 K and 1600 K produced the maximum system efficiency.	[24]
Beltran et al. (2012)	Numerical	Maximum Efficiency of a Receiver	The receiver efficiency and heat transfer rate at 273 K ambient temperature and 0.13 m aperture diameter were 94.5% and 9250 W, respectively.	[23]
Mawire and Taole (2014)	Experimental	An examination of the Cavity receiver's thermodynamics	Under strong sun radiation, the parabolic dish system achieved an optical efficiency of 52%.	[6]
Mao et al. (2014)	Simulation	Optimum cavity configuration	At an aspect ratio of 1.5 and a height of 300 mm, the cavity absorbed the greatest amount of heat.	[21]
Wang et al. (2014)	Numerical	Performance investigation of an Impinging System	By positioning impinging nozzles on the cavity surface, an inner diameter of 200 mm and a cavity length of 350 mm were able to absorb the maximum amount of solar energy.	[22]
Wang et al. (2014)	Numerical	Ideal Intruding Array	The best instance for controlling the temperature distribution on the absorber surface was a 16 x 13 mm single-ring array.	[18]
Wang et al. (2015)	Numerical and simulation	Temperature Distribution in Cavities	Raising the impinging receiver thickness resulted in an increase in temperature distribution uniformity but no change in the cavity temperature distribution.	[20]
Loni et al. (2016)	Numerical and simulation	Increasing a Cavity's Efficiency	The average collector efficiency increased to 66.01% when the cavity depth was set to 2D and the cavity tube diameter was set to 10 mm.	[8]
Wang et al. (2016)	Numerical and simulation	Receivers Impinging on Cooling Nozzles	the impinging arrangement of d10n12, the thermal efficiency decreased from 82.7% to 81.9%, and the outlet temperature rose as a result of a rise in DNI from 800 W/m^2 to 1000 W/m^2.	[19]
Azzouzi et al. (2017)	Experimental and Numerical	The Cavity Receiver's Propensity	The thermal efficiency increased by approximately 10% when the inclination angle was raised from 36 to 60 degrees.	[12]
Loni et al. (2017)	Numerical	Nanofluid in the Receiver	The thermal efficiency decreases as the concentration of Nano fluid increases. The highest and lowest thermal efficiencies were found in $SiO2$/oil and Cu/oil nanofluids, respectively.	[7]
Loni et al. (2018)	Experimental	Nano fluid in the cavity receiver	The working fluid used, Nano fluid, resulted in a 13.12% increase in thermal efficiency. The heat loss coefficient also went down.	[14]
Garrido et al. (2018)	Experimental and Numerical	Electrical power of a cylindrical Receiver	At a temperature of 1020 K, a cavity with an aperture diameter of 190 mm and a mean thickness of 95 mm had the highest electric output	[4]
Yan et al. (2018)	Numerical	Distributed flux in cylindrical Cavity Receiver	The optical efficiency and the direct effective energy ratio of a discrete solar dish concentrator (DSDC) were 92.17% and 86.27%, respectively.	[16]
Soltani et al. (2019)	Numerical and simulation	Helically baffled cylindrical cavity receiver	The thermal efficiency rose by almost 65% when the cavity was positioned at the ideal place and focal line.	[17]

Other useful characteristics that should be taken into account for improving cavity efficiency are the ideal depth, copper tube diameter, and cavity aspect ratio. Therefore, it is recommended to have a lower cavity depth, a smaller tube diameter, and a larger aspect ratio. A quick summary of the relevant investigations conducted throughout the years regarding the cylindrical cavity receiver is provided in Table 1.

3. Hemispherical Cavity Receivers

Many solar cavity receiver shapes and their applications for parabolic dish concentrators have been researched. The hemispherical design is one of the probe shapes for the cavity receivers. The performance and tube configuration of the hemispherical cavity are appropriate when compared to other cavity receiver designs. Helically coiled tubes surround the inner cavity surface and the aperture area's bottom, where the working fluid throws the tubes and absorbs the heat fluxes, in this receiver design. Figure. (2) displays a shell and tube of a hemispherical hollow.

Figure. (2): Black chrome-coated hemispherical cavity receiver with wounded copper tubes [27].

3.1 Thermodynamic Researches on Hemispherical Cavity receivers

The cavity receiver's performance can be influenced by the kind of working fluid used, and using nanofluids can improve the receiver's overall efficiency. 2018 saw the utilization of TiO_2/oil, CuO/oil, and Al_2O_3/oil based nanofluids by Khan et al. [28]. Al_2O_3/oil-based systems exhibited the highest total energy and energy efficiencies, measuring 36.27% and 33.73%, respectively, according to the results.

A solar dish concentrator and an organic Rankine cycle were combined by Refiei et al. [29]. The scientists examined the thermal performance of the system while using the Nano fluid in a hemispherical cavity receiver. The findings show that using MWCNT/oil Nanofluid resulted in 21.4% organic Rankine cycle efficiency, compared to 18.9% for pure oil.

Furthermore, in 2019 they combined a hybrid solar desalination system with a solar dish concentrator. The thermal efficiency was 66% and the cavity heat gain was 1500 at an intake temperature of 40°C. Additionally, freshwater generation reached a value of roughly 19kg/h. The amount of solar energy that is absorbed through the absorber tube is considered the receiver heat gain [30].

An inverse relationship was found between the cavity efficiency and the flow rate when a hemispherical cavity receiver was used in a dish collector; at high temperatures, the efficiency increased as the flow rate fell [31].

A numerical simulation examining a hemispherical cavity receiver from the field synergy principle's perspective was conducted in 2015. First, as the cavity-opening ratio grew, more heat was lost from the cavity to the surrounding air by natural convection. On the other hand, when the inclination angle rose, the heat losses were reduced. where a 90° cavity inclination angle and a 0.5 opening ratio yield the lowest heat losses [32].

3.2 Experimental Researches on Hemispherical Cavity Receivers

The experimental performance of hemispherical cavity receivers was studied by numerous researchers.

Tan et al. [33] employed a semi-spherical cavity receiver sample in 2014, which was a 10 mm-diameter copper tube that had been twisted 23 and 5 turns over the aperture bottom and the hemispherical interior surface. The receiver's aperture and cavity diameter measured 0.25 and 0.35 meters, respectively. To lessen convective heat loss, a 25mm thickness isolator is placed on the outside of the receiver. Figure. The hemispherical cavity receiver is depicted in Figure 3.

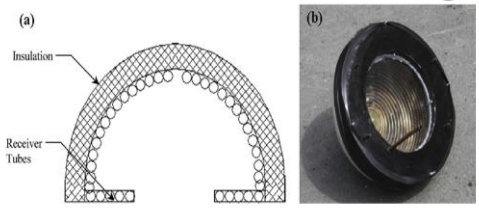

Figure (3): shows the geometry of a hemispherical cavity receiver, including (a) the cavity cross-section and its constituent parts and (b) an experimental model [33].

Alumina/oil and silica oil were the two types of nano-fluids that Loni et al. [34] studied using hemispherical cavity receivers as working fluids. The results showed that using an alumina/oil nanofluid resulted in the maximum thermal efficiency of roughly 73.37% and the lowest energy efficiency of 16%.

Additionally, when utilized in the hemispherical cavity receiver, the alumina/oil combination provides a minimal heat loss coefficient. The MWCNT/oil Nano-fluid with a 0.8% nanoparticle mass fraction was employed by the researcher in a hemispherical cavity receiver that same year. The use of MWCNT/oil Nano fluid increased the thermal efficiency to around 12.93% [35].

Nano fluids including Cu, CuO, TiO2, and Al2O3 were studied in water and thermal oil in 2018 by Pavlovic et al. [36]. In a corrugated tube, the Cu/oil Nano fluid demonstrated the maximum exergy efficiency of 12.29%. The results showed that employing Nanofluid increased energy efficiency by 14%.

Loni et al. used the earlier Nanofluids to investigate the thermal efficiency that same year. When Al2O3 nanoparticles are used, thermal efficiency increases by 35% at a concentration ratio of 28.46 [37].

The average thermal efficiency of a hemispherical cavity receiver was as high as 74% at volumetric flow rates and beam radiations of 250 L/h and 532 w/m^2, respectively. Furthermore, there was a direct correlation between the thermal efficiency and the beam radiation and flow rate. These findings were illustrated by Reddy et al. [38].

3.3 Design and Modeling on Hemispherical Cavity Receivers

Using a 3-D numerical simulation, Reddy and Kumar [39] calculated the natural convection heat loss for a hemispherical cavity receiver. The cavity inclination angle of 0 degrees yields the most natural convection heat loss, while 90 degrees yields the smallest natural convection heat loss, according to the researchers' findings.

In order to improve system performance, Yang et al. [40] looked into the performance of a two-stage dish concentrator design with a semi-spherical hollow heat pipe, as shown in Fig. 4. The findings demonstrated that an increase in overall efficiency from 61.3% to 68.6% is feasible.

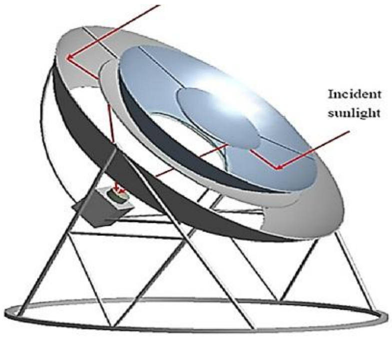

Figure (4): The 2-stage Dish Concentrator Configuration Using a Hemispherical Cavity [40]

The effectiveness of a Stirling device in conjunction with a hemispherical cavity receiver was examined by Zhi-Gang et al. [41]. When the concentrator's cavity aperture and focal face match, the highest optical efficiency of 85.6% is achieved. Because of the shape and size of the aperture, the hemispherical cavity receiver's natural convection heat losses are more significant than those of other forms. Variations in the wind flow and inclination angle are two examples of characteristics that can have a significant impact on cavity heat losses. The temperature differential between the working fluid and the wall tube decreased when the working fluid inlet temperature was raised, suggesting that this method might help lower cavity heat losses. The cavity's open-side ratio was raised in order to improve the heat transfer to the surrounding air. On the other hand, the cavity heat transmission can be roughly reduced and controlled by raising the inclination angle. Furthermore, a low-pressure drop among the usual cavity geometries characterizes the hemispherical design [24]. The performance and characteristics of the hemispherical cavity receiver are explained and briefly summarized in Table 2.

Table (2): Summary of the Hemispherical Cavity Receivers studies.

Author(s)	Type of Study	Brief Title	Highlights	Ref.
Reddy et al. (2009)	Numerical and Simulation	Cavity's Natural Convection Heat Loss	At an angle of ɵ = 0o and 90o, respectively, the highest and minimum natural convection heat losses were recorded.	[39]
Zhi-Gang et al. (2011)	Numerical and Simulation	Circular Cavity with Stirling Motor	The greatest reported thermal and optical efficiencies were 67.1% and 85.6%, respectively.	[41]
Tan et al. (2014)	Experimental	Receiver Inclination Angle effect	Compared to other angles, there was a more noticeable rise in the overall heat loss rate between 0 and 300 degrees of inclination.	[33]
Li et al. (2015)	Numerical and Simulation	Analyzing Cavity Heat Loss	The natural convection heat loss was reduced by increasing the inclination angle approaching 90 degrees.	[32]
Reddy et al. (2015)	Experimental	Cavity Thermodynamic Analysis	With a flow rate of 250 L/h and beam radiation of 532 w/m², thermal efficiency was at 74%.	[38]
Loni et al. (2017)	Numerical and Simulation	Wind's Impact on Heat Losses in Cavities	Increasing wind speed resulted in a drop in cavity temperature and an increase in cavity heat loss	[27]
Pavlovic et al. (2018)	Experimental	Analysis of Cavity Receiver's Exergy	The corrugated tube had the maximum exergy efficiency at 12.29%, whereas the smooth tube had the lowest exergy efficiency at roughly 9.4% for Al_2O_3/water.	[36]
Loni et al. (2018)	Experimental	Receiver Based on Nanofluid	The solar collector's thermal efficiency was 35% when Al_2O_3 was used as the working fluid.	[37]
Loni et al. (2018)	Numerical and Experimental	Cavity Thermal Analysis Using Nanofluid	The working fluid, MWCNT/oil Nanofluid, increased thermal efficiency by 12.93%.	[35]
Loni et al. (2018)	Experimental	Hydrodynamics in a Half-Sphere Cavity	The thermal efficiency ranges for alumina/oil and thermal oil were 72.10% - 74.41% and 68.26% - 66.18%, respectively.	[34]
Yang et al. (2018)	Numerical and Simulation	Dish Design's Impact on Cavity Heat Loss	Applying a hemispherical cavity two-stage dish concentrator raised the overall efficiency from 61.3% to 68.6%.	[40]
Refiei et al. (2019)	Numerical and Simulation	Desalination of Solar Water Using a Hemispherical Cavity	The maximum amount of freshwater output was approximately 19 kg/h, while the thermal efficiency and heat gain were equal to 66% and 1500 W.	[30]
Refiei et al. (2020)	Numerical and Simulation	Nanofluid for ORC Function	The overall efficiency was raised to 21.4% by using MWCNT/oil Nano fluid, compared to 18.9% when using pure oil.	[29]

4. Conical Cavities Receivers

Conical shapes are another option for receiver designs; academics have looked into these shapes. In order to sufficiently absorb the reflected sun radiation, the absorber tube in a conical cavity receiver is often helically shaped. This model has a flat back plate design with a sharp angle, unlike the back plates of the other receivers. Additionally, this cavity receiver also has a cone frustum, which is positioned in the positive or reverse (See Fig. 5).

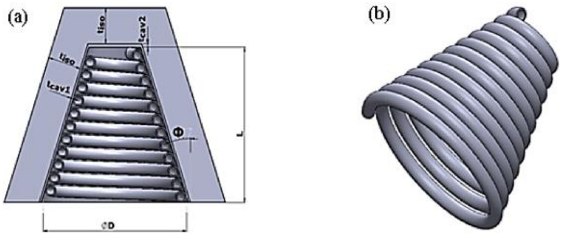

Figure. 5. Conical cavity receiver shape: receiver spiral tube (b) and cavity cross-section (a) [42].

4.1 Thermodynamical Researches on Conical Cavity Receivers

2018 saw an investigation on the conical and spiral cavities' performance by Pavlovic et al. [43]. The results of the optical analysis indicated that, at an oil input temperature of 200 C, the thermal efficiencies of the conical and spiral cavities were 78.7% and 56.0%, respectively, with the conical cavity's optical efficiency being greater by 1.15%.

In order to investigate the exergy and energy of the cavity receiver, Pavlovic et al. [44] tested three distinct working fluids: air, water, and Therminol VP-1. Therminol VP-1 at an inlet temperature of 155 C yields an optimal exergy efficiency of 8%, as demonstrated by the exergy study. On the other hand, in terms of thermal efficiency, water was a good choice at the low temperature in contrast to other fluids. However, at high temperatures, Therminol VP-1 achieved the highest thermal efficiency.

A conical cavity receiver with a spiral tube and Therminol VP-1 as the working fluid was investigated by Li et al. [45]. The findings demonstrated that an 81 K temperature differential between the input and ambient temperatures may achieve a 60% thermal efficiency.

4.2 Experimental Researches on Conical Cavity Receivers

Experimental studies of the conical cavity energy performance and exergy were conducted by Thirunavukkarasu et al. [46]. The results show that the highest thermal efficiency was around 66.75% and the highest exergy efficiency was 10.35% at a flow rate of 2.5 L per minute. A further useful parameter for its operation is the cavity receiver tube's position.

For a pressurized air receiver, Chu et al. [47] used dual spiral tubes with a 4mm inner tube at the bottom of a conical chamber. The obtained results demonstrated that the power outputs and thermal efficiency were 3.96 kW and 53.16%, respectively, at a flow rate of 0.0048 kg/s. In a different investigation, the researchers attained thermal efficiency and exergy of 56.21% and 5.45%, respectively, by using an exterior spiral tube [48].

Venkatachalam and Cheralathan [49] look into how the aspect ratio (L/D) affects the conical cavity receiver's thermal performance. The obtained results show that when the aspect ratio was lowered, the receiver's temperature and thermal performance rose. At an ideal aspect ratio of 0.8, the thermal and exergy efficiency achieved their maximum levels. On the other hand, 58 W/K, the minimal heat loss, was reached.

4.3 Design and Modeling on Conical Cavity Receivers

On a conical receiver, Bashir and Gio Vannelli [50] used phase change material (PCM). The findings demonstrated that the temperature distribution in the PCM and the cavity wall was more favorable in the cavity with a length of 30 cm and an opening diameter of 21 cm. To improve the temperature distribution on the cavity receiver surface, Khalil et al. [51] employed an Inconel spot-welded with variable shape in the same year.

Hernandez et al.'s investigation [52] uses a particular conical cavity receiver design to examine the dish concentrator with a 90-rim angle. A double layer of circulating working fluid allowed the cavity receiver to absorb solar radiation from both the inner and outer sides (Fig. 6). The findings show that while increasing the diameter of the inner cavity side raised the concentration value, increasing the diameter of the outer cavity side decreased the concentration value.

The optical efficiency of a conical cavity with various tube loop counts and inclination angles is examined by Xiao et al. [53]. They found that eight loops and a 15° inclination angle produced the best optical results. Findings are shown in Fig. 7, demonstrate how increasing the number of loops improves both the thermal and overall efficiency. Prior to a declining trend being passed by increasing the inclination angle, there was an increase in both the thermal and overall efficiency [54]. A few key details regarding the conical cavity receivers are shown in Table 3.

Author(s)	Type of Study	Brief Title	Highlights	Ref.
Hernandez et al. (2012)	Both Experimental and simulation	Effective Cavity Performance Parameters	The cavity efficiency rose when the flow rate was increased and the inlet temperature was lowered.	[52]
Li et al. (2015)	Simulation	Conical operation using a spiral tube	At a flow rate of 0.5 L/s and an ambient/inlet temperature differential of 81 K, a 60% thermal efficiency was achieved.	[45]
Thirunavukkarasu et al. (2017)	Experimental	Performance of Conical Frustum Cavity	At a flow rate of 2.5 L/min, the maximum thermal efficiency and energy were around 66.75% and 10.35%, respectively.	[46]

Pavlovic et al. (2017)	Both Experimental and numerical	Cavity's Thermal Performance	The best exergy and thermal efficiencies were obtained using a working fluid of Therminol VP-1, which was as much as 8% and 34%, respectively.	[44]
Chu et al. (2018)	Experimental	Thermal Exam of the Cavity	The thermal efficiency and power production with two spiral tubes and a 4 mm inner diameter tube were 53.16% and 3.96 kW, respectively.	[47]
Pavlovic et al. (2018)	Simulation	Cavities Operation	For conical and spiral cavities, the maximum optical efficiencies were approximately 85.21% and 84.06%, respectively.	[43]
Xiao et al. (2019)	Simulation	Maximum Recipient Efficiency	With eight loops and a cavity angle of 150, the best optical efficiency was attained.	[53]
Bashir and Giovannelli (2019)	Numerical	Thermal Retention of Energy	Si-Mg was used as PCM, and because of its great heat conductivity, the PCM was completely melted with a constant temperature distribution.	[50]
Venkatachalam and Cheralathan (2019)	Experimental	Aspect Ratio's Impact on Efficiency	The overall heat loss factor decreased to 58 W/K by an aspect ratio of 0.8.	[49]
Zhang et al. (2020)	Both Numerical and simulation	Cavity Performance Study	An ideal cavity inclination angle of 50 produced an overall efficiency of 63.6%.	[54]

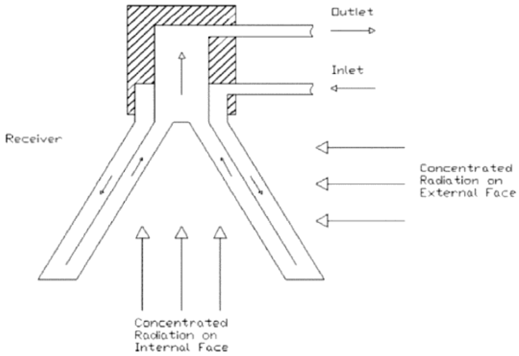

Figure 6. Radiation-absorbing cavity receiver that has both inner and outside walls [52]

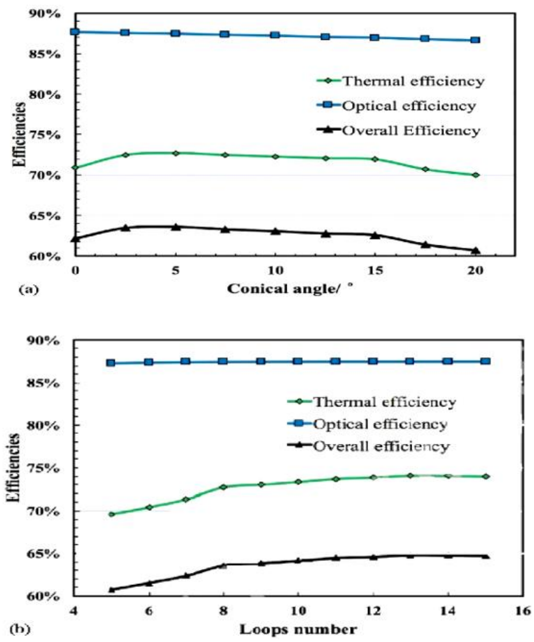

Figure 7. Conical angle (a) and conical cavity efficiency (b) are effective characteristics. loop reference [54]

5. Cavity Receiver with Flat Sides

Rectangular and cubical cavity designs are common in flat-side cavity receivers. A cavity shape with a cubic design and a ratio of cavity depth to aperture length equal to one is an ideal cubical cavity receiver construction. However, in the case of the rectangular shape, this ratio is more than 1. Because of its sharp corners and larger outside surface area, cubical cavities exhibit higher pressure drops and heat losses than cylindrical cavities. It is assumed that other flat side cavities, like the polyhedral shape, are unusual cavity geometries.

5.1 Flat Sides Thermodynamical Research's

A research by Beltrán-Chacon et al. [55] examined a parabolic dish placed inside a rectangular chamber in 2015. The outcomes demonstrated an improvement in electrical efficiency, with a Stirling engine's efficacy rising to 23.38% at a DNI of 974 W/m^2.

A rectangular chamber was used as a heat source in the ORC cycle by Loni et al. [56]. The researchers came to the conclusion that the cavity efficiency would rise if the inner tube diameter and the working fluid's inlet temperature both dropped. At an inner diameter of 10mm the conclusion that the cavity efficiency would rise if the inner tube diameter and the working fluid's inlet temperature both dropped. At an inner diameter of 10 mm and an inlet temperature of 70 ^{o}C, the greatest thermal efficiency was 70.51%.

Loni et al. [57] employed R11, methanol, and ethanol as working fluids in the same year. The ORC cycle receives thermal energy via a square prismatic cavity receiver form. When methanol is utilized, the greatest thermal efficiency is achieved. R11, on the other hand, had the lowest thermal efficiency and the minimum irreversibility.

5.2 Flat Sides Experimental Research's

Experimentally, flat cavity heat losses were explored by Taumoefolau et al. in 2004 [58]. The researchers looked at various angles of cavity inclination. The findings demonstrated that an angle of 900 by an exposure ratio of 0.5 produced the least amount of heat loss by natural convection.

The flat-side cavity receiver temperature was examined in a variety of radiative scenarios by Alvarado-Juarez et al. [59], and both experimental and numerical research was done on the Surface Thermal Radiation (STR) and Radiative Participating Media

(RMP) instances. They employed an 8-cm-long, 8-cm-high, square open cavity design built of cement. As depicted in Fig. 8. They positioned a 0.06-cm-thick copper plate at the back of the cavity, connecting 14 thermocouples to the interior cavity surface. The RMP case outperformed the STR one, according to the testing data. The variation value of the experimental results was 3.5% for the RMP and 7.8% for the STR when compared to the numerical results.

Lopez et al. [60] assessed the heat losses and cavity efficiency after covering a flat cavity aperture with glass. While the cavity efficiency increased by 20%, the researchers saw a drop in convective heat loss. By covering the cavity aperture, where the HTF temperature was 150^{o}C, the maximum efficiency of 70% was achieved.

5.3 Flat Sides Design and Modeling

Le Roux et al. [61] used an open-rectangular cavity to study the scaled-down solar thermal Brayton cycle (STBC) in 2014. They show that, at an input temperature of 900 K, the optimal ratio of the cavity aperture to its area was approximately 0.0035, yielding a receiver efficiency of roughly 68%.

The impact of the cavity depth and inner cavity tube diameter on the exergy performance was investigated by Loni et al. [62]. When the tube diameter was reduced and the cavity depth was equal to the aperture length, the maximum energy efficiency was achieved. In another study conducted that same year, researchers used artificial neural networks (ANNs) and numbers to predict cavity performance. The cavity depth and tube diameter were taken into consideration as modifiable elements in the study. The correlation coefficient (R2) for the outlet temperature was found to be approximately 1 when the ANN model was compared to numerical findings [63].

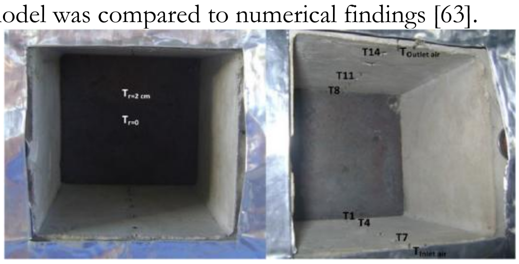

Figure 8. a square, open cement hole showing the locations of the thermocouples [59].

6. Comparative Studies Between Various Cavities

One of the most effective collectors among solar concentrating power systems are the dish concentrators with the solar cavity receiver. Therefore, the cavities are built using a variety of optimum designs in order to achieve the maximum efficiency. The maximum solar energy collection rate, the lowest cavity heat loss, and the lowest construction cost are the three most crucial factors that need to be rated in the cavity design. The most common forms of cavities are cubical, hemispherical, conical, and cylindrical. Some comparison research between various cavity-shape designs are highlighted in this section.

2018 saw a comparison of cylindrical, hemispherical, and cubical cavity receivers operating under identical conditions with water or oil as the working fluid by Loni et al. [64]. The findings showed that the receiver with a hemispherical cavity had the lowest pressure drop and the most energy. Figure. This comparison at various temperatures is explained in 9. They advised utilizing oil fluid in the hemispherical cavity at high temperatures.

A parabolic dish with three different kinds of cavities—cubic, hemispherical, and cylindrical—was examined by Loni et al. [65]. As a working fluid, they use alumina-oil Nano-fluid. It was observed that by increasing the concentration of the nanofluid and decreasing the size of the alumina nanoparticles, the cavity thermal performance enhanced.

As seen in Fig., Loni et al. [66] investigated the performance of two artificial cavities in a different study: a cubical cavity with an outer length of 145 mm and a made cylindrical cavity with an outer diameter of 160 mm. Ten. The primary results demonstrated that the thermal efficiency of the cubical cavity outperformed that of the cylindrical one.

Three different receiver types—spherical, cylindrical, and conical—had their cavity optical efficiency examined by Daabo et al. [67] using different absorptivity values of 75%, 85%, and 100%. They took into consideration cavities with a focal distance ranging from 55.5 to 59 cm and an exterior diameter of 20 cm. Furthermore, a dish concentrator featuring a 45-degree rim angle, a concentrating ratio of five, and a diameter of 100 cm was selected. The greatest optical efficiency values for conical, spherical, and cylindrical receivers were around 72.2%, 68.7%, and 65.4%, respectively, for a 75% absorptivity. With an absorptivity of 85%, the conical cavity receiver absorbed the most energy on average when it was at a focal point of 56 cm.

Three modified hemispherical cavity receivers with various aperture diameters were investigated by Kumar and Reddy [68]. By changing the cavity inclination to 90 degrees, the maximum convective heat loss was achieved at inclination 0 degrees.

Si-Quan et al. [69] investigated and contrasted the optical efficiency of spherical, conical, and cylindrical cavity forms. The obtained optical efficiency values for the three cavity geometries—cylindrical, conical, and spherical—with comparable inner diameters and thicknesses were around 88.6%, 87.5%, and 88.9%, respectively. in a different search.

Using a parabolic dish, Kaushika and Reddy [70] used several hemispherical cavity types. With a 3.5 cm aperture radius and 450 oC operating temperature, the updated design of the receiver achieved a maximum efficiency of roughly 70–80%.

Shuai et al. [71] conducted an experimental and computational analysis of the dimensionless radiation flux distributions of teardrop cavity receivers that were spherical, conical, and upside-down in 2010. The findings showed that the radiation flux distribution uniformity was lowest for the conical receiver. Nevertheless, the radiation flux distribution's homogeneity was satisfactory in the shape of an upside-down teardrop receiver.

Conical and dome cavities were exercised and compared by Seo et al. [72]. In the receiver with a dome cavity, operating temperature of 200 oC, and mirror size of 10 cm*10 cm, the receiver efficiency was approximately 92.5%. When the mirror size was 20 cm by 20 cm, the efficiency in the dome receiver increased from 0.8% to 3.1%.

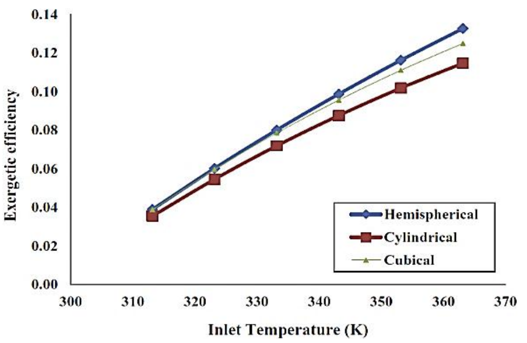

Figure 9. Comparing the energetic efficiency of three different cavity receiver types at different input temperatures [64]

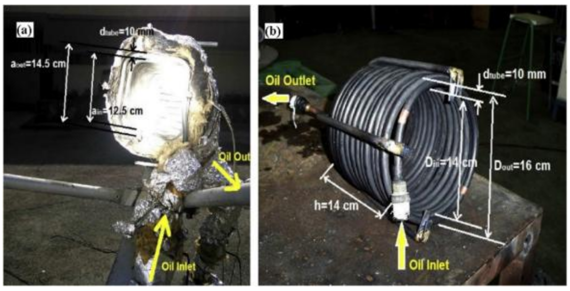

Figure.10. The dimensions of the cavity receivers utilized in the investigation are as follows: (a) cubicula cavity; (b) cylindrical cavity [66].

8. Conclusions

Of all the renewable energy sources, solar energy is one of the most useful. All around the world, solar energy is acknowledged as a clean and economical energy source. In this publication, the investigations of dish collector solar cavity receivers are reviewed and discussed, with an initial focus on geometry. For solar thermal power plants, using a parabolic dish collector with a cavity receiver is an efficient method. One important problem that has to be solved is the optimization of the solar cavity receivers. By categorizing their diverse shapes, a thorough examination of the solar cavity receiver performance has been carried out. The literature review leads to the following conclusions, which are crucial points:

- One of the key and effective technologies of solar thermal power plants is solar power concentration. For high rates of generation, enough heat, cooling, desalination, and power could be produced with a parabolic solar dish concentrator.
- Because solar dish systems have excellent thermal and energy efficiency, they can be used as feedstock for prime movers that operate at high temperatures, such as the Rankine cycle, Bryton cycle, ORC, and micro-gas turbine.
- The maximum optical efficiency for the cylindrical shape will be 95.3% when Ysz TBC is coated at the end of the cavity and Pyromark 2500 is used as a coating on the surface.
- the maximum thermal efficiency possible from a hemispherical cavity receiver, featuring a reflector surrounding the cavity aperture side and a spiral coil on the exterior.
- A cylindrical-conical cavity design is referred to as having a maximum exergy efficiency of 35.73%.
- The ideal cavity length for the majority of solar cavity receiver geometries is equal to its aperture; this is especially true for the conical, cylindrical, and rectangular designs.
- One weak region for the absorption of solar energy is thought to be the blank space at the rear of the hollow. By filling the empty space, combining two suitable cavity geometries could improve receiver performance.
- Because of its sharp corners and tube arrangement, the rectangular cavity design had the largest pressure drop, while the hemispherical cavity design had the lowest pressure drop.

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