ENHANCEMENT OF COP OF VORTEX TUBE REFRIGERATION SYSTEM BY USING DIVERGENT TUBE

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ABSTRACT

Ranque Hilsch vortex tube is a mechanical thermal device with no moving parts which generate hot and cold air streams concurrently with high-pressure air as working fluid. The flow and mass separation in a vortex tube highly depend on factors like diameter of the nozzle, No. of the nozzle, length of the vortex tube, nozzle press, outlet hole size, and cold mass fraction. But all these parameters are examined previously by many researchers. In this paper numerical analysis is carried out to understand and compare the flow pattern and allied temperature separation in a VT for different types of the tube includes atubular and divergent tube. The VT consists of four tangential in letnozzles in vortex generator,one hot outlet,and one cold outlet in a counter direction. The paper shows that numerically prediction of the behavior of flow separation inside VT using ideal gas assumption. The numerical study predict that temperature separation increases with input nozzle pressure from 6 to 10 Bar and also varies from tubular pipe to divergent pipe and maximum temperature separation of divergent tube is achieved at optimum pressure value of 8 and 9 bar.

Keywords: *Vortex tube, Convergent Tube, Refrigeration, Cooling, COP*

Introduction

The VT is a mechanism that separates a high-pressure flow inflowing tangentially into two low- pressure streams, thereby providing a temperature separation. The VT has no moving parts and consists of two circular tubes, nozzles, and a choke valve to adjust flow at the hot side and then successively at the cold side relatively at lower pressure. High-pressure air enters the VT tangentially through the nozzles which increase angular velocity and thus produces a swirl effect in the vortex generator. The hot outlet is situated in the outer radius near the farthest end of the nozzle and the cold outlet is in the core of the tube next to the vortex generator. The airstream differentiates into two counter-current layers. The gas nearer to the center has a low temperature and is released through the cold outlet and the gas near the periphery of the tube has a high temperature which released through the hot outlet. This effect was first discovered by Ranque in the cyclone dust separator. Another researcher has proposed the idea that the flow energy transfer is due to counter expansion and compression during the flow. The proposed mechanism includes secondary circulation which exchanges energy with each other and inner flow giving energy to the peripheral stream and successively decreases the temperature of the cold stream. Zhuohuan [1] proposed that the heat energy separation is due to the tangential separation of micro streams with different tangential velocities in the vortex tube. Later, Ranque-Hilsch did various investigational and the oretical studies to improve the COP of the vortex tube. He proposed that the central layer giving heat to the outer layer meanwhile expanding and rising cold region in the core of VT. The effect of the number of the nozzle has been investigated by the different researchers by employing no. of nozzles in the combination of 4, 6 at vortex generator. Eiamsa-ard [2] investigate that the rise in the no. of nozzles and the entry pressure leads to the rise of the swirl or vortex strength and therefore the energy separation in the tube efficiently. Hamdan et al. [3] have shown that VT performance changes noticeably with several nozzles and that the best possible number provides the best performance. Xue and Arjomandi [4] noticed that the vortex angle of a nozzle at vortex generator has a straight effect on VT and that lesser vortex inclination shows a larger temperature difference and better performance for the cooling efficiency of the VT. It was reported [5] that cooling the VTimproves the cooling capability by 5-9%. The result of vortex entrance circumstance is

given in [6] which indicated that VT effectiveness can be improved by rounding the notch access. Researchers worked in improving VT by redesigning the nozzle inlet and utilizing diffuser VT which showed reasonable improvement [6] and discover exact stream patterns. An adaptation to VT has been wished for [7] by introducing a double-circuit VT which showed improvement in the VT efficiency. In literature, several studies have been conducted to analyze the VT process using computational fluid dynamics which showed satisfactory agreement with published data. A full conference of CFD study is presented by Behera et al. [8] in which they reported a maximum COP of 0.83 if we used it as a refrigerator and 0.53 as a heat pump. N. F. Aljuwayhel [9] has numerically found out that the secondary energy flow degrades the performance of theVT.

Material and Method

The geometrical parameter of the VT and the 3-D model of the VT are presented in Table-1. A vortex tube, with a working length of 100 mm, an internal diameter of 14 mm, and nozzle diameter 2 mm was used. Ideal Air was admitted as the working fluid of the VT at inlet temperature 298 K with 5 different nozzle input conditions were analyzed with the pressure varying from 6 to 10 Bar, for both types of VT model. The meshing and analysis software Ansys CFX was used to generate the structured Mesh for a fluid domain of current analysis. The computational mesh grid structure of the VT is shown in Fig-3 and Fig-4. The scale and dimension of both tubular and Divergent VT are presented in Table 1. In this model, a regular tetrahedral ordered grid has been used which satisfying allparameter.

