RES MILITARIS
REVUE EUROPEENNE D ETUDES EUROPEAN JOURNAL OF MILITARY STUDIES

Social Science Journal

Implementation of Hydroponics System in Agriculture to Improve the Productivity

By

Rohit Kumar Shakya
Assistant Professor, Shivalik College of Engineering, Deharadun-248197, India

Amit Singh
Assistant Professor, Shivalik Institute of Professional Studies, Dehradun

Preeti Kuniyal
Assistant Professor, College of Pharmacy, Dehradun-248197, India

Abstract

Agriculture is the only occupation that produces the food as well as raw material required for preparing food. As the population of the world is rising the demand for food is also increasing so to maintain food production proportional to the growing population and decrease agricultural area so hydroponic systems are developed. So the focus of the study is to know the importance of hydroponics in effective agricultural production using smart technology. There are many hydroponics systems in existence that are developed to implement soil-less production using water and cultural broth. Different studies are done on many types of hydroponic systems which highlights their importance in food production. Thus it can be said that the hydroponic system is beneficial for farmers to develop disease-free crops without using soil to fulfill the requirement of food for the growing population. In the next few years, soil-less cultivation will be implemented by most farmers due to reducing the land for agriculture.

Keywords: Agriculture, Crops, Hydroponics, Production, Water.

1. Introduction

A sort of soilless gardening called hydroponics may be carried out both indoors and outdoors. It's a fantastic alternative for those who wish to cultivate herbs and veggies all winter long or who have a small or no gardening area. In comparison to soil-based farming, hydroponic gardening uses less area and uses less water. There are no weeds when plants grow in water. Even in Minnesota, hydroponically growing is possible all year long with artificial illumination. Hydroponically, however, practically anything may be grown. Herbs including leafy greens are excellent options for indoor cultivation in the winter as are crops with a short growing season or those that don't yield fruit. Strawberries, tomatoes, cucumbers, and peppers are all delicious options in the summer. Commercial farmers of these crops are increasingly using hydroponics rather than soil to raise their harvests [1]–[4].

Strawberries, bell pepper, lettuces, cherry tomatoes, leafy green vegetables, and cannabis are among the plants that are frequently raised hydroponically in a garden or other enclosed environment. Arabidopsis thaliana is also one of these plants which are used as a prototypical species in plant science and heredities. Numerous benefits of hydroponics include less water being used in agriculture. 400 gallons of water are needed to cultivate 1 kilogram

(2.2 lb) of tomato utilizing intensive farming techniques, compared to 70 liters for hydroponics and 20 liters for aeroponics. In the future, it could be feasible for people to cultivate their food in arid locations with limited access to water because hydroponics uses a lot less water to produce food [5]–[7].

The 1627 publication of Francis Bacon's publication Sylva Sylvarum or "A Natural History," which was done a year following his death, is the first instance of growing land plants without soil being documented. His study led to the widespread use of water culture as a research method. John Woodward documented his spearmint water cultivation experiments in 1699 and discovered that less pure water sources produced plants more effectively than purified water. By 1842, a list of nine ingredients was compiled that were deemed to be needed for plant development, and this led to the development of soilless agriculture. Soil culture eventually gave way to a more specific term, "solution culture," to describe the practise of growing plants in mineral fertilizers solutions rather than on soil [8]–[10].

It swiftly evolved into a common research and instruction method and is still commonly applied in plant nutrition studies today. A variant of hydroponics known as nutrient solutions or liquid culture currently uses an inert medium to control plant development. Fish waste, duck dung, commercial chemical fertilizers, or synthetic nutrient solutions are just a few examples of the many various sources of nutrients that may be employed in hydroponic systems. [16]–[19] Vegetables, chilies, melons, tomatoes, salad greens, and cannabis are among the plants that are frequently cultivated in hydroponic systems in a greenhouse or other enclosed environment on inert material. Arabidopsis thaliana is also regularly used which is used as a classical species in plant biology and heredities. [20]– [23]. Researchers working in e-Science fields such as meteorology, connectomics, sophisticated physics simulations, biology, genomics, and environmental studies meet difficulties.[16]- [41].

