International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878, Impact Factor (2014): 3.05

Solar Water Heating Systems: A Review

Vishal G. Shelke[1], Chinmay V. Patil[2], Kishor R. Sontakke[3]

. [1]M.E. Student, Advance Manufacturing and Mechanical System Design, SSGMCE, Shegaon (M.S.) India

[2]Assistant Professor, Department of Mechanical Engineering, SSGMCE, Shegaon (M.S.) India

[3]Head of Department of Mechanical Engineering, PLITMS, Buldana (M.S.) India

Abstract: ***In the present review paper, the existing solar water heating systems are studied with their applications. Solar energy is free, environmentally clean, and therefore it is accepted as one of the most promising alternative energy sources. The effective use of solar energy is hindered by the intermittent nature of its availability, limiting its use and effectiveness in domestic and industrial applications especially in water heating. Now a day, plenty of hot water is used for domestic, commercial and industrial purposes. Various resources i.e. coal, diesel, gas etc, are used to heat water and sometimes for steam production. Solar energy is the main alternative to replace the conventional energy sources. The size of the systems depends on availability of solar radiation, temperature requirement of customer, geographical condition and arrangement of the solar system, etc. Therefore, it is necessary to design the solar water heating system as per above parameters. The available literature is reviewed to understand the construction, arrangement, applications and sizing of the solar thermal system.***

Keywords: Solar energy collector, solar water heating systems, active & passive system

1. Introduction

We are blessed with Solar Energy in abundance at no cost. The solar radiation incident on the surface of the earth can be conveniently utilized for the benefit of human society. One of the popular devices that harness the solar energy is solar hot water system (SHWS).

The solar energy is the most capable of the alternative energy sources. Due to increasing Demand for energy and rising cost of fossil type fuels (i.e., gas or oil) solar energy is considered an attractive source of renewable energy that can be used for water hearing in both homes and industry. Heating water consumes nearly 20% of total energy consumption for an average family. Solar water heating systems are the cheapest and most easily affordable clean energy available to homeowners that may provide most of hot water required by a family.

Solar heater is a device which is used for heating the water, for producing the steam for domestic and industrial purposes by utilizing the solar energy. Solar energy is the energy which is coming from sun in the form of solar radiations in infinite amount, when these solar radiations falls on absorbing surface, then they gets converted into the heat, this heat is used for heating the water. This type of thermal collector suffers from heat losses due to radiation and convection. Such losses increase rapidly as the temperature of the working fluid increases.

2. Solar Water Heating System

SWH systems are generally very simple using only sunlight to heat water. A working fluid is brought into contact with a dark surface exposed to sunlight which causes the temperature of the fluid to rise. This fluid may be the water being heated directly, also called a direct system, or it may be a heat transfer fluid such as a glycol/water mixture that is passed through some form of heat exchanger called an indirect system. These systems can be classified into three main categories:

2.1 Active Systems

Active systems use electric pumps, valves, and controllers to circulate water or other heat-transfer fluids through the collectors. So, the Active systems are also called forced circulation systems and can be direct or indirect. The active system is further divided into two categories:
- Open-loop (Direct) Active System
- Closed-loop (Indirect) Active System

a) Open-Loop Active Systems

Open-loop active systems use pumps to circulate water through the collectors. This design is efficient and lowers operating costs but is not appropriate if the water is hard or acidic because scale and corrosion quickly disable the system. These open-loop systems are popular in non-freezing climates.

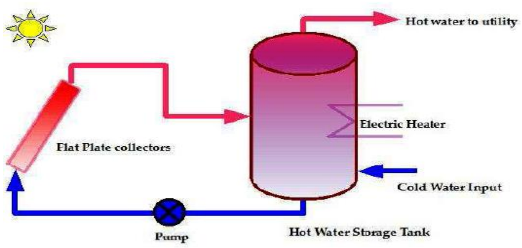

Figure 1: Open-Loop Active Systems [1]

b) Closed-Loop Active Systems

These systems pump heat-transfer fluids (usually a glycol-water antifreeze mixture) through collectors. Heat exchangers transfer the heat from the fluid to the household water stored in the tanks. Closed-loop glycol systems are popular in areas subject to extended freezing temperatures because they offer good freeze protection.

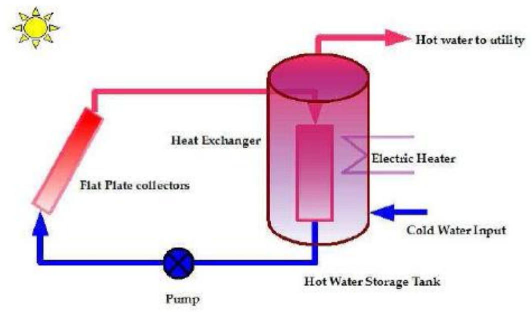

Figure 2: Closed-Loop Active Systems [1]

2.2 Passive Systems

Passive systems simply circulate water or a heat transfer fluid by natural convection between a collector and an elevated storage tank (above the collector). The principle is simple, as the fluid heats up its density decreases. The fluid becomes lighter and rises to the top of the collector where it is drawn to the storage tank. The fluid which has cooled down at the foot of the storage tank then flows back to the collector. Passive systems can be less expensive than active systems, but they can also be less efficient. Thermosiphon system is the best example of passive systems.

a) Thermosiphon Systems

In the thermosiphon system, water comes from the over head tank to bottom of solar collector by natural circulation and water circulates from the collector to storage tank as long as the absorber keeps absorbing heat from the sun and water gets heated in the collector. The cold water at the bottom of storage tank run into the collector and replaces the hot water, which is then forced inside the insulated hot water storage tank. The process of the circulation stops when, There is no solar radiation on the collector. Thermosiphon system is simple and requires less maintenance due to absence of controls and instrumentation. Efficiency of a collector depends on the difference between collector temperature and ambient temperature and inversely proportional to the intensity of solar radiation.

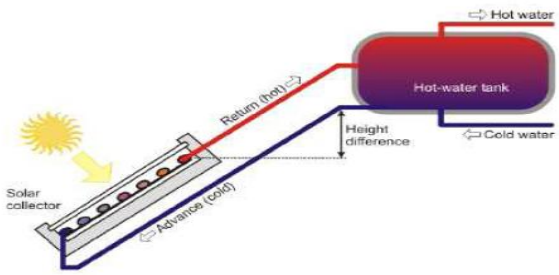

Figure 3: Thermosiphon Systems [1]

2.3 Batch Systems

Batch System (also known as integral collector storage systems) are simple passive systems consisting of one or more storage tanks placed in an insulated box that has a glazed side facing the sun. Batch systems have combined collection and storage functions. Depending on the system, there is no requirement for pumps or moving parts, so they are inexpensive and have few components in other words, less maintenance and fewer failures.

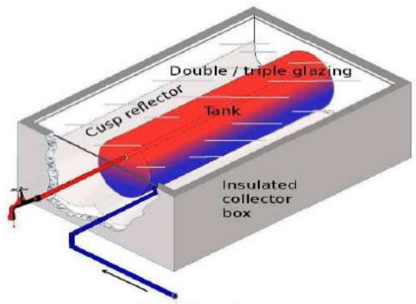

Figure 4: Batch System [1]

3. Components of Solar Water Heating System

SWH generally consists of a solar radiation collector panel, a storage tank, a pump, a heat exchanger, piping units, and auxiliary heating unit. Some of important components are described in the next sections.

3.1 Solar Collectors

The choice of collector is determined by the heating requirements and the environmental conditions in which it is employed. There are mainly three types of solar collectors like flat plate solar collector, evacuated tube solar collector, concentrated solar collector.

a) Flat Plate Collectors

Flat-plate collectors are used extensively for domestic water heating applications. It is simple in design and has no moving parts so requires little maintenance. It is an insulated, weatherproofed box containing a dark absorber plate under one or more transparent covers. They collect both direct and diffuse radiation. Their simplicity in construction reduces initial cost and maintenance of the system. A more detailed picture of these systems is of interest and is presented in the following section.

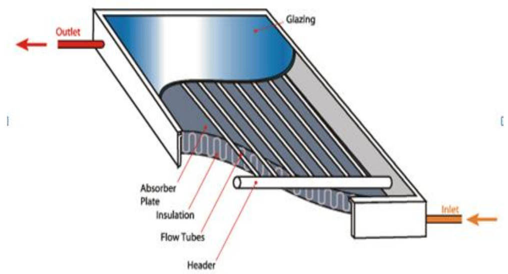

Figure 5: Flat Plate Collector [1]

Fig 6. Shows a number of absorber plate designs for solar water heaters that have been used with varying degrees of success [2]. Fig. 6A shows a bonded sheet design, in which the fluid passages are integral with the plate to ensure good thermal conduct between the metal and the fluid. Fig. 6B and C shows fluid heaters with tubes soldered, brazed, or otherwise fastened to upper or lower surfaces of sheets or strips of copper. Copper tubes are used most often because of their superior resistance to corrosion. Thermal cement, clips, clamps, or twisted wires have been tried in the search for low-cost bonding methods. Fig. 6D shows the use of extruded rectangular tubing to obtain a larger heat transfer area between tube and plate

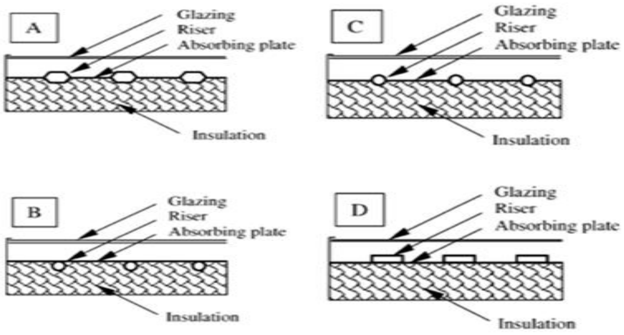

Figure 6: Various Types of Flat-Plate Solar Collectors [2].

b) Evacuated-Tube Collectors

Evacuated-Tube Collectors are made up of rows of parallel, transparent glass tubes. Each tube consists of a glass outer tube and an inner tube, or absorber, covered with a selective coating that absorbs solar energy well but inhibits radiative heat loss. The air is withdrawn ("evacuated") from the space between the tubes to form a vacuum, which eliminates conductive and convective heat loss. They are most suited to extremely cold ambient temperatures or in situations of consistently low-light. They are also used in industrial applications, where high water temperatures or steam need to be generated where they become more cost effective

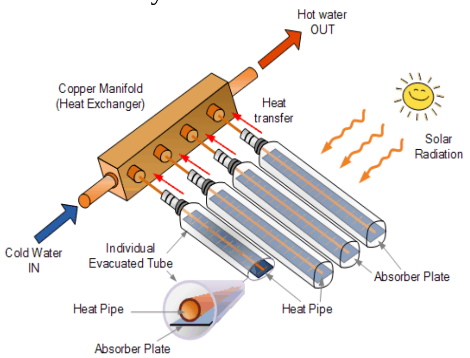

Figure 7: Evacuated Tube Collector [1]

c) Concentrating Collectors

Concentrating collectors use mirrored surfaces to concentrate the sun's energy on an absorber called a receiver. A heat-transfer fluid flows through the receiver and absorbs heat. These collectors reach much higher temperatures than flat-plate collectors and evacuated-tube collectors, but they can do so only when direct sunlight is available. However, concentrators can only focus direct solar radiation, with the result being that their performance is poor on hazy or cloudy

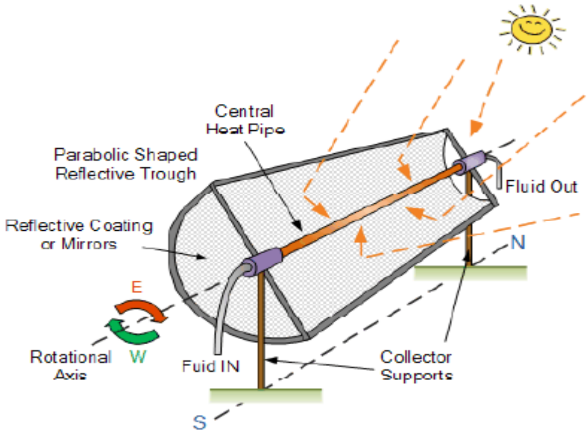

Figure 8: Concentrating Collector [1]

3.2 Storage Tank

Most commercially available solar water heaters require a well-insulated storage tank. Thermal storage tank is made of high pressure resisted stainless steel covered with the insulated fiber and aluminum foil. Some solar water heaters use pumps to recirculation warm water from storage tanks through collectors and exposed piping. This is generally to protect the pipes from freezing when outside temperatures drop to freezing or below

3.3 Heat Transfer Fluid

A heat transfer fluid is used to collect the heat from collector and transfer to the storage tank either directly or with the help of heat exchanger. In order to have an efficient SHW configuration, the fluid should have high specific heat capacity, high thermal conductivity, low viscosity, and low thermal expansion coefficient, anti-corrosive property and above all low cost. Among the common heat transfer fluids such as water, glycol, silicon oils and hydrocarbon oils, the water turns out to be the best among the fluids. Water is the cheapest, most readily available and thermally efficient fluid but does freeze and can cause corrosion.

4. Literature Review

Soteris A. Kalogirou et al [2] presents a survey of the various types of solar thermal collectors and applications. All the solar systems which utilize the solar energy and its application depends upon the solar collector such as flat-plate, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish and heliostat field collectors which are used in these system. The solar collectors are used for domestic, commercial and industrial purposes. These include solar water heating, which comprise thermosiphon, integrated collector storage, direct and indirect systems and air systems, space heating and cooling, which comprise, space heating and service hot water, air and water systems and heat pumps, refrigeration, industrial process heat, which comprise air and water systems and steam generation systems, desalination, thermal power systems, which comprise the parabolic trough, power tower and dish systems, solar furnaces, and chemistry applications.

Table 1. Comparision of the Collectors [2]

Motion	Collector type	Absorber type	Concentration ratio	temperature range (°C)
Stationary	(FPC)	Flat	1	30–80
	(ETC)	Flat	1	50–200
	(CPC)	Tubular	1–5	60–240
Single-axis tracking	(LFR)	Tubular	15-45	60–250
	(PTC)	Tubular	15–45	60–300
	(CTC)	Tubular	10–50	60–300
Two-axes tracking	(PDR)	Point	100–1000	100–500
	(HFC)	Point	100–1500	150–2000

Mustafa AKTAß et al [3] describe experimental analysis of optimum fin size, which can be used in heat exchanger in solar energy systems, has been performed. For this purpose, two systems, one of which is classic and the other finned, were designed and manufactured. According to the experimental tests, which lasted for six days, the system with a fin is 7% more efficient than the classical system. Therefore, it has been concluded that it is useful to use fins in solar energy systems with a suitable sizing

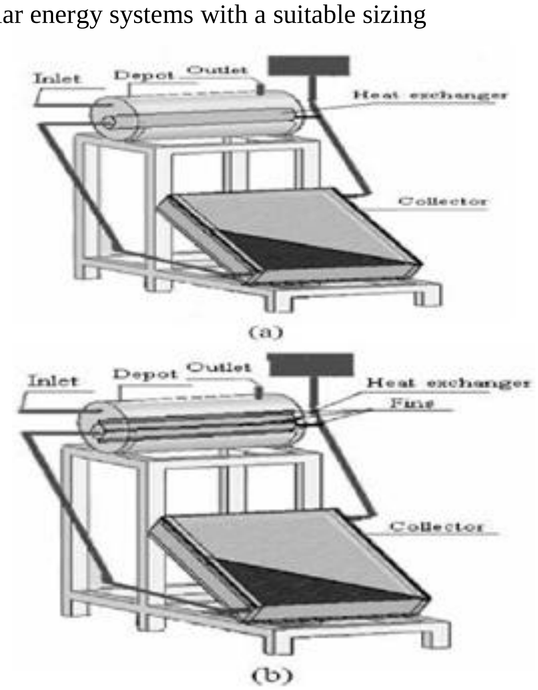

Figure 9: (a) Classical System (b). Finned System [8]

Samara Sadrin et al [4] present the alternative method of solar water heating system. This automated system would allow the user to get hot water from the solar water heater as long as the solar water heater can supply hot water above a set temperature. If the solar water heater is unable to supply water above the set temperature, then only will the electric water heater come into action. It is efficient because our controller ensures that the solar water heater is used to supply hot water 80% of the time, and the rest 20% will be supplied by the electric water heater. It is cheap because, our system runs on solar energy which is abundant and free. It uses very small amount of electricity and therefore, reduces the expenses for the user.

P. Rhushi Prasad et al [5] present experiment analysis of flat plate collector and comparison of performance with tracking collector. A flat plate water heater, which is commercially available with a capacity of 100 liters/day is instrumented and developed into a test-rig to conduct the experimental work. Experiments were conducted for a week during which the atmospheric conditions were almost uniform and data was collected both for fixed and tracked conditions of the flat plate collector. The results show that there is an average increase of 40C in the outlet temperature. The efficiency of both the conditions was calculated and the comparison shows that there is an increase of about 21% in the percentage of efficiency.

R. Herrero et al [6] describe enhancement techniques for flat-plate liquid solar collectors. Tube-side enhancement passive techniques can consist of adding additional devices which are incorporated into a smooth round tube (twisted tapes, wire coils), modifying the surface of a smooth tube (corrugated and dimpled tubes) or making special tube geometries (internally finned tubes). For the typical operating flow rates in flat-plate solar collectors, the most suitable technique is inserted devices. Based on previous studies from the authors, wire coils were selected for enhancing heat transfer. This type of inserted device provides better results in laminar, transitional and low turbulence fluid flow regimes.

K. Sivakumar et al [7] represent the design of Elliptical heat pipe flat plat solar collector and tested with a collector tilt angle of 11° to the horizontal. Experimental analysis of the effect of condenser length/evaporator length (Lc/Le) ratio of the heat pipe, different cooling water mass flow rates and different inlet cooling water temperature were analysed. Five numbers of elliptical heat pipes with stainless steel wick has been fabricated and used as transport tubes in the collector. Copper tube has been used as container material with methanol as working fluid of the heat pipe. These heat pipes were fixed to the absorber plate of the solar collector and the performance of elliptical heat pipe solar collector has been studied and results were compared. It has been found from the experimental trials that the elliptical heat pipe solar collector having Lc/Le ratio of 0.1764 achieved higher instantaneous efficiency.

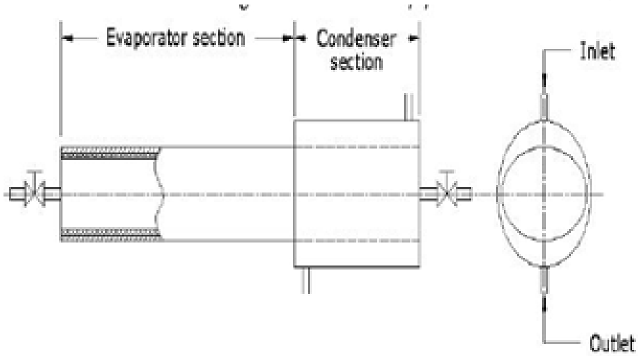

Figure 10: Detail of Heat Pipe

Wattana Ratismith et al [8] describes the design of the PTC in which increase the outlet temperature by reducing heat loss. In this design the maximum efficiency of the collector is 32% and has an ability to achieve high output temperature, the maximum temperature at header of evacuated tube is 235 degrees Celsius, and is therefore suitable for high temperature application such as industrial uses.

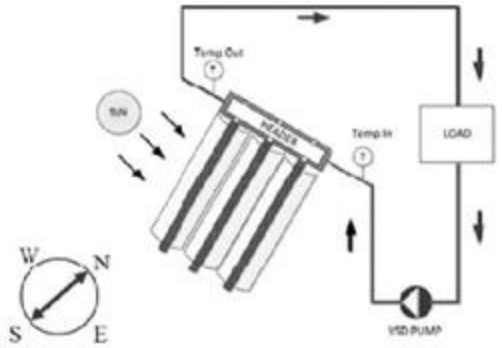

Figure 11: Diagram of Test Arrangement [5]

P. Sivakumar et al [9] discuss improving the performance of a flat plate solar energy collector by changing the design parameters of the number of riser tubes and the arrangement of riser tubes in zig-zag pattern from the existing flat plat collector system. Experiments were conducted using copper tube in header and riser with different dimensions. The performance shows that the efficiency is 59.09% when increasing the number of riser tubes and its 62.90% in the zig-zag arrangement (Z- Configuration) of the riser tube.. The maximum collector efficiency during the day of experiment at any particular time considered is obtained in case 3 experiment using zig-zag arrangement.

K.K. Chong et al [10] discuss optical analysis, experimental study and cost analysis of the stationary V-trough solar water hea1111111111ter system are presented. The novel stationary V-trough solar water heater with the maximum solar concentration ratio of 1.8 suns has been proposed to improve the thermal efficiency of the whole system. The advantages of the new proposal are that easy to be fabricated, cost effective and high thermal efficiency. The collected data has shown that the prototype has achieved the optical efficiency of 70.54% or 1.41 suns and the temperature of 85.9 ^{0}C. The prototype can be easily constructed through DIY using off-the-shelf materials with total cost of RM 1489.40 and total payback period of 12.2 year for discounted form or 8.9 years for undiscounted form.

S. Sadhishkumar et al [11] paper summarizes the previous works on solar water heating systems with various heat transfer enhancement techniques include collector design, collector tilt angle, coating of pipes, fluid flow rate, thermal insulation, integrated collector storage, thermal energy storage, use of phase change materials, and insertion of twisted tapes. This paper also discussed the methods to optimize and simulate the solar water heating systems to understand flow and thermal behavior in solar collectors that would lead to the improvement of the thermal performance of solar collectors.
The enhancement of heat transfer in the solar collector with twisted tape is found to be better than the conventional plain tube collector. In solar water heating systems twisted tape has been used as one of the passive techniques to augment the heat transfer. Twisted tape has been used in heat exchangers but their applications are limited in solar water heating systems.

5. Conclusion

At Present, Solar water heating systems are installed with different configurations and arrangements. The basic technology concrete of these systems are studied and it is found that there is a need to work on the generated design procedure to select, install and monitor the solar water heating system as per the availability**.**

References

[1] Dilip Johari, Ashok Yadav, Ravi Verma "Study of solar water heaters based on exergy analysis" Proceedings of the National Conference on Trends and Advances in Mechanical Engineering,YMCA University of Science & Technology, Faridabad, Haryana, Oct 19-20, 2012.
[2] Soteris A. Kalogirou, "Solar thermal collectors and applications.", Progress in Energy and Combustion Science 30 (2004) 231–295.
[3] Mustafa AKTAß, Olhan CEYLAN,Hikmet DOĞAN " The Thermal Effectiveness Compression Of The Classical And Finned Solar System" Isı Bilimi ve Tekniği Dergisi, 26, 2, 29-33, 2006. J. of Thermal Science and Technology ©2006 TIBTD Printed in Turkey ISSBN 1300-3615.
[4] Samara Sadrin, Maherin Hossain, Ehsanul Mohith, "Alternative solar water heater for domestic purpose".
[5] P.Rhushi Prasad, H.V. Byregowda, P.B.Gangavati, "Experiment Analysis of Flat Plate Collector and Comparison of Performance with Tracking Collector" European Journal of Scientific Research, ISSN 1450-216X Vol.40 No.1 (2010), pp.144 -155, EuroJournals Publishing, Inc. 2010.
[6] R. Herrero Martín, A. García Pinar, J. Pérez García "Experimental heat transfer research in enhanced flat-plate solar collectors", World Renewable Energy Congress -2011, Sweden.
[7] K. Sivakumar, N. Krishna Mohan and B. Sivaraman "Performance analysis of elliptical heat pipe solar collector" Indian Journal of Science and Technology.
[8] Wattana Ratismith, "A Novel Non-Tracking Solar Collector for High Temperature Application.", proceedings of ecos 2012 - the 25th international conference on efficiency, cost, optimization, simulation and environmental impact of energy systems June 26-29, 2012, Perugia, Italy.
[9] P. Sivakumar1, W. Christraj, M. Sridharan1 and N. Jayamalathi1,"Performance Improvement Study Of Solar Water Heating System", ARPN Journal of Engineering and Applied Sciences, VOL. 7, NO. 1, January 2012, ISSN 1819-6608.
[10] K.K. Chong, K.G. Chay, K.H. Chin, "Study of a solar water heater using stationary V-trough collector", Renewable Energy 39 (2012) 207-215.
[11] S.Sadhishkumar T.Balusamy "Performance improvement in solar water heating systems"—A review Renewable and Sustainable Energy Reviews 37(2014)191–198.

Author Profile

Vishal G. Shelke is a student of Master of Engineering in, Advance Manufacturing and Mechanical System Design S.S.G.M. College of Engineering, Shegaon (M.S.) India. He received a degree of Bachelor of Engineering in Mechanical Engineering from SGBAU University, Amravati.

Chinmay V. Patil is currently holding a position as Assistant Professor in Mechanical Engineering Department of S.S.G.M. College of Engineering, Shegaon (M.S.) India. He has 10 years of experience in academics. His research interests include Computer Aided Design and Manufacturing and Solar Energy Utilization.

Kishor R. Sontakke is currently holding position as Head of Department in Mechanical Engineering Department PLITMS, Buldana (M.S.) India. He has 17 years of experience in academics.