Table -1: Geometrical Specification of VT model

Geometry Specification	Tubular Tube	Divergent tube
Nozzle Diameter	2 mm	2 mm
Cold Outlet	4 mm	4 mm
Hot outlet	10-8 mm	14-12 mm
Tube Diameter	10 mm	8 mm
Hot tube length	120 mm	80 mm
Cold outlet length	10 mm	10 mm

Grid Independence Test

To reduce error because of the unevenness of mesh, a grid independence test was used to carry out.The deflection of cold temperature difference is verified with different types of mesh combinations, i.e. number of elements varied from 55,900 to 320000 elements. Beyond 290000 elements it is noticed that the cold end temperature has almost a constant temperature difference obtained which is only 0.1 %. Therefore the no. of elements select for meshing is varying from 292000 to 295000. The mesh type used for meshing is tetrahedral with medium smoothing and the inflationtype usedfor this grid is total thickness with a growth rate is 1.2and maximum thickness is 1.4 mm.

Boundary Conditions

In CFD simulation, boundary conditions given to VT are proportionally to maintain transparency and soundness. CFD analysis has been performing using an implicit solver by the pressure-based System in the steady-state input. The adiabatic and no-slip wall condition is set to the aluminum metal body of VT. The RNG k-ε turbulent model with Scalable wall function used for turbulent flow. The ideal gas assumption has been employed to account for density variation because flow through VT is compressible and turbulent. The pressure outlet condition for the cold tube is atmospheric pressure and for divergent tube, pressure selection is based on variable mass fractions given in Table - 2. Nozzle input pressure for both types of VT starts from 5 Bar to 10 Bar, pressure for the cold and hot outlet is adjust with atmospheric pressure with the addition of gauge pressure rages from 10Kpa to 30Kpa. Therefore absolute pressure at the outlet is in a range from 1.1 to 1.3 Bar. For computations of VT generally utilize a SIMPLE (Semi-Implicit Method for Pressure Linked Equations) algorithm. This algorithm is a pressure correction-based iterative type algorithm used for discrediting the convective transport expressions. A compressible form of the Navier–Stokes equation and the RNG k-Epsilon model by second-order upwind equations have been used to simulate the phenomenon of fluid

flow inside VT using the Ansys CFX softwarepackage.

Result and Discussion

The temperature difference gets from the CFD simulation for both types of pipe by fixing all other conditions is given in Table-2. The end temperature difference at the hot and cold outlet is increase with the increase in nozzle pressure at the inlet for both types of VT. But if consider the same output pressure for both types of tubes then cannot get the proper temperature difference and mass fraction at the cold and hot side at the same nozzle pressure. To get the temperature difference to adjust the output pressure in a divergent type tube and take the reading temperature at the hot and cold outlet. The rate of change in temperature in the tubular pipe is less as compared to temperature in a divergent pipe in a change in pressure condition used in a divergent pipe. But if we used the same pressure condition for both types of tubes then observations of mass flow fractions are changed and those are beyond our application where we used VT so apply different outlet pressure conditions for the Divergent tube is necessary. The temperature obtained from cylindrical and divergent vortex tubes in form of 3D streamlines views is shown in Fig-3. From this 3D streamline, we can easily understand the temperature difference get from VT in different arrangements. The analysis of pressure in the core shows that as the air moves to the hot exit, the hot stream is compressed by declining pressure, and the cold stream undergoes an increase in pressure.At the hot exit some energy loose, and this decreased energy will produce an elevated pressure in the core of the tube near the hot outlet. This energy shift will effect in stagnation and concurrent flow, and the opposing flow will move to the cold outlet. This justification on the process of declining the pressure drop of cold inner flow replicate that the pressure approaches the least before the flow comes to the cold outlet. The ΔP over the central tube tracing denotes a decrease in temperature for the fluid flow through the centre. By using a divergent vortex tube, the high pressure formed by flow accessing the tube is carried to the hot exit and the mixing in the inlet region of the stream and at the base of the nozzles will belighter.

