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Combination System Optimization of Solar Collector/ Photovoltaic with Genetic Algorithms

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Abstract

The aim of this study was to investigate the optimization of solar thermal collectors and photovoltaic cells that has been integrated into the system and be able to cogenerate the heat and electric energy. The purpose of using the integrated PVT systems were to improve the electrical efficiency of photovoltaic cells at high temperatures from heating and cooling using lost heat absorption by the solar collector. In order to optimize this combination, matlab genetic algorithm software was used in this article

Keyword: Genetic Algorithms (GA), Exergy efficiency, Solar cells, Photovoltaic combination system.

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1. Introduction

Many industrial engineering design challenges necessitate sophisticated optimization tasks that are challenging to perform with traditional optimization techniques including FEM, neuro-fuzzy and Genetic Algorithms. Despite the fact that it requires experimental validation and has a high computational cost, the Finite Element Method (FEM) has been employed for design and optimization. G might replace FEM-based models, which are currently inefficient (GA). The ease with which these fuzzy logic systems can be designed has been the key to their success in comparison to older approaches like optimum and adaptive control techniques [1-3]. A solar collector can be considered as a special type of heat exchanger (heat) in which solar radiation is absorbed by a dark surface and changed into heat. In fact, the solar radiation passes through the transparent cover and black absorber after hitting the surface, where it is absorbed and converted into heat energy or heat. Flat plate collectors were designed for applications requiring energy delivery at moderate temperatures, perhaps up to 100 ° C above ambient temperature. They use both direct and diffuse solar radiation [4].

In 1990, Dutta Gupta studied the Exergy analysis of thermal heat loss coefficient of the collector with a constant and fluid inlet temperature and changes carried out and the optimal inlet temperature for some cases [5]. In 1991, Wing Han et al, assuming constant coefficient of lost heat of solar collectors used the concept of Exergy for ranking more production on four different collector [6]. In 2004, Torres-Reyes et al studied the dimensionless relationships for Exergy, optimum temperature and fluid flow path was optimized for a flat plate collector set of functional requirements found in the air and calculated the lost heat coefficient from a series of experimental relations. But these relationships were limited. In 2005, Luminosu et al considered the overall lost heat coefficient of collector fixed and other heat transfer coefficients to find the optimal performance of their flat collector [4,5].

1.1 The governing equations for the design collector and thermal parameters

By writing the energy balanced equation in terms of input and output temperatures, the absorbed useful heat Q_u can be gained:

$$Q_u = \dot{m}C_p\left(T_{out} - T_{in}\right) \quad (1)$$

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In the above relation, T_{in} and T_{out} are the entry and exit of fluid from the collector of C_p $\dot{m}$ temperature and the heat capacity and mass fluid debi. The collector of lost heat to the environment can be achieved by taking back the energy relationship as follows [6]:

$$Q_u = A_p F_R \left[S - U_l \left(T_{in} - T_a \right) \right] \quad (2)$$

In the above relation, T_a is the ambient temperature and F_R heat recovery coefficient which is defined as follows:

$$F_R = \frac{\dot{m} C_p}{U_l A_p} \left[1 - \exp\left(-F' U_l A_p / \dot{m} C_p \right) \right] \quad (3)$$

In this regard F' is the collector efficiency factor and is obtained as follows:

$$F' = 1 \Bigg/ \left(W U_l \left[\frac{1}{U_l \left[(W - D_o)\varphi + D_o \right]} + \frac{\delta_a}{k_a D_o} + \frac{1}{\pi D_i h_f} \right] \right) \quad (4)$$

Energy balance is shown permanently for absorber plate this relation:

$$Q_u = A_p S - U_l A_p \left(T_p - T_a \right) \quad (5)$$

In recent relations between ducts attached to the absorber plate, and D_0 D_i were the outer diameter of the inner diameter ducts, h_f was convective heat transfering coefficient inside the ducts, δ_p and δ_a were the average thickness of the absorber plate and duct tape attached to the absorber plate, k_p and k_a were the conductivity powered by absorbing heat and glue connecting ducts to the absorber, T_p was the absorber plate and A_p was the average temperature of collector surface area. U_l was the overall lost heat coefficient, which was fixed in all studies, this factor was considered fixed or deemed to have little effect if it is not fixed in the past [7].

This parameter was based on W/m^2.K and consisted of three heat loss coefficient comprising U_t of the top, U_b bottom and U_e side surfaces of the collector. (6) and (7).

$$U_l = U_t + U_b + U_e \quad (6)$$

$$U_b = k_i / \delta_b \quad (7)$$

k_i Was the low thermal conductivity of insulation and δ_b was the insulation thickness collector. (8) and (9):

$$U_e = \left(L_1 + L_2 \right) L_3 k_i / L_1 L_2 \delta_e \quad (8)$$

$$L_3 = \delta_1 + \delta_2 + \delta_b \quad (9)$$

In these relationships L_1 , L_2 , L_3 ,and δ_2 , δ_1 distance between width, height, the length,were δ_e the first cover, respectively, the cover of the collector side. Assuming that absorber plate and glass coatings form a system of infinite parallel plates, the heat flow was one-dimensional and permanent drop in temperature throughout the thickness of the coating as well as the interaction of the incoming solar radiation absorbed by the coating and waste output, and regardless of which has a long wavelength was reflected outbound, glass coatings are like a black object, the three equations and three unknowns to obtain the following nonlinear heat loss coefficient as: (10-14).

$$Q_t / A_p = h_{p-c1} \left(T_p - T_{c1} \right) + \frac{\sigma \left(T_p^4 - T_{c1}^4 \right)}{\left(1/\varepsilon_p + 1/\varepsilon_c - 1 \right)} \quad (10)$$

$$Q_t / A_p = h_{c1-c2} \left(T_{c1} - T_{c2} \right) + \frac{\sigma \left(T_{c1}^4 - T_{c2}^4 \right)}{\left(1/\varepsilon_c + 1/\varepsilon_c - 1 \right)} \quad (11)$$

$$Q_t / A_p = h_w \left(T_{c2} - T_a \right) + \sigma \varepsilon_c \left(T_{c2}^4 - T_{sky}^4 \right) \quad (12)$$

$$U_t = \frac{Q_t / A_p}{\left(T_p - T_a \right)} \quad (13)$$

$$T_{sky} = T_a - 6 \quad (14)$$

In these relations Q_t / A_p , h_{p-c1} , h_{c1-c2} , h_w , T_{c1} , T_{c2} , T_{sky} , σ , ε_p , ε_c were respectively, the rate of lost heat from the high level on collector level, absorbing and cover convective heat transfer coefficient between the first, convective heat transfer coefficient between the first cover and the second cover, convective heat transfer coefficient, the second cover and the surrounding air, the temperature of the first and second glass cover, temperature, sky effective, Stefan-Boltzmann constant coefficient for issuing page absorbing longwave radiation coefficient and glass coatings for longwave radiation [8]. The three equations solve three passive nonlinear uncertain parameters of Q_t / A_p ,fter lacement rates, and a T_{c2} and T_{c1} and other parameters. It should be h_w , h_{c1-c2} , h_{p-c1} noted that the recent heat transfer coefficients were calculated from a series of empirical relations as well as for the collector heat loss coefficient of modeling heat transfer, correlations have been proposed. The overall lost heat coefficient recent relations revealed that a function of parameters such as temperature, glass coatings, glass coatings properties and domestic air outside, properties and dimensions of the side surfaces and the lower level, temperature, air temperature, average temperature absorber plate, wind speed wind and radiation properties of surfaces. The collector surface area, the product of length and outer diameter ducts in the collector was considered 10% higher than the internal diameter (15-16) [9].

$$A_p = L_1.L_2 \quad (15)$$

$$D_o = D_i + 0.1D_i \quad (16)$$

The thermal efficiency of the collector was given by the following equation:

$$\eta_{Th} = Q_u / A_p I_T \quad (17)$$

The optical analysis*:* The entire received radiation absorbent collector do not absorb from the plate.

Parameter S absorbed radiation flux absorbed by the absorbent screen is as follows:

$$S = (\tau\alpha) I_T \quad (18)$$

I_T is the sun flame and $(\tau\alpha)$ in the collector of panel is optic yield of η_o as follows:

Exergy analysis: Part of the thermal energy that can be used to determine the ideal conditions become effective is the need for Exergy analysis system. Exergy efficiency or efficiency of second law specifies the quality of energy for us. Exergy, generally were devided into two ways of collector system. One of them is the system collector and the other transfered heat [10]. Exergy incompressible fluid flow with the difference in temperature and ambient pressure is defined by the following equation

$$\dot{E} = \dot{m}C_p\left(T - T_a - T_a \ln(T/T_a)\right) + \dot{m}\Delta P/\rho \quad (19)$$

And Exergy exchange through heat transfer $\dot{Q}$ between hot T_h and cold T_c temperatures, obtained by the following equation:

$$\dot{E} = \int_{T_c}^{T_h} \dot{Q} \frac{T_a}{T^2} dT \quad (20)$$

Exergy balance equation is generally written as follows: (21-22)

$$\dot{E}_i + \dot{E}_s + \dot{E}_o + \dot{E}_l + \dot{E}_d = 0 \quad (21)$$

$\dot{E}_i$, $\dot{E}_s$, $\dot{E}_o$, $\dot{E}_l$, $\dot{E}_d$

Exergy were input, storage, discharge, leak or damaged, respectively. Exergy is input to the collector consists of two parts. Exergy entered with flow:

$$\dot{m}C_p\left(T_{in} - T_a - T_a \ln(T_{in}/T_a)\right) + \dot{m}\Delta P_{in}/\rho \quad (23)$$

And Exergy radiation absorbed by the collector, which is commonly found in previous work the following formula was used to calculate the Patellar Component theory, one can easily show that this relationship for such a system violates the second law of thermodynamics.

$$\eta_o I_T A_p \left[1 - \frac{4}{3} T_a/T_s + \frac{1}{3}(T_a/T_s)^4\right] \quad (24)$$

Patellar Component efficiency is already included in the bracket η_P [11]. A proper relationship with the assumption that the sun is a source of extreme heat as follows:

$$\eta_o I_T A_p \left(1 - (T_a/T_s)\right) \quad (25)$$

As the amount of optical efficiency is $\eta_o = S/I_T$. The sum of the equation (23) and (25) of the collector exergy input form. Exergy is stored in a stable condition zero. Exergy Exergy flow output is: (26)

$$-\dot{m}C_p\left(T_{out} - T_a - T_a \ln(T_{out}/T_a)\right) - \dot{m}\Delta P_{out}/\rho \quad (26)$$

The relations (23) and (26), ΔP_{in} and ΔP_{out} the pressure difference between the entrance and exit of the collector fluid environment, including heat from absorber to the environment: (27)

$$-U_l A_p (T_p - T_a)(1 - T_a/T_p) \quad (27)$$

Exergy destruction is divided into three parts. Exergy destroyed due to pressure drop in the pipe:

$$-\frac{\dot{m}\Delta P}{\rho} \frac{T_a \ln(T_{out}/T_a)}{T_{out} - T_{in}} \quad (28)$$

Exergy destroyed because of the sun's temperature difference absorbing the absorbers plate: (29)

$$-\eta_o I_T A_p T_a \left((1/T_p) - (1/T_s)\right) \quad (29)$$

$(T_s = 4350\ K)$

The effective temperature of the sun is the amount of black body temperature 0.75 and Exergy destroyed due to the temperature $(5800\ K)$ difference between the absorber plates with fluid:

$$-\dot{m}C_pT_a\left(\ln\left(T_{out}/T_{in}\right)-\left(T_{out}-T_{in}\right)/T_p\right) \qquad (30)$$

Replacing ties (23) to (30) in the exergy balance equation (22) and sorting obtained by:

$$\left(\dot{m}C_p\left(T_{out}-T_{in}\right)-\frac{\dot{m}\Delta P}{\rho}\right)\left(1-\frac{T_a\ln\left(T_{out}/T_{in}\right)}{T_{out}-T_{in}}\right)=$$
$$I_TA_p\left(1-T_a/T_s\right)-\left\{\left(1-\eta_o\right)I_TA_p\left(1-T_a/T_s\right)+\right.$$
$$\left.+\begin{matrix}\eta_oI_TA_pT_a\left(1/T_p-1/T_s\right)+U_lA_p\left(T_p-T_a\right)\left(1-T_a/T_p\right)\\+\dot{m}C_pT_a\left(\ln\left(T_{out}/T_{in}\right)-\left(T_{out}-T_{in}\right)/T_p\right)\end{matrix}\right\} \qquad (31)$$

Exergy efficiency of the collector is defined according to the increase Exergy flow to the primary radiation source (31) Exergy collector efficiency equation is obtained:

$$\eta_E=\frac{\dot{m}\left[C_p\left(T_{out}-T_{in}-T_a\ln T_{out}/T_{in}\right)-\frac{\Delta P}{\rho}\right]}{I_TA_p\left(1-T_a/T_s\right)}=$$
$$1-\left\{\left(1-\eta_o\right)+\frac{\eta_oT_a}{\left(1-T_a/T_s\right)}\left(1/T_p-1/T_s\right)+\right.$$
$$+\frac{\dot{m}\Delta P}{\rho I_TA_p\left(1-T_a/T_s\right)}\frac{T_a\ln\left(T_{out}/T_a\right)}{T_{out}-T_{in}}+ \qquad (32)$$
$$\frac{\dot{m}C_pT_a}{I_TA_p}\frac{\left(\ln\left(T_{out}/T_{in}\right)-\left(T_{out}-T_{in}\right)/T_p\right)}{\left(1-T_a/T_s\right)}+$$
$$\left.+\frac{U_l}{I_T\left(1-T_a/T_s\right)}\left(T_p-T_a\right)\left(1-T_a/T_p\right)\right\}$$

The words in brackets on the right of (32) show Exergy fall in demand Exergy loss due to optical loss is the first sentence. Exergy second term decline due to the temperature difference between the sun and the page is absorbing. Third including Exergy destroyed due to fluid pressure inside the tube. Exergy destroyed the quarter due to the temperature difference between the temperature of the absorbing fluid and the fifth Exergy is damaged due to heat loss from the absorber. Pressure drop due to the mass flow in ducts, duct diameter, fluid properties and coefficient of friction and Moody diagram was obtained.

1.2 Finding the optimal values of the parameters affecting the efficiency Exergy

The objective function was equation (32) and equations (1) to (19) can be used as constraints and variables depending on the issue, taking into account the conditions regarding optimization and design of the collector may include variables such as the following parameters:

T_{in}, L_1, A_p, S, U_l, Qu, φ, F', F_R, $\dot{m}$, T_p, T_{out}, D_i, L_3, L_2 Given the number of variables in the equations and constraints of the problem, the degree of freedom of the system was determined. Since non-linear equations were formed they were numerically solving the optimal values of parameters that maximize the efficiency Exergy they appear. For this reason, a genetic algorithm in MATLAB software was used. Installing the collector for a case study in Tehran, Iran: while they considered important when installing compilers included: basic building maintenance and design time if collectors were not designed to be integrated with home, then, you have to keep them out of the base, however, base frame should be loads of snow, rain and wind as well This tolerance can be fixed and mobile terminals. Bases have to equip with slope, covering the compilers should be well impacts from rain, snow and wind loads, as well as ice formed on the surface of transparent cover to tolerate. Access to compile: generally, when installing a solar system all have enough space to access cleaning, repair, etc. hosting: solar compilers such objects should be placed so the shadow of the surrounding buildings, chimneys, antenna.... particulary in times of day and monthes of the year which the amount of solar energy is maximized, minimized installation those between the collector regarding to the collector's position when installing the collectors in rows shadows shoulb be attentioned in these cases the collectors (d) according to the following obtained relationship: (33) and (34)

$$d\geq\frac{\sin(\beta+\gamma\min)}{\sin\gamma\min}I_c$$

$$tg\left(\gamma_{\min}\right)=+tg\left(\alpha/\cos\gamma_s\right)$$

Angle of the sun height is α and the angle of sun is s

ẏ have to be calculated for hours of 3 pm in the shortest day of the year. The light reflections from glass collectors around the house proved to be avoided as much as possible, because it reflection can be harmful to the eye, in addition, as to increase radiation, the levels of stranding comes to use, the mentioned point can be considered.

The solar collector design: solar energy in the summer is more than the winter, hence, there is a seasonal variation in solar radiation. The need to water heater in a building is essentially and constant. If compilers are designed for winter, an economic in cold areas, the system is designed for the average solar radiation in the cold areas, the system for the chapters' day by a cloud of auxiliary systems. In temperate or warm considering the amount of radiation required thermal economic evaluation and decision-making system should be measured relative to the size of the collector. Hence, in this project for Tehran, Iran 15th day of each month, a selected collection designed.

The calculation of design: we want to design collector for a family of five individuals, so that 50% of the heat energy required providing annual (the rest will be provided by fossil fuels). In order to achieve the highest possible efficiency, depending on the material before we collect and consider the parameters initial values:

-Collection of 1 x 2 m
-Managing the flow of water and Glycol
-Fluid Debi
-To gather input fluid temperature 40 ° C (specific heat c=3.43 Kj/kgc)
-Tinox coated copper absorber plate with a thickness of 8 mm
-95% = α emission coefficient absorption coefficient Page £=5%
-The average temperature of plate 100
-Transparent glass (too little iron) with a thickness of 6 mm
-The number of layers of glass 2
-The gap between the glasses and absorbers plate 20 mm
-Polyurethane insulation (thickness 3/2 cm in conductivity coefficient
-The glass layers of 2.
-The gap between the glass and the absorber plate 20 mm
-Insulated polyurethane foam (2.3 cm in thickness and conductivity 0.023)
-5 cm insulated storage tank
-The collector design was considered in 15 September for Tehran, Iran. Therefore, the following parameters should be considered:
-Calculations based on a 15th of each month 8 am to 8 pm
-Ambient temperature 28 °C
- Sunlight intensity 830 watts per square meter
-Wind speed 2m/s

Collector slope for 15th each month based on the previous month, according to the tables above and the relations expressed in high profile acts as the working fluid amount flowing water collector efficiency was calculated as follows:

Etha = 0.8321

As expected, the high efficiency was achieved because of the reviews were the best values for the parameters chosen. As mentioned before, the average energy consumption for heating and houses' heat (5-person households) in Iran was 121 million MJ per year. Hence, n percent required of the energy by the sun and solar system efficiency etha collector area needed would be achieved. (35)

$$Q = n.I.A.\eta$$

$$A = \frac{n.Q}{I.\eta}$$

I was the annual average solar energy on the slopes in the country observed (6700 MJ/m). Assuming the collectors' level 2m percent of the energy needed can per 5 individulas family. Almost 10 percents of this energy can be provided by collectors and the rest by fossil fuels. If 50 percent of the energy required by the sun provides the required surface area is equivalent to:

$$A = \frac{0.5*121*(10\wedge 3)}{6700*0.8904} \rightarrow$$

$$A \cong 10m^2$$

So, half of the energy needed for a family of 5 individuals listed by the sun to 5 collector-profile design with high efficiency so that we wanted to design the collector with the highest efficiently would meet the needs of a family of 5 individuals want to know the impact of each of the parameters on the efficiency. Now, we want to know the parameters which influence the efficiency of the design more and which less effective. Because this will help us to understand what parameters should be given more consideration? Before analyzing the genetic algorithm parameters fixed and variable parameters it has to be identified. Fixed parameters are those parameters were established during the design of the variable parameters have changed in a certain range, and directly or indirectly affect the efficiency. Fixed parameters:
- The calculation of 15th of each month, from April to March.
- Transparent plass (with too little iron) with a thickness of 6 mm.
- Absorber copper plate coating thickness 6 mm tinox.
- Water factor fluid and glikon, polyurethane (with a thickness of 2.3 cm circumference)
- The gap between the glass and reinforced absorbent 20 mm (according to the diagram)
- Copper tube to the outer diameter of 1.25 cm
- Speed of fluid copper tube (because of corrosion), less than 2 m / s
- 5 cm insulated storage tank
- Pressure downfall 3-7

1.3 Variable parameters

- Fluid temperature 40 ° C input collected (specific heat c = 3.43kj / kg)
- The slope of the collector 15th of each month from April to March
- Ambient temperature 28 °
- Fluid Debi 0.04kg/s
- The number of tubes was 8
- The average temperature of 100 degrees Celsius
- The number of layers of 2 glasses

- Collection of 1 x 2 m
- Wind speed of 2 meters per second
- Absorber plate coefficient absorption coefficient of 95% and 5%
-Solar radiation intensity of 830 watts per square meter
-The thickness of the insulation in the bottom 5 cm conductivity 0.023

2. Results and Discussion

To check the efficiency of the numerical curve, we fitted practices and operations based on genetic algorithms implemented in this way. On the other hand we have the tools in MATLAB genetic algorithm which were used to optimize the productivity. Solving approach is defined as follows:
- Selection of parameters
- Defined objective functions
- Define some parameters such as population
- The tool box run

Figure 1. The objective function for genetic algorithm is shown in repeated rings.

As a result of the above comparison chart can be seen with reference both to optimum reach almost of 58 generations. This validation provides accuracy of analysis results. The comparison between thermal and thorough heat exergy and Pareto charts on genetic algorithms in MATLAB is done according to the code

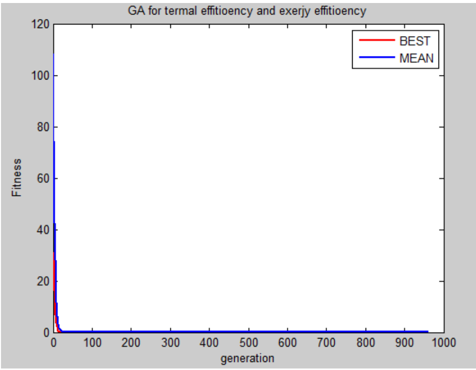

Figure 1. Optimization of the amount of generation.

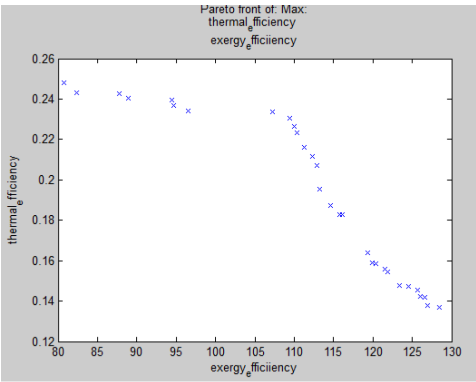

Figure 2. Diagram Pareto genetic algorithm compared to heat and thermal efficiency

The results of numerical optimization optimal cross section and optimum light intensity are reported in Table 1 that with choicing those, comparing between optimizing the efficiency of heat and thorough exergy perform.

Table 1. The optimal levels and optimized radiation

The cross-section optimization	Optimal radiation
18.4175	29.9387
17.5795	29.7984
10.1641	29.6894
10.5340	29.7572
19.2715	29.4719
19.3694	29.9185
10.0388	29.0522
13.3921	29.7918
15.3652	29.5262
10.0356	24.7853
10.0698	20.1986
10.2682	20.6069
11.2149	29.9554
12.3743	29.5112
10.0760	22.5448
16.0050	29.2998
16.0638	29.4087
10.4089	29.5822
10.1812	22.8480

3. Conclusion

In this study, the genetic algorithm was used to determine the efficiency of solar systems PV/T to determine parameters such as the thickness of the cover glass, toddler, silicon solar cells, the duct system within PV/T and inlet air temperature. The following results were obtained, according to the current study: water collector productivity electric PV/T with respect to operational parameters and design changes are gradual and partial. The efficiency of energy-efficient heat collector solar collector is always more of PV modules and the productivity and efficiency of the whole system to increase the efficiency of the system increases. When the inlet air temperature or water collectors within PV/T or over the air duct are increased, the efficiency of the energy efficiency and reducing its thermal collector decreased. While one of the thickness such as insulation thickness, toddler thickness, glass thickness, or the thickness of the silicon solar cells increase the productivity and efficiency of air thermal collector PV/T is also increasing. Increase or decrease in the air mass flow rate of radiation heat transfer coefficient increases the total productivity and it will eventually become the best point of the water collector PV/T.

References

1. Jafarpour, V., M. Abasi, Optimization of load values in pipe hydroforming process using fuzzy load control algorithm, 3(2022), 4683.https://doi.org/10.36937/ben.2022.4683

.2 Jafarpour, V., Parameter Optimization of Spot-Welded Aluminum Plates Using the Adaptive Neuro-Fuzzy System with Genetic Algorithm. Mapta Journal of Mechanical and Industrial Engineering (MJMIE), 2022.6(01):p.10–17.

3. Jafarpour, V. and Moharrami, R. 2022. Numerical Stress Analysis of Creep-Feed Grinding Through Finite Element Method in Inconel Alloy X-750. Mapta Journal of Mechanical and Industrial Engineering (MJMIE). 6(1): 1–9.

4. Dutta Gupta KK, Saha S. 1990. Energy Analysis of Solar Thermal Collectors. *Renewable energy and environment*. 1990 : 283-287.

5. Wing Han K, Chiang Lee C. A Second Law Concept of An Equivalent Solar Collectors. *Energy*. 1991; 16(5): 859-865.

6. Hall CA, Glakpe EK, Cannon JN, Kerslake TW. Thermodynamic Analysis of Space Solar Dynamics Heat Receivers with Cyclic Phase Change. *Journal of Solar Energy Engineering*. 1999; 121: 133-144.

7. Torres-Reyes E, Navarrete-Gonzalez JJ, Cervantes-de Gortari JG. Thermodynamic Optimization as an Effective Tool to Design Solar Heating Systems. Energy. 2004: 2305-2315.

8. Luminosu I, Fara L. Determination of the Optimal Operation Mode of a Flat Solar Collector by Exergetic Analysis and Numerical Simulation. Energy. 2005: 731-747.

9. Moghadam H, FarshchiTabrizi F, ZolfaghariSharak A, 2011. Optimization of solar flat collector inclination.Desalination. 256: 107-111.

10. Shariah A, Al-Akhras MA, Al-Oman IA, 2002. Optimizing the tilt angle of solar collectors. Renewable Energy. 26: 587–598.

11. Skeiker K, 2009. Optimization tilt angle and orientation for solar collectors in Syria. Energy Conversion and Management, 50: 2439-2448.