2. Review of Literature

Hermala et al., (2022) [11] examined that the provision of a human being's most fundamental need, food, makes agriculture an essential industry. It will rise in proportion to the growth of the population. The Internet of Things (IoT) was successfully adapted to a hydroponic system and was fueled by solar energy in this research. The IoT was able to effectively control the factors of the hydroponic system as well as the power generated by the solar panels. During the day, the solar panels generated up to 2.5 kW of power, which was then used to power the greenhouse, which requires approximately 477 W of power. A study was carried out in which the productivity of traditional farming was compared to that of hydroponic smart farming. In this study, traditional and smart farming methods were used to raise plants of four different species: Ipomea Aquatica, Lactuca sativa, Brassica Chinensis, and Brassica rapa. The plants' physical characteristics were examined and studied. It was discovered that the height of Ipomoea Aquatica was 52.63cm when grown using smart farming, however, the height was only 42.66cm when grown using traditional farming. As a result, it gives better plant production than conventional methods, as measured by the average height and weight of the plants as well as the number of leaves because smart farming provides optimal nutrition.

Nguyen et al., (2022) [12] stated that the conventional mode of farming is today confronted with a great number of challenges and roadblocks. One of the reasons is that the environment has become harsher as a result of climate change, and there are also more illnesses and pests. Additionally, the growth of industrial zones has resulted in a considerable reduction in the amount of arable land. To be successful in overcoming these challenges, farmers will need to make adjustments to their agricultural practices and integrate newly available scientific and technical knowledge into their operations. This paper presents a report on the design and development of an autonomous monitoring system for hydroponic farming which is based on the concept of the internet of things. The data from the sensors can be acquired in real-time due to this method. An IoT gateway and a virtual server were constructed to send the information that was obtained to the cloud and to store it. The user can monitor all of the sensor data of the environment and the hydroponic solution through the web interface, and they are also able to manage the farming machinery. During the growing of lettuce in an NFT hydroponic system, the system was tested and assessed for its effectiveness. The findings of the experiments indicate that the system being suggested keeps a stable operation and achieves a high level of reliability. During the cultivation process, the acquired sensor data that is kept on the server may be used to study and assess the influence that a variety of environmental elements have on plant development.

Borrero, (2021) [13] observed that changes in both the environment and society are having a significant impact on the present agricultural and food production systems. Rural regions have difficulties in terms of agricultural growth as a result of agricultural techniques that are not sustainable and the poor profitability of small farmers. Through an analysis of previously published research, patented literature, and other commercial products, the purpose of this investigation is to design a new vertical hydroponic farm system that is both modular and economical. Following an in-depth process of conception, my institution was responsible for the fabrication and testing of a prototype to confirm the product's degree of technological readiness level (TRL). The results demonstrated that the existing utility model is both usable and effective, but they also called attention to some improvements that had to be made before the model can go to the next TRL. The outcomes of this study demonstrate that the prototype has the potential to aid in the campaign against food insecurity, as well as to benefit society by promoting innovations in food production and bettering people's standard of living. This can be accomplished thanks to the research that was conducted.

Suryaningprang et al., (2021) [14] analyzed that farmers in the West Java region are working to use the most efficient farming method possible to meet the demands of both the local and global markets. Farmers in the area have challenges when trying to develop their companies and raise their production yields due to the constraints imposed by conventional farming methods, such as the need for extensive plots of land, a ready supply of farmer labor, and a longer harvesting period. Hydroponic farming is a novel farming system that differs from traditional farming methods yet is readily applicable to the needs of today's small-scale farmers. Since big plots of land are not necessary for hydroponic farming, they may be applied everywhere, even in urban areas. The “Nutrient Film Technique (NFT)” is one of the emerging hydroponic methods that can be used in both high and low altitudes. The yields from this method are likely to be high-quality. Farmers benefit from the NFT system because it allows them to expand their operations into limited urban space by expanding their expertise in hydroponic farming and the number of agricultural commodities they can produce. Due to the utilization of effective fertilizer, water, and non-pesticide materials, the goods produced are of superior quality while also being kind to the environment. Despite the higher yield and quicker time to harvest, this hydroponic system still needs a considerable expense to acquire the necessary materials. As a result of the high economic value and potential improvement to the farmers' welfare, more and better agricultural products are encouraging local farmers to operate a hydroponic system to fulfill market demands.

Srinidhi et al., (2020) [15] intended that the capacity to provide an adequate quantity of food for humans is becoming more challenging as the world's population continues to rise while at the same time natural resources continue to dwindle. The amount of agricultural land available for cultivation falls at a rate that is directly proportionate to the size of an expanding population. As a result, the quantity of food that can be produced will drop dramatically and won't be enough to meet the necessities of the expanding population. In the not-too-distant future, conventional agricultural practices will no longer be adequate. An approach to farming that is both effective and makes use of today's tools and resources have to be developed and implemented in the sector of agriculture. The use of machine learning algorithms is utilized in this study, which makes use of hydroponics, an effective way of farming. For the advantage of the crops that are being cultivated, the system that has been planned and constructed is automated, and it makes judgments about what to do with sensor data by using KNN and the Lasso Regression algorithm. It has developed this approach in the hopes that it would alleviate any future food shortages and ensure that everyone has access to fresh produce throughout the whole year. When compared to traditional agricultural practices, the consumption of water in hydroponic farming is reduced by 90%. The method ensures the highest possible quality and yield of the crops cultivated in the system by supplying the climatic conditions and nutrients that have been shown through scientific research to be optimal for the specific crop that is to be grown.

2.1 Comparison of Reviewed Technique

The following study expands on the previous Implementation of Hydroponics system In Agriculture to Improve the Productivity; several researchers explain their findings as seen in table 1 below.

3. Discussion

In static nutrient solutions, plants are raised in nutrient solution-filled containers like planters, buckets, bathtubs, or tanks (usually used in domestic settings). The solution is often gently aerated; however, this is not required. If the solution is not aerated, it is kept at a level where most plants are above the liquid to provide them with ample oxygen. Each plant has a hole carved (or punched) in the reservoir's top; if the reservoir is jars or tubs, the lid may be used; if not, the top may be made of cardboard, tinfoil, newspaper, wood, or metal. A single reservoir may be used by several plants or just one. As plant size grows, reservoir capacity can be expanded. Aqua pumps, aquarium gates, which are formed by photosynthesis, can be utilized to provide aeration in a handmade system set up in plastic containers or glass canning jars.

Table1. *Comparison of reviewed technique*

Authors [Ref.]	Technique	Outcome
Hermala et al., (2022) [11]	IoT	As a result, it gives better plant production than conventional methods, as measured by the average height and weight of the plants as well as the number of leaves because smart farming provides optimal nutrition.
Nguyen et al., (2022) [12]	NFT hydroponic system	The findings of the experiments indicate that the system being suggested keeps a stable operation and achieves a high level of reliability.
Borrero, (2021) [13]	TRL	The results of this research demonstrate that the prototype has the potential to aid in the fight against food insecurity, as well as to benefit society by promoting innovations in food production and bettering people's standard of living.
Suryaningprang et al., (2021) [14]	NFT	As a result of the high economic value and potential improvement to the farmers' welfare, more and better agricultural products are encouraging local farmers to operate a hydroponic system to fulfil market demands.
Srinidhi et al., (2020) [15]	KNN and Lasso regression	As a result, the consumption of water in hydroponic farming is reduced by 90% when compared to traditional agricultural practices.

The effects of negative phototropism may be mitigated by coating clear containers with materials such as tin foil, butcher's sheet, black plastic, or even other materials. The nutritional solution may be changed on a regular schedule, when the absorption drops below a certain level, as measured by an electrical conductivity metre. Either a new nutrition solution or water is supplied whenever the solution drops below a particular point. The solution level can be automatically maintained using a float valve or a Mariotte bottle. Plants are grown in a raft saline environment, which involves floating a sheet of buoyancy plastic over the nutrient solution. In this manner, the roots are always above the solution level.

The nutrient solution moves continually around the plant's roots in a cultivation method known as continuous-flow solution culture. When compared to the static solution culture, this method is much easier to automate since it only requires a single big storage tank to monitor and adjust the temperature, pH, and nutrient levels for thousands of plants. The nutrient film technique, also known as NFT, is a well-liked variation in which a very superficial water stream containing the all-nutrient solution essential for plant development is recirculated inside a thin layer past a bed of bare-root plants with a top surface exposed to air in a watertight channel. As a result, the plant's root systems receive a generous quantity of oxygen. The use of the appropriate channel slope, flow rate, and length is the basis for the development of an efficient NFT system. The NFT system's primary benefit over other hydroponic systems is the fact that plant materials are exposed to sufficient quantities of water, air, and nutrients.