Hot O. Temp.	ColdO. Temp.	Diff Hot	Diff Cold	ΔT	COP
338.53	286.67	40.53	11.33	51.86	0.074837513
341.93	284.49	43.93	13.51	57.44	0.135539116
342.87	282.6	44.87	15.4	60.27	0.187167631
345.34	279.77	47.34	18.23	65.57	0.229189627
348.78	276.63	50.78	21.37	72.15	0.264820937
350.67	275.43	52.67	22.57	75.24	0.300293834

Hot O. Temp.	ColdO.Temp.	Diff Hot	Diff Cold	ΔT	COP
328.53	281.67	30.53	16.33	46.86	0.120079363
329.93	279.49	31.93	18.51	50.44	0.174647164
332.82	273.11	34.82	24.89	59.71	0.205449149
334.31	271.57	36.31	26.43	62.74	0.241192562
339.72	270.93	41.72	27.07	68.79	0.286213187
343.67	268.45	45.67	29.55	75.22	0.315597489

[Cold and hot exit pressure given in above table is gauge pressure and reference pressure is 1 atm]

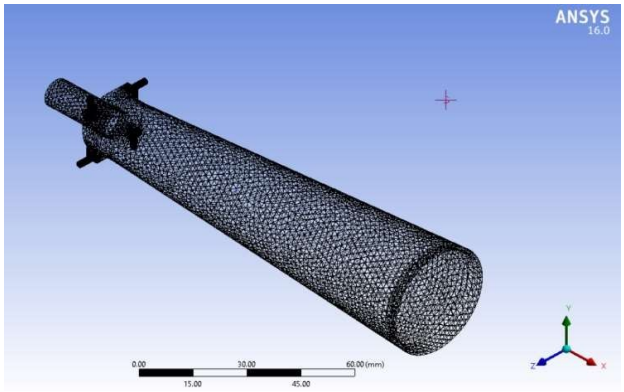


Fig-1Tetrahedral Mesh of Divergent Vortextube Vortextube

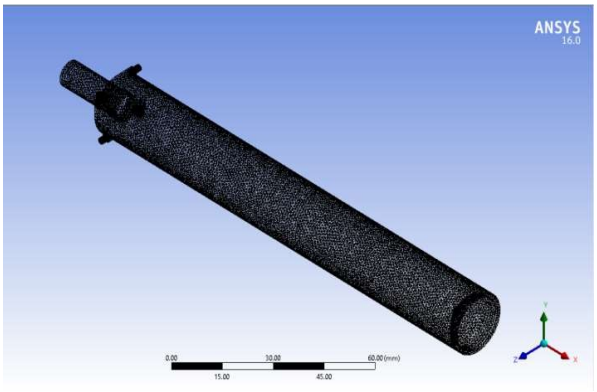


Fig-2 Tetrahedral Mesh of Tubular

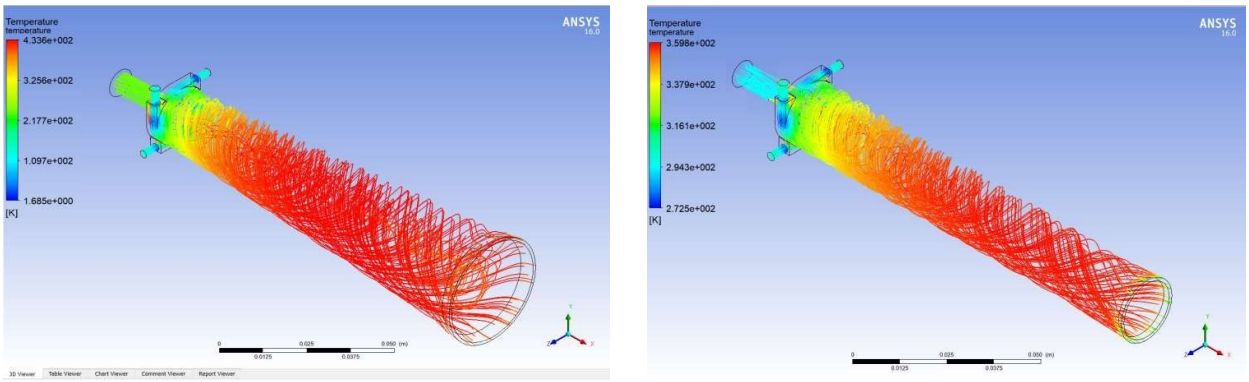
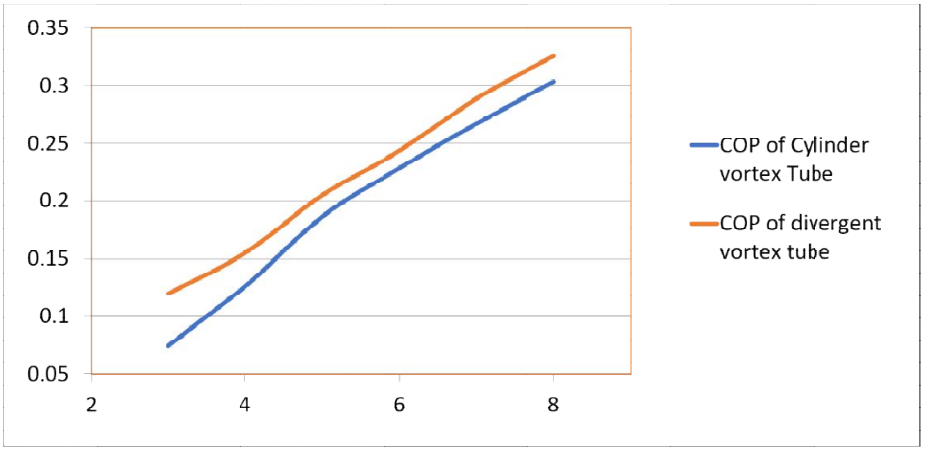


