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Güneş Bacası Güç Santrallerinde Kule Çapının Çıkış Gücüne Etkisi

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MAKALE BİLGİSİ

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***Anahtar Kelimeler*:**
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Çıkış gücü
Enerji analizi

ÖZ

Güneş bacası güç santralleri düşük bakım maliyetleri ve sıfır CO_2 salınımları ile çok cazip güneş enerjisi sistemleridir. İlk uygulaması olan Manzanares tesisinden sonra geometrik ve iklimsel parametrelerin sisteme etkisi ile ilgili sayısız çalışma yapıldı. Bu çalışmada literatürde yeterince irdelenmeyen baca çapı değişiminin sisteme etkisi detaylı olarak incelendi. ANSYS ticari yazılımı ile oluşturulan 3 boyutlu CFD modelinde güneş ışın izleme algoritması ve DO (ayrık koordinatlar) modeli ile RNG k-ε türbülans modelleri kullanılarak simülasyonlar yapıldı. Diğer geometrik parametreler için referans tesis örnek alınarak baca çapı 4.865-64.866 m arasında değiştirilmek suretiyle sistem davranışı araştırıldı. Baca çapı değişiminin ilk olarak sistem içerisindeki basınç ve hız dağılımına etkisi referans durumla karşılaştırılarak analiz edildi. Ayrıca baca çapı değişiminin sistemin güç çıkışı, kütlesel debisi, verimi ve türbin konumunda ortalama basınç farkına etkisi değerlendirildi. Manzanares pilot tesisi için maksimum performans veren baca çapı değerinin 24.325 m olduğu sonucuna varıldı. Baca çapı 24.325 m yapıldığında referans duruma göre güç çıkışının % 85.9 artarak 101 kW olacağı tespit edildi. Benzer şekilde verim de referans duruma göre % 94 artış göstererek % 0.194 olarak hesaplandı.

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Impact of Tower Diameter on Power Output in Solar Chimney Power Plants

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ABSTRACT

Solar chimney power plants (SCPPs) are very attractive solar energy systems with low maintenance costs and zero CO_2 emissions. After its first application, the Manzanares facility, numerous studies were conducted related to the impact of geometric and climatic parameters on the system. In this study, the impact of chimney diameter change on the system, which has not been adequately examined in literature, has been investigated in detail. In the 3D CFD model created with ANSYS commercial software, simulations have been conducted by using the solar ray tracing algorithm and DO (discrete ordinates) model along with RNG k-ε turbulence model. By referencing the Manzanares facility for the other geometric parameters, system behaviour has been assessed by changing the chimney diameter between 4.865-64.866 m. The impact of the change in tower diameter on the pressure and velocity distribution in the system has been analysed first in comparison with the reference situation. In addition, the influence of diameter change on the power output, mass flow rate, efficiency of the system and the average pressure difference at the turbine position has been evaluated. It has been concluded that the chimney diameter value that gives maximum performance for the Manzanares pilot plant is 24.325 m. When the chimney diameter has been configured as 24.325 m, it has been seen that the power output will improve by 85.9% compared to the reference situation and will be 101 kW. Similarly, the efficiency rises by 94% in comparison with the reference case, and becomes 0.194%.

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1. INTRODUCTION *(GİRİŞ)*

Increasing living comfort with technological developments has pushed people to consume more energy. With the notable rise in world population, this situation has increased the energy demand significantly. The need for more energy has revealed the importance of the terms like efficient use of energy resources and environmental consciousness. Despite the widespread use of high-efficiency technological products in recent years, energy consumption is increasing day by day. This situation causes serious environmental issues due to the fact that energy sources are mostly fossil fuels. One of the best ways to combat environmental pollution is to use renewable energy sources instead of fossil fuels. The most common renewable energy source is the sun. The sun, which can be reached from any point in the world, is an attractive renewable energy source with its high potential. Although there are different ways of harnessing energy from the sun, the most common solar energy technology can be asserted as photovoltaic (PV) systems. PV systems provide direct conversion of photons into electrical energy through semiconductor devices [1]. The most outstanding handicap of PV based electricity production is the high investment cost and perspicuous dependence on climatic conditions notably solar intensity potential. Besides direct conversion of sunlight into electricity through PV technology, it is also possible to generate electricity through some other systems [2].

One of these systems is solar chimney power plants (SCPPs). SCPP systems, which are not as popular as PV systems, attract the attention of researchers due to their zero CO2 emissions and low maintenance costs. Its first application was the Manzanares facility established in the Spanish countryside in the 1980s [3]. This facility with a chimney height of 194.6 m, a collector radius of 122 m and a chimney diameter of 10.16 m gives a power output of 50 kW at noon in September, with an efficiency of 0.1% [4]. After the first installation, researchers show intense interest in SCPP systems. Based on experimental data, Mullet [5] analyses SCPP systems with a mathematical model he developed. The proposed model claims that the efficiency of the system to be designed at 1000 m chimney height will be 1%. Three| factors that affect the performance of SCPP systems in general can be listed as climatic parameters, geometric parameters and design parameters. Climatic parameters are ambient temperature and solar intensity. Cuce et al. [6] analyse the effect of climatic parameters on the performance of the Manzanares pilot plant with the 3D CFD model they developed. They emphasise that solar intensity has a positive impact on power output. They report that the power output, which is 7.16 kW for the solar intensity of 200 W/m2 at the ambient temperature of 293.15 K in the reference geometry, will approach 6 times and becomes 49 kW when the solar intensity is 1000 W/m2. They also indicate that an increase in ambient temperature will have the opposite effect, reducing the power output. Similarly, researchers argue in their studies that solar radiation increases the power output since it enhances the energy entering the system, but the increase in ambient temperature has an opposite impact [7-9]. Since the climatic parameters may vary, it may be difficult to predict their influence on system performance in advance, but by analysing the geometric parameters in advance, an idea about the system performance can be obtained. Since the chimney is the driving force of the system, the increase in the height of the chimney directly increases the performance of the system [10]. Researchers emphasise in their works referencing the Manzanares pilot plant that increasing the height of the chimney will increase the power output and efficiency of the system [10-14].

The reason why SCPPs are called as a solar energy system is that they transfer the solar radiation to the air inside with the collector in its structure. For this reason, the increase in the collector area increases the energy entering the system, thus increasing the performance characteristics of the system. Ikhlef and Larbi [15] analyse the effects of the use of the energy storage unit and the change in geometric parameters on the system in their study that references the Manzanares pilot plant. They claim that the system with a collector radius of 120 m in the reference geometry gives a power output of 50 kW, while the power output will be 200 kW if the collector radius is modified as 240 m. Different researchers also present studies supporting that increasing the collector radius will increase the performance of the system [11,12].

Some researchers, on the other hand, claim that increasing the collector radius will increase the system performance up to 300 m when the geometric and material properties of the Manzanares pilot plant are taken into consideration, and after the collector radius of 300 m, it is reported that the system will be adversely affected [7]. The chimney is the driving force of the system and its diameter as well as its height is a critical parameter for the SCPP. Since the increase in the diameter of the chimney will evacuate more air from the system and increase the mass flow rate, it increases the performance of the system up to a certain point, but after this point it has a negative effect on the system [11,15].

Besides the geometric parameters, the design aspects are also effective in the performance of the system. Design parameters generally include the convergent-divergent structure of the collector and chimney. Hassan et al. [16] carry out a 3D CFD research with reference to the Manzanares pilot plant. In order to analyse the influence of divergent chimney structure and collector slope on the performance of the SCPP system, they adopt solar load approach, DO (discrete ordinates) technique, and RNG k-ε turbulence model (TM). When they examine the performance of the divergent chimney degree between 1º-3º, they claim that the maximum power output is 108% higher in 1º divergent chimney compared to the reference situation. When they evaluate the collector slope for 4, 6, 8 and 10º, they observe that the mass flow rate, temperature and air velocity figures of the system increase with the collector slope. For divergent and convergent chimney structure, researchers define the ratio of chimney outlet area to chimney entrance area as AR (area ratio) [17-19]. Cuce et al. [19] investigate the effect of chimney design on the performance of the system with a 3D CFD model. When they evaluate the outputs of the system for the AR range of 0.5-10, they achieve that the divergent chimney design gives higher performance than the convergent chimney design. They claim that while the power output for AR=1 in the reference case is 54.1 kW, for the ideal AR range (4-6), the power output will increase about 3 times to 168.5 kW. Another design parameter that affects the performance of the system as much as the collector and the chimney is the floor. Since the slope to be given to the floor of the system will support the upward air movement under the collector, it increases the performance of the system [20,21].

When the existing literature is examined, it is seen that the chimney height and collector radius have been analysed many times by researchers as geometric parameters, but the chimney diameter has not been adequately interpreted. In this study, simulations are conducted at a solar intensity of 1000 W/m^2, and a constant ambient temperature of 293.15 K, based on the geometric dimensions of the Manzanares pilot plant. By keeping the chimney height and collector radius constant, the effect of the chimney diameter on the system is interpreted for values ranging from 4.865 to 64.86 m. In the study, the expression of slenderness, which has been previously addressed in the literature, is adopted. Slenderness represents the ratio of chimney height to chimney diameter in SCPP systems. Within the scope of this research, the slenderness is represented by θ (H_{ch} / D_{ch}).

2. WORKING PRINCIPLE AND GOVERNING EQUATIONS *(ÇALIŞMA PRENSİBİ VE KORUNUM DENKLEMLERİ)*

Although SCPP systems take up a lot of structural space, there are basically 3 system elements. These are the glazing cover, the tower/chimney and the turbine. Thanks to its semi-permeable structure, the collector is the starting element that ensures the transfer of solar radiation to the system during the day. The solar radiation transferred from the collector to the system and reaching the ground from here causes an increase in the temperature of both the system air and the ground. The density of the system air with increasing temperature decreases and starts to move upwards. Heat transfer occurs from the ground with an increased temperature to the system air. The air moving upwards is directed towards the chimney in the centre of the collector. Due to its high structure, the chimney creates a constant pressure difference. In addition, the chimney supports the upward movement of the air, whose temperature has increased under the collector, and allows it to leave the system. In this way, the system is in a continuous loop. The kinetic energy of the air moving upwards in the chimney is converted into electrical energy by the turbine placed at a certain height from the ground.

This study is carried out based on the structural dimensions of the Manzanares pilot plant, which is the first application of SCPP systems. The chimney diameter is changed between 4.865-64.86 m while keeping other geometric parameters constant. With this change, the effect of the slenderness (θ) value on the change of the mass flow rate, power output, efficiency and average pressure difference in the turbine location is analysed. In all CFD analyses, the ambient temperature and solar intensity are kept constant. In addition, continuity, momentum, energy, and turbulence equations are solved simultaneously with the following assumptions in terms of convenience and economy in the analyses:

- There is a 3D, constant and turbulent flow regime
- There is no change in environmental conditions throughout the analyses
- System air is considered incompressible
- For density calculations, Boussinesq model is adopted

The governing equations of the present work are listed below [22]:

1. Continuity equation:

$$\nabla.(\rho.\vec{v}) = 0 \quad (1)$$

2. Energy equation:

$$\nabla.\left(\vec{v}(\rho E + p)\right) = \nabla.\left(k_{eff}\nabla T - h\vec{J} + \left(\mu\left[(\nabla\vec{v} + \nabla\vec{v}^T) - \frac{2}{3}\nabla.\vec{v}I\right].\vec{v}\right)\right) \quad (2)$$

3. Momentum equation

$$\nabla(\rho.\vec{v}.\vec{v}) = -\nabla p + .\left(\mu\left[(\nabla\vec{v} + \nabla\vec{v}^T) - \frac{2}{3}\nabla.\vec{v}I\right]\right) + \rho\{\vec{g}\} \quad (3)$$

The air under the collector in the system is exposed to convection effects only by solar radiation and the temperature increase on the ground. In this case, there is natural convection and the Ra number for the natural convection can be calculated with the following equation [19]:

$$Ra = \frac{g\beta\Delta T H_{coll}{}^3}{\alpha\upsilon} \quad (4)$$

In the equation, α represents the thermal diffusion coefficient, υ the kinematic viscosity, and Hcoll the collector height. 109 is the critical value for the Ra number, since the Ra value is about 8.5×10^9 in the conducted study, the flow can be taken as turbulent [23]. The RNG k-ε TM, which is one of the 3 different TMs available in the ANSYS FLUENT software, is used in the study. The equation of the model is given as [22]:

$$\frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\alpha_k \mu_{eff}\frac{\partial k}{\partial x_j}\right] + G_k + G_b + \rho\varepsilon - Y_M + S_k \quad (5)$$

$$\frac{\partial}{\partial x_i}(\rho\varepsilon u_i) = \frac{\partial}{\partial x_j}\left[\alpha_\varepsilon \mu_{eff}\frac{\partial \varepsilon}{\partial x_j}\right] + C_{1_\varepsilon}\frac{\varepsilon}{k}(G_k + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} - R_e + S_\varepsilon \quad (6)$$

Haaf [4] states that there is not much increase in the temperature of the air in the system through the experimental measurements on the pilot plant. In this case, the Boussinesq model, which was accepted in previous studies, is used for the density in the CFD study [19-21,24]. The equation of the model is as follows [19]:

$$(\rho - \rho_a)g \approx -\rho_a\beta(T - T_a)g \quad (7)$$

In the equation, ρ_a and T_a are the initial density and initial temperature, β is the thermal expansion coefficient and g is the gravitational acceleration, respectively. The turbine pressure drop (ΔP_t) is used to calculate the power output of the system. The power output (P_o) can be obtained from the following equation:

$$P_o = \eta_t \Delta P_t Q_v \quad (8)$$

Q_v stands for volumetric flow rate. η_t is efficiency of turbine-generator system and is assumed to be 0.8 [19-21]. The most common use for calculating the turbine pressure drop is to exploit the pressure difference in the chimney [3]. In this study, pressure drop across the turbine is calculated by taking the average pressure difference (P_t) at the turbine location from the CFD results. The equation is as follows:

$$\Delta P_t = r_t P_t \quad (9)$$

r_t in the equation is the turbine pressure drop ratio and is taken as 2/3 [4,10]. The efficiency of the system (η) expresses how much of the energy entering the system is converted into electrical energy, and its equation is as follows:

$$\eta = \frac{P_o}{A_{coll}G} \quad (10)$$

Here, A_{coll} denotes the collector area and G refers to solar intensity.

3. SYSTEM PROPERTIES AND CFD MODEL
(SİSTEM ÖZELLİKLERİ VE HAD MODELİ)

The parameters affecting the performance of SCPP systems are repeatedly analysed in the literature. In particular, the effect of chimney height and collector radius changes on the system is assessed in many studies. This study aims to examine in detail the effect of chimney diameter variation on the performance of the system based on the Manzanares pilot plant. The geometric details of the pilot plant referenced in the study are given in Table 1.

The effect of different chimney diameters is evaluated with ANSYS FLUENT commercial software. First, a 3D model is created for CFD work and two planes of symmetry (XZ and YZ planes) are used for economy. Since the temperature does not change after 0.5 m in the experimental data, this ground thickness is considered sufficient [4].

Table 1. Characteristic system details of Manzanares facility [3] *(Manzanares tesisinin karakteristik sistem detayları)*

Parameter	Value
Glazed cover height (H_{coll})	1.85 m
Glazed cover radius (R_{coll})	122 m
Chimney height (H_{tow})	194.6 m
Ground thickness	0.5 m
Chimney diameter (D_{ch})	4.865 – 64.86 m
Slenderness (θ)	3 – 40

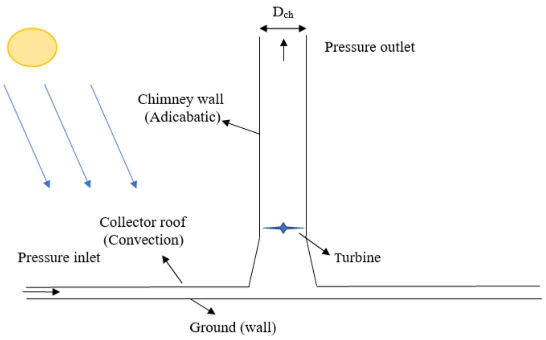

Figure 1. The model for SCPP system and relevant boundary conditions

(SCPP sistem modeli ve ilgili sınır koşulları)

Provided that other geometric parameters are kept constant, the diameter of the chimney is increased from 4.865 m to 64.86 m at different intervals. Since the pressure differences at the collector inlet and chimney outlet are very small, they are neglected. The schematic and boundary conditions of the system are given in Figure 1. There is convection between the system air and the collector and 10 W/m^{2}K is taken as the convective heat transfer coefficient. In addition, since the chimney and the ground wall are considered adiabatic, the convective heat transfer coefficient is taken as 0 W/m^{2}K for the aforesaid surfaces. The materials used in the system are given in Table 2 with reference to the Manzanares pilot plant. The simulations carried out in the study are conducted with the ANSYS FLUENT software, which is based on finite volume method. RNG k-ε TM is preferred in the analyses, which is compatible with the nature of the problem. The SIMPLE algorithm is adopted for the relationship between air velocity and pressure, and the PRESTO technique is adopted for pressure interpolation. DO (discrete ordinates) radiation method is applied to the system with solar ray tracing algorithm (SRTA). The quadratic UPWIND discretisation method is implemented in all of the governing equations. The Boussinesq method is considered appropriate for the change in the density of the system air. 10^{-6} is accepted as convergence criterion in all analyses. CFD solver parameters and climatic figures are given in Table 3.

Table 2. Physical properties of materials adopted in CFD calculations *(HAD hesaplamalarında benimsenen malzemelerin fiziksel özellikleri)*

Mater. prop. (unit)	Collector	Ground	Tower
Dens. (kg.m^{-3})	2.5×10^3	2.16×10^3	2.719×10^3
Ther. Cond. (W.m^{-1}K^{-1})	1150×10^{-3}	1830×10^{-3}	2024×10^{-1}
Spec. heat cap. (J.kg^{-1}K^{-1})	7.5×10^2	7.1×10^2	8.71×10^2
Transmis. coeff.	9×10^{-1}	Opaq.	Opaq.
Abs. coeff.	3×10^{-2}	9×10^{-1}	0
Refrac. index	1.526	1	1
Emiss. coeff.	1×10^{-1}	9×10^{-1}	1
Thickness (m)	4×10^{-3}	5×10^{-1}	1.25×10^{-3}

Table 3. CFD model values and environmental data *(HAD model değerleri ve çevresel veriler)*

Sol. Intensity (W.m^{-2})	1×10^3
Atmosp. pressu. (Pa)	101.325×10^3
Amb. temp. (K)	2.9315×10^2
Amb. air dens. (kg.m^{-3})	1204×10^{-3}
Gravita. acceler. (m.s^{-2})	9.81
Air cond. (W.m^{-1}K^{-1})	2.59×10^{-2}
Ideal gas const. (J.kg^{-1}K^{-1})	2.87×10^2
Kinem. visc. (m.s^{-2})	14.8×10^{-6}
Air heat cap. (J.kg^{-1}K^{-1})	1.006×10^3
Turb. pressu. drop ratio	0,6666
Stefan-Boltzmann const. (W.m^{-2}K^{-4})	5.67×10^{-8}

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4. RESULTS AND DISCUSSION *(BULGULAR VE TARTIŞMA)*

In this study, a mesh independent solution is first implemented to examine the effect of chimney diameter variation on the system behaviour of the Manzanares facility. For the mesh independent solution, three different mesh structures are examined for the maximum air velocity (V_{max}) in the plant. The number of cells, maximum air velocity and percent change values for the mesh independent solution are given in Table 4. A change of 1.5% is observed for V_{max} between the solutions with a cell number of 386k (k=1000) and 305k. This value is considered sufficient; thus the rest of the analyses are carried out for the cell number of 386k. The model and the mesh image used in CFD analysis are given in Figure 2.

Table 4. Mesh-free analysis for V_{max} *(V_{max} için ağ bağımsız analiz)*

Cell num.	V_{max} (m/s)	% diff.
259k	14.42	-
305k	13.99	2.98
386k	14.20	1.5

Experimental findings are used to determine the accuracy of the model created without changing the diameter of the chimney. The experimental results for the power output of the Manzanares pilot plant at different solar intensities and the findings of the present study are given in Figure 3 [25]. It is seen that the CFD results are in agreement with the experimental data.

The main parameters affecting the power output of SCPP systems are air flow volume per second and pressure drop across the turbine. The volumetric flow rate and turbine pressure drop are directly related to the air flow rate and pressure in the system. Therefore, in principle, the effect of the change in the diameter of the chimney on the air velocity and pressure distribution in the system is interpreted. The pressure distributions in the system for the reference situation and the chimney diameter of 24.325 m are given in Figure 4. It is seen that the increase in the slenderness value decreases the maximum pressure difference in the system.

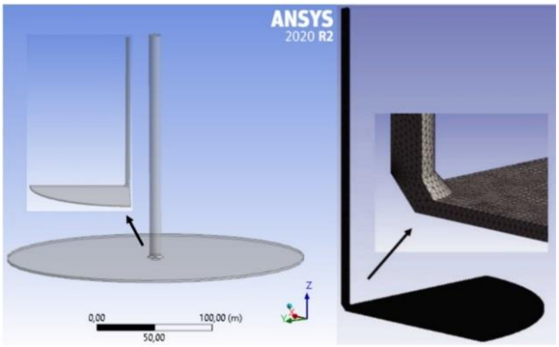

Figure 2. Model and mesh visuals
(Model ve ağ görselleri)

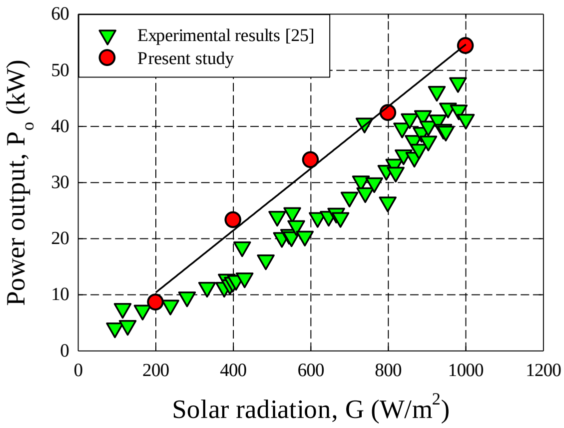

Figure 3. Verification of the CFD model via the power output (P_o)
(HAD modelinin çıkış gücü (P_o) yardımıyla doğrulanması)

While the maximum pressure difference is approximately 154 Pa in the reference case, when the chimney diameter is 24.325 m (θ=8), it is seen to decrease by 35% to 100 Pa. It is obtained that the maximum difference in pressure is reached around the chimney inlet in the reference geometry. In the pilot plant, the turbine is fixed at 9 m height above the ground. This location is the region where the difference in pressure in the plant is the highest. When looking at the end of collector, it is noticed that the pressure difference is more pronounced for D_{ch} = 24.325 m (θ=8) compared to the reference geometry. The reason for this is the sudden expansion of the system air due to the increase in the diameter of the chimney. When the diameter of the chimney is increased, it is seen that the pressure distribution in the chimney changes significantly. In this case, it can be said that the point where the difference in pressure is highest may change according to the reference situation. Since the maximum pressure difference will mean maximum power output, the pressure difference should be well analysed when designing in different geometries. It is seen in Figure 5 that the change in chimney diameter also affects the air velocity in the system. It is understood that the air velocity at the collector outlet in the reference state exceeds approximately 8 m/s. For D_{ch} = 24.325 m (θ=8), it is found that it cannot reach 2 m/s at the collector output.

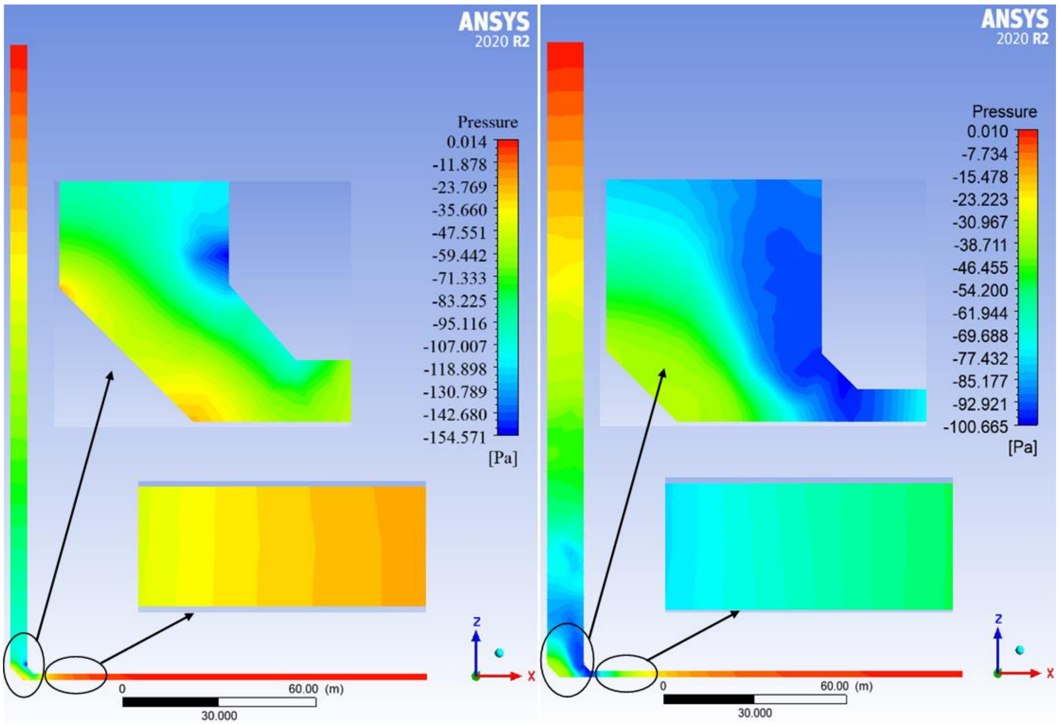

Figure 4. Pressure distributions for references geometry and θ=8

(Referans geometri ve θ=8 için basınç dağılımları)

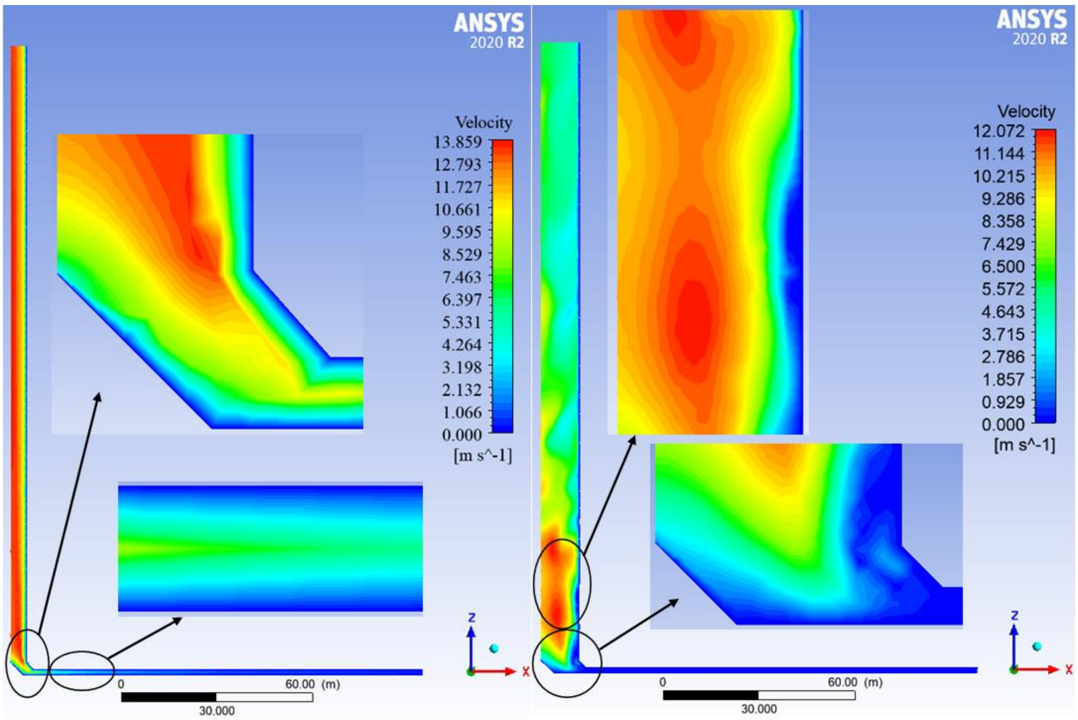

Figure 5. Velocity distributions for references geometry and θ=8

(Referans geometri ve θ=8 için hız dağılımları)

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The reason for this is that the mass flow rate of the system increases with the increase in the diameter of the chimney. When the mass flow rate increases, the increase in the temperature of the air under the collector decreases as the energy entering the system remains constant. This leads to a decrease in the kinetic energy and velocity of the system air. In addition, with the increase in the diameter of the chimney, the air velocity in the chimney decreases rapidly in the upward direction.

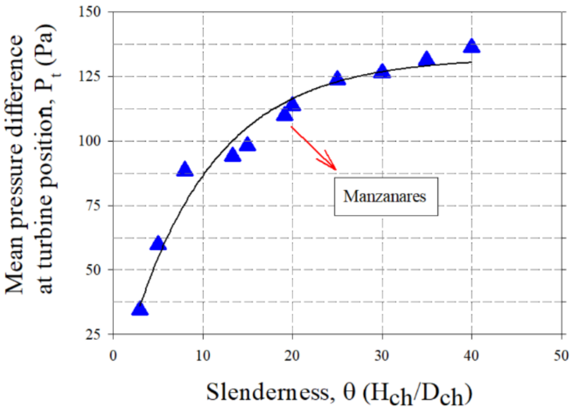

Figure 6. Effect of slenderness to mass flow rate
(Narinliğin kütlesel debiye etkisi)

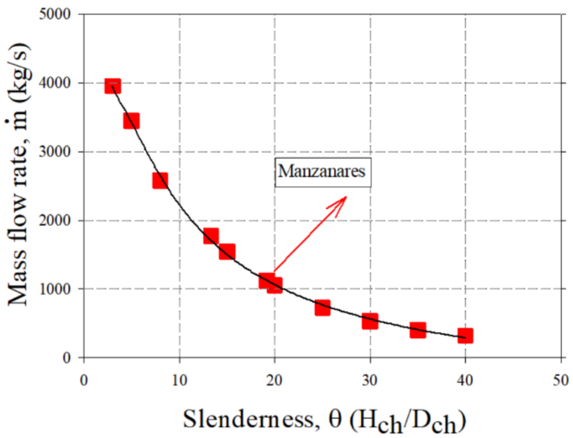

Figure 7. Effect of slenderness on mean pressure difference at turbine position *(Narinliğin türbin pozisyonundaki ortalama basınç farkına etkisi)*

The increase in chimney diameter causes more air to enter and to discharge the system. This is due to the increased cross-sectional area and high flow even at low air velocities. The relationship between the slenderness value and the mass flow rate of the system is given in Figure 6. The mass flow rate of the system, which is approximately 1120 kg/s in the reference case, becomes 2580 kg/s by exceeding its double when the diameter of the chimney is 24.325 m (θ=8).

After the slenderness value of 20, the increase in the mass flow rate decreases and a convergence trend is observed. Increasing the mass flow rate increase the power output of the system. However, an increase in mass flow rate means that more air passes through the system. This reduces the temperature rise and causes the air velocity to decrease. The decrease in air velocity reduces the pressure difference in the plant and negatively affects the power output. In this case, the mass flow rate and the pressure difference are inversely proportional. The effect of the slenderness value on the mean pressure difference at the turbine position is given in Figure 7. It is noticed that the average difference in pressure in turbine position increases with the slenderness value.

It is understood that the pressure difference for θ=8 has decreased from 110 kPa to 88.5 Pa compared to the reference situation. The mass flow rate increases with the diameter of the chimney, and the average pressure difference decreases at the turbine position. Since the increase in mass flow rate is much higher, the performance of the system increases with the diameter of the chimney. However, this is valid up to a certain point. The relationship between slenderness and power output is given in Figure 8. The Manzanares pilot plant for θ=8 gives maximum power output. The chimney diameter corresponding to this value is 24.325 m. It is understood that this chimney diameter is the peak point for power output.

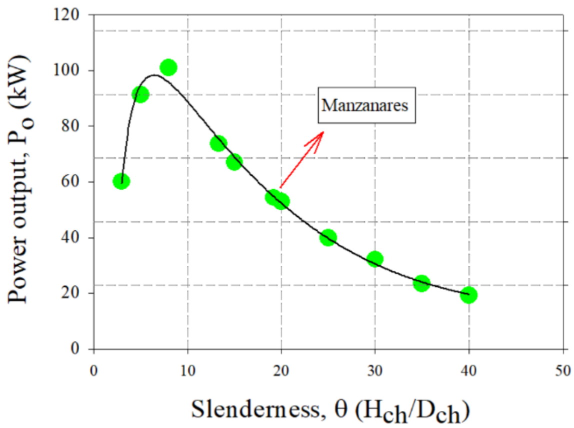

Figure 8. Effect of slenderness on power output
(Narinliğin çıkış gücüne etkisi)

The efficiency of the system tends to be similar to the power output. The relationship between the slenderness value and the efficiency is given in Figure 9. This study, which references the Manzanares pilot plant, shows that the diameter of the chimney is an important parameter for the plant to be built in the range where the system is most efficient will give much more power output than the reference situation.

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In future studies, numerical analyses will be carried out to increase the power output by changing more than one of the geometric parameters at the same time.

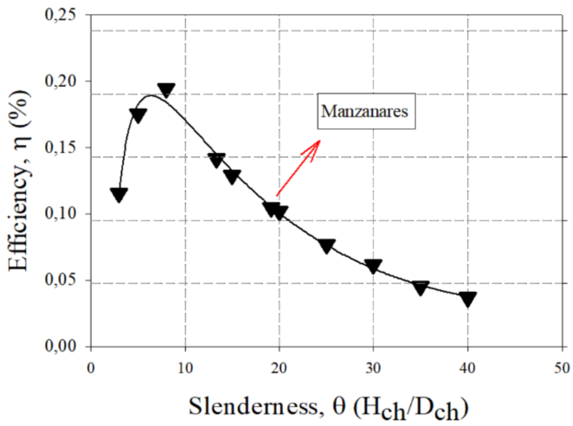

Figure 9. Effect of slenderness on system efficiency
(Narinliğin sistem verimine etkisi)

5. CONCLUSIONS *(SONUÇLAR)*

In the present study, a numerical analysis with experimental validation is presented to investigate the impact of chimney diameter on performance figures of SCPP systems through the actual dimensions of the Manzanares facility. In the study with the 3D CFD model, DO is simulated using the SRTA and the RNG k-e TM. The ratio of chimney height to chimney diameter is defined as slenderness (θ). The following conclusions can be drawn from the study:

- Chimney diameter is an important parameter for SCPP systems.

- The DO SRTA and the RNG k-e TM offer the ideal methodology for the numerical analysis of SCPP systems.

- The slenderness value, which gives the maximum power output for the Manzanares pilot plant, is 8.

- In turbine position, the mean pressure difference decreases with the diameter of the chimney.

- At θ=8 where maximum power output is achieved, the average pressure difference in turbine position is 88.5 Pa. This pressure difference is 19.5% less than the value in the reference geometry.

- At the maximum performance range, the efficiency of the system is 0.194% by showing 94% rise compared to the reference case.

- SCPPs have shown a perspicuous progress over the last four decades [26]. In further works, optimum design and operation conditions are expected to be analysed for further improvement in the performance figures of this renewable and eco-friendly energy technology.

- Although limit values in efficiency figures of PV systems have almost been reached [27,28], SCPPs can be integrated with the thin film PV cells as some part of the collector area. Continuous natural flow of air under the collector enables passive cooling of PV cells, which yields to notable enhancements in PV cell parameters [29]. This can also help to reduce payback period of SCPPs.

CONFLICT OF INTEREST STATEMENT *(ÇIKAR ÇATIŞMASI BİLDİRİMİ)*

The authors declare that there is no conflict of interest.

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