There is a contradiction between the provision of these requirements in all other kinds of production since too much or too little of one cause and unbalance of the other or both of the others. The architecture of NFT allows for simultaneous fulfillment of all three conditions for healthy plant development, provided that the straightforward idea of NFT is constantly recalled and used. Because of these advantages, bigger yields of higher-quality food may be gained over a lengthy period during cropping. One disadvantage of NFT is that it has a very inadequate amount of buffering against flow disturbances. However, in general, it's one of the most effective methods. In an aeroponics system, roots are maintained intermittently or continuously in a space saturated with tiny drops of nutrient solution (a mist or aerosol). The process involves growing plants in a shallow air or growing chamber with their roots floating and regularly misting them with a thin mist of isolated nutrients without using any substrate. The fundamental benefit of aeroponics is excellent aeration, as seen in Figure 1.

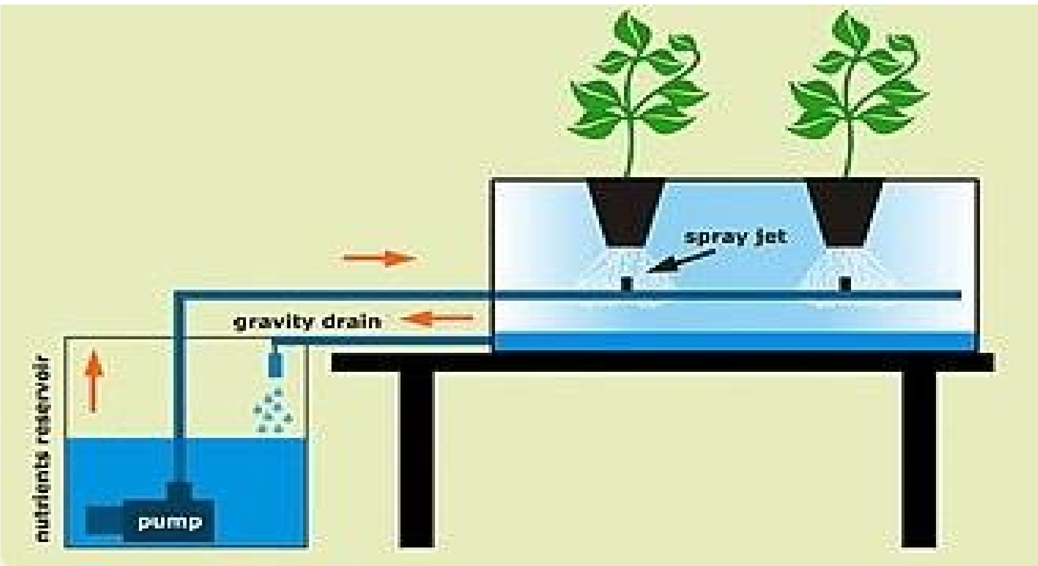

Figure 1. *Represents the Aeroponics System Used for Better Production of Crops [Source: Wikipedia].*

For multiplication, seedling growth, seedling potato and tomato cultivation, leaf crops, and microgreen production, aeroponic methods have been commercially effective. Since 1983, when inventor Richard Stoner first made aeroponic technology commercially available, aeroponics has been used all over the world as an alternative to hydroponic systems that require a lot of water. The drawback of hydroponics is that, whether or not aerators are used, 1 kilogram (2.2 lb) of liquid could only hold 8 milligrams (0.12 gm) of air.

The hydroponic technique of growing plants involves floating the root growth in a nutrient- and oxygen-rich water solution. The roots of the plant are immersed in nutrients and are enclosed in a net pot that is deferred from the middle of a plastic bucket or another big container in traditional techniques. A combination of porous stones and an air pump that is saturated with oxygen is the remedy. The roots of the plants develop significantly more quickly with this strategy because of how much oxygen they are exposed to. The Kratky Method employs a non-circulating water tank yet is comparable to deep water cultivation.

A commercial hydroponic system known as a rotating hydroponic garden is designed inside a circular frame and revolves continually throughout the whole development cycle of the plant being cultivated. Systems usually rotate once every hour, allowing a plant 24 complete spins within the circle throughout 24 hours, however, system specifics vary. Each rotational hydroponic garden may include an intensity grow lamp in the middle that is intended to mimic sunshine, frequently with the help of a mechanical timer.

The hydroponic solution combination is watered at regular intervals and the plants are rotated daily to ensure they get all the nutrients they require. Plants often mature significantly more rapidly than that when cultivated in soil or other conventional hydroponic growth methods, as seen in Figure 2, because of the plants' constant struggle against gravity. Due to their compact size, rotating hydroponic systems enable the growth of more plant material per square foot of floor area than other conventional hydroponic schemes.

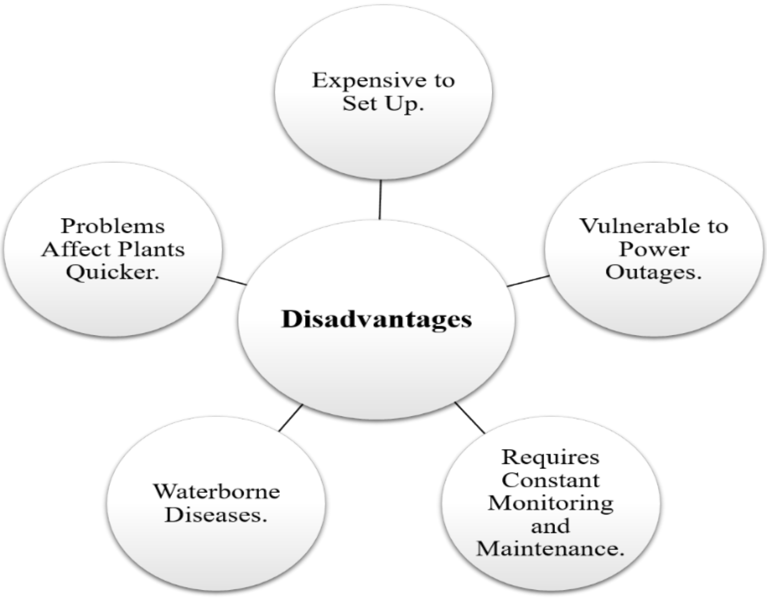

Figure 2. *Represents the Disadvantages of Hydroponics System by Comparing Different Factors.*

Passive sub-irrigation is a method of growing plants that is also known as passive hydroponics, mild hydroponics, or hydro culture using an inert porous medium and capillary action to deliver water and nutrients to the roots as needed from a separate basin. This method saves labor and ensures that the roots always have access to water. The easiest way involves placing the pot on a capillary pad that has been drenched with nutrients or in a deep solution of fertilizer and water. Enlarged soil and coconut fiber are two examples of hydroponic media that are available. These materials have more country airspace than more conventional potting soils, which increases the amount of oxygen that reaches the roots and is crucial for epiphytic plants like orchids as well as bromeliads, for which the roots are naturally visible to the air. The decrease in root rot and the increased ambient humidity brought on by evaporation are additional benefits of passive hydroponics.

4. Conclusion

Hydroponics is a subset of hydro culture that entails increasing plants (often crops) without soil by use of aqueous solutions of mineral fertilisers. Plants growing either on land or in water may have their roots supported by an inert medium like vermiculite, sand, or other substrates, or they can be granted unrestricted access to the nutrient-rich liquid. Despite an inert medium, root exudates and pH variations in the rhizosphere can have an impact on the biological and physiologic equilibrium of the nutrient solution. Fish waste, duck dung, commercial chemical fertilizers, or synthetic nutrient solutions are just a few examples of the many various sources of nutrients that may be employed in hydroponic systems. Thus, hydroponics is a very useful and productive method if it is maintained properly to increase productivity. Therefore, the utilization of hydroponic systems will have a new effect on agriculture at a large scale for the production of food without the usage of soil.

References

Mehra, Manav, Sameer Saxena, Suresh Sankaranarayanan, Rijo Jackson Tom, and M. Veeramanikandan. "IoT based hydroponics system using Deep Neural Networks." Computers and electronics in agriculture 155 (2018): 473-486.

AlShrouf, Ali. "Hydroponics, aeroponic and aquaponic as compared with conventional farming." American Academic Scientific Research Journal for Engineering, Technology, and Sciences 27, no. 1 (2017): 247-255.

Naik, P. K., B. K. Swain, and N. P. Singh. "Production and utilisation of hydroponics fodder." Indian Journal of Animal Nutrition 32, no. 1 (2015): 1-9.

Quagrainie, Kwamena K., Roberto Manolio Valladão Flores, Hye-Ji Kim, and Verena McClain. "Economic analysis of aquaponics and hydroponics production in the US Midwest." Journal of Applied Aquaculture 30, no. 1 (2018): 1-14.

Huang, Yi, Keisuke Miyauchi, Chihiro Inoue, and Ginro Endo. "Development of suitable hydroponics system for phytoremediation of arsenic-contaminated water using an arsenic hyperaccumulator plant Pteris vittata." Bioscience, biotechnology, and biochemistry 80, no. 3 (2016): 614-618.

Li, Qiansheng, Xiaoqiang Li, Bin Tang, and Mengmeng Gu. "Growth responses and root characteristics of lettuce grown in aeroponics, hydroponics, and substrate culture." Horticulturae 4, no. 4 (2018): 35.

Al-Tawaha, Abdel Razzaq, Ghazi Al-Karaki, Abdel Rahman Al-Tawaha, Sitti Nurani Sirajuddin, Ibrahim Makhadmeh, Puteri Edaroyati Megat Wahab, Refat A. Youssef, Wael Al Sultan, and Adnan Massadeh. "Effect of water flow rate on quantity and quality of lettuce (Lactuca sativa L.) in nutrient film technique (NFT) under hydroponics conditions." Bulg. J. Agric. Sci 24, no. 5 (2018): 793-800.

Liu, Zhigang, Kun Gao, Shengchen Shan, Riling Gu, Zhangkui Wang, Eric J. Craft, Guohua Mi, Lixing Yuan, and Fanjun Chen. "Comparative analysis of root traits and the associated QTLs for maize seedlings grown in paper roll, hydroponics and vermiculite culture system." Frontiers in Plant Science 8 (2017): 436.

Storer, Christopher S., Zachary Coldrick, Daniel J. Tate, Jack Marsden Donoghue, and Bruce Grieve. "Towards phosphate detection in hydroponics using molecularly imprinted polymer sensors." Sensors 18, no. 2 (2018): 531.

Jensen, Merle H. "Hydroponics worldwide." In International Symposium on Growing Media and Hydroponics 481, pp. 719-730. 1997.

Hermala, Irvan, Agus Ismail, Nur Hendrasto, Azqia Maulida Darda, and Syukur Daulay. "The application of IoT-based hydroponic system and solar power to increase agricultural production and horticultural crop productivity." International Journal of Engineering & Technology 11, no. 1 (2022): 20-26.

Nguyen, Huu Cuong, Bich Thuy Vo Thi, and Quang Hieu Ngo. "Automatic Monitoring System for Hydroponic Farming: IoT-Based Design and Development." Asian Journal of Agriculture and Rural Development 12, no. 3 (2022): 210-219.

Borrero, Juan D. "Expanding the Level of Technological Readiness for a Low-Cost Vertical Hydroponic System." Inventions 6, no. 4 (2021): 68.

Suryaningprang, Andre, Jaja Suteja, Mulyaningrum Mulyaningrum, and Erna Herlinawati. "Hydroponic: Empowering Local Farmer Knowhow to Gain Value Added on Agriculture Commodity." Budapest International Research and Critics Institute (BIRCI-Journal): Humanities and Social Sciences 4, no. 1 (2021): 787-796.

Srinidhi, H. K., H. S. Shreenidhi, and G. S. Vishnu. "Smart Hydroponics system integrating with IoT and Machine learning algorithm." In 2020 International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT), pp. 261-264. IEEE, 2020.

Panwar, Kuldeep, et al. "Thermal and Resistance Analysis of Perforated Fin Using CFD." Advances in Fluid and Thermal Engineering. Springer, Singapore, 2019. 603-611.

Nikhil Kanojia, Shivasheesh Kaushik, Vipin Uniyal, Kuldeep Panwar, Satyendra Singh, Shubham Singh Karki, Samriddhi Vashishth, Anurag Rawat, Ashish Nayal, 2022. Experimental Study of Heat Storage and Heat Elimination in Packed Bed using Nylon 6 Spiral Balls, Neuro Quantology, Vol. 20, Pages 2335-2343

Kanojia, Nikhil, et al. "Experimental investigation of optimum charging and discharging time on packed bed heat regenerator for space heating and solar drying application." Materials Today: Proceedings 46 (2021): 6712-6718.

Kaushik, S., Singh, S., and Panwar, K., 2021. Comparative Study for Thermal and Fluid Flow Peculiarities in Cascading Spiral Inner Tube Heat Exchanger with or without Diverse Inserts over Spiral Tube Comparative analysis of thermal and fluid flow behaviour of diverse nano fluid using Al2O3, ZnO, CuO nano materials in concentric spiral tube heat exchanger, Materials Today: Proceeding, , Vol. 46, Part 15, doi: https://doi.org/10.1016/j.matpr.2021.04.100, 6625-6630.

Kaushik, S., Singh, S., Kanojia, N., Rawat, K. and Panwar, K., 2020. Comparative Study for Thermal and Fluid Flow Peculiarities in Cascading Spiral Inner Tube Heat Exchanger with or without Diverse Inserts over Spiral Tube, IOP Conf. Series: Materials Science and Engineering 802, doi:10.1088/1757-899X/802/1/012009.

Panwar, Kuldeep, and D. S. Murthy. "Design and evaluation of pebble bed regenerator with small particles." Materials Today: Proceedings 3.10 (2016): 3784-3791.

Bisht, Neeraj, P. C. Gope, and Kuldeep Panwar. "Influence of crack offset distance on the interaction of multiple cracks on the same side in a rectangular plate." Frattura ed Integrità Strutturale 9.32 (2015): 1-12.

Panwar, Kuldeep, and D. S. Murthy. "Analysis of thermal characteristics of the ball packed thermal regenerator." Procedia Engineering 127 (2015): 1118-1125.

Shivasheesh Kaushik, Vinay Sati, Nikhil Kanojia, Kuber Singh Mehra, Himanshu Malkani, Harshvardhan Pant, Hina Gupta, Abhay Pratap Singh, Aman Kumar, Ashwarya Raj Paul, and Ritu Kumari, 2021. Bio-Diesel a Substitution for Conventional Diesel Fuel: A Comprehensive Review, Lecture Notes in Mechanical Engineering, Springer Nature Singapore, https://doi.org/10.1007/978-981-16-0942-8, 113-122.

Shivasheesh Kaushik, Satyendra Singh, 2019, Analysis on Heat Transmission and Fluid Flow Attributes in Solar Air Accumulator Passage with Diverse Faux Jaggedness Silhouettes on Absorber Panel, International Journal of Engineering and Advanced Technology, 8, 32-41.

Kaushik, S., Singh, S., and Kanojia, N., Naudiyal R., Kshetri R., Paul A. R., Kumari R., Kumar A. and Kumar S., 2020. Effect of introducing varying number of fins over LED light bulb on thermal behaviour, Materials Today: Proceeding, Vol. 46, Part 19, doi: https://doi.org/10.1016/j.matpr.2020.10.876, 9794- 9799.

Uniyal, V., Joshi, S. K., Kaushik, S., and Kanojia, N., 2020. CFD Investigation of Transfer of the Heat and Turbulent Flow in Circular Copper Tube with Perforated Conical Rings of Aluminum Material, Materials Today: Proceeding, Vol. 46, Part 15, doi: https://doi.org/10.1016/j.matpr.2021.04.217, 6619-6625.

Ayushman Shrivastav, Shivasheesh Kaushik, Kuldeep Rawat, Abhishek Ghildyal, Vijay Singh Bisht, Kamal Rawat, Prabhakar Bhandari 2022. Influence of M shaped, Wedge shaped and Reverse Wedge shaped Turbulators in Solar Air Heater, Neuro Quantology, Vol. 20, Pages 2308-2312

Nikhil Kanojia, Shivasheesh Kaushik, Subhan Ali, Ashish Joshi, Satyendra Singh, Aman Kumar, Bashishtha Kumar Rewani, Prince Kumar Gupta, Sahwaj Alam, 2022. Review on Sustainable Thermal Energy Storage Technology with Packed Bed Regenerator, Neuro Quantology, Vol. 20, Pages 2324-2334

Ayushman Shrivastav, Shivasheesh Kaushik, Kuldeep Rawat, Jaya Bohra, Vijay Singh Bisht, Prabhakar Bhandari, Kamal Rawat 2022. Exergy Analysis of Solar Air Heater roughened with Z-Shaped Baffles, Neuro Quantology, Vol. 20, Pages 2313-2317.

Kuldeep Rawat, Avinash Singh, Krishna Sati, Manish Kumar, Ashish Negi, Kuldeep Panwar, 2021. CFD analysis of fixed matrix with glass refractory particle regenerator, Materials Today: Proceedings, Volume 46, Part 15, Pages 6871-6875, https://doi.org/10.1016/j.matpr.2021.04.450.

anwar, K., Hasan, E., Singh, R., Chaudhary, V., Rawat, K. 2019. Thermal and Resistance Analysis of Perforated Fin Using CFD, Advances in Fluid and Thermal Engineering. Lecture Notes in Mechanical Engineering. Springer, Singapore, Vol. 46, https://doi.org/10.1007/978-981-13-6416-7_56

Nikhil Kanojia, Shivasheesh Kaushik, Mayank Singh, Manish Kumar Sha, 2021. A Comprehensive Review on Packed Bed Thermal Energy Storage System, Lecture Notes in Mechanical Engineering, Springer Nature Singapore, https://doi.org/10.1007/978-981-16-0942-8, 165-174.

Shivasheesh Kaushik, Ashish Joshi, Nikhil Kanojia, Subhan Ali, Avinash Guleria, Aman Thakur, Mohit Nayal, Yash Khandsaliya, 2022. Comparative Analysis of Physio-Chemical, Performance-E Emission Properties Between Diesel and varying blend of Castor Biodiesel with Iso-Propanol, Neuro Quantology, Vol.20, 2272-2285.

Shivasheesh Kaushik, Subhan Ali, Ashish Joshi, Kuldeep Panwar, Ashish Benwal, Arshad Khan, Dheeraj Kumar, Divyanshu Kumar, 2022. Experimental Analysis of Performance and Emission Characteristic between Diesel and Varying Blends of diesel-Isopropanol-Biogas with different CR, Neuro Quantology, Vol.20, 2272-2285. 2286-2307.

Rahul Kshetri, Shivasheesh Kaushik Vinay Sati, Kuldeep Panwar, Ajay 2020. Investigation of cutting parameters and its effects on surface roughness in high-speed turning of 52100 bearing steel, Advances in Materials Engineering and Manufacturing processes, Springer, Multidisciplinary Industrial Engineering, doi: https://doi.org/10.1007/978-981-15-4331-9, 105-115,

G. Pant, S. Kaushik, S. Kandwal, A. K. Singh, 2021. Finite Element Modeling and Parametric Investigation of Friction Stir Welding (FSW), Advances in Industrial Machines and Mechanism, Springer, Lecture Notes in Advances in Industrial Machines and Mechanisms, doi: https://doi.org/10.1007/978-981-16-1769-0_23, 251-259.

Vinay Sati, Shivasheesh Kaushik, Satyendra Singh, Rahul Kshetri, Kuldeep Panwar, Rahul Pandey, 2019. Reduction of losses in 90 Degree Pipe Bends by varying Design Parameters using CFD Software, International Journal of Engineering and Advanced

Technology, Vol. 8, 78-87.

Rahul Kshetri, Shivasheesh Kaushik, Ajay, Vinay Sati, Kuldeep Panwar, Rahul Pandey, 2019. Tool Wear Analysis during Turning of Hard Material by Simulink, "International Journal of Engineering and Advanced Technology, Vol. 8, 78-87.

Shivasheesh Kaushik, Rahul Kshetri, Nikhil Kanojia, Kuldeep Rawat, Vipin Uniyal, 2020. Effects of plasma nitriding on mechanical, tribological and corrosion properties of friction stir welded joints of Al 2024, Materials Today: Proceeding, Vol. 46, Part 15, D.O.I.: https://doi.org/10.1016/j.matpr.2021.04.218 , 6626-6632.

Vinay Sati, Shivasheesh Kaushik, Rahul Kshetri, Kuldeep Panwar, Rahul Pandey 2020. Comparison of a Classical Cyclone Separator and Protruding Surface Cyclone Separator using CFD Software, IOP Conf. Series: Materials Science and Engineering, Vol. 802, doi:10.1088/1757-899X/802/1/012009.