Fig-3: 3-D View of Temperature Streamline Tubular Vortex tube and Divergent Vortex tube



COP vs Nozzle temp (bar)

Conclusion

Numerical investigation and succeeding CFD simulations of VT were brought to know the effect of nozzle pressure, cold mass fractions, and end temperature by use of the different shapes of the vortex tube. Subsequent conclusions were carried out from the current study:-

1. The temperature separation at the cold and hot end of VT increases with an increase in nozzle pressure for tubular as well as divergentpipes.
2. The outcomes of CFD simulation of vortex tube is validate with experimental results of literature data.[10]
3. End temperature difference and cooling mass separation values of tubular VT, is lower than that of divergent VT at all values of nozzle pressure with the improved manner and maximum cooling temperature separation is get at pressure 8 to 9bar.
4. Result of CFD has been employed to formulate the primary physical mechanism accountable for the betterment of the effect of VT in insulatedconditions.
5. Inference of VT in industrial weld cooling-like appliances indicates VT's capability to reduce the required time for cooling and subsequently increase gains for the concern by used for a divergenttube.
6. As the inlet nozzle pressure increases, the measures of static temperature decreases remarkably. The static temperature of central axial fluid layers is higher than that of circumferential fluidlayers.
7. Higher cooling power separation for the increasing amount of input pressure implies that divergent VT required a high-pressure difference required at the hot and cold outlet to separate mass fraction compared to tubularVT.

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USE OF NANOTECHNOLOGY IN REFRIGERATION AND AIR CONDITIONING : A REVIEW

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ABSTRACT

In the current era of energy science environment pollution is the important issue for all the researchers and to minimize it is the only focus of them. The refrigerants from refrigeration and air conditioning are one of the causes of environmental damages like global warming effect, ozone depletion. It is challenge for all researchers to enhance the performance of system with reducing or without increasing GWP and Ozone layer depletions effect. Consequently, the researchers from the refrigeration area could not stay away from the ever growing skyline of Nanofluid applications. The research in the area of refrigerant based nanofluids or a Nanorefrihgerants/Nano lubricants is quite at low rate but of course it is growing year by year. Many researchers have observed a rise in the boiling heat transfer coefficient; the refrigeration systems become more energy efficient by the addition nanoparticles in the refrigerant or refrigerant-oil mixture which encourages them to pursue further research in this field. This review paper sheds more light on all the aspects of Nano-refrigerants such as its historical developments, nanoparticle production techniques, preparation methods, difficulties face during use nano-refrigerant. Current research review paper discusses about limitations of literature reviewed and also informs about future research directions required in this field.

Keyword: *Performance Coefficient, Nano-refrigerants, Refrigeration and Air conditioning.*

Introduction

The nano-particles recieved the focus of the researchers in the field of RAC as its ability to improve the properties of refrigerants to the large extent. Nano-refrigerants are nanofluids with base as a refrigerant and provided an improvement in thermo-physical properties of various refrigerants in different conditions. Different theoretical and experimental models are provided by the researchers have been used for the evaluation of different properties of refrigerant in terms of thermal conductivity, density, specific heat and viscosity of the refrigerants. In this effort, a number of models, and correlations have been used to result in the improvement in these properties by the use of Nano -refrigerants.[1][2]

Vapour compression refrigeration system is predominantly used for refrigeration and air-conditioning systems nowadays. R134a refrigerant has replaced the Chlorofluorocarbon's and Hydrofluorocarbons' as they were said to have high ozone depleting potential. R134a has its own limitations like global warming potential, high power consumption and so on. In order to get better options for the current power scantiness, energy efficient refrigeration system with high heat transfer coefficient has to be developed. Nanofluids are thermal fluids prepared by suspending nano sized particles in conventional base fluids like water, ethylene glycol and base refrigerant. Nanofluids are said to have higher thermal conductivity value (K) when it compared with the base fluids and hence are said to improve the heat transfer characteristics of the base fluids. These thermophysical properties of nano fluids make it possible to be used in refrigeration systems. The use of nano-powder along with the traditional refrigerants in vapour compression refrigeration cycle is a relatively a new idea, where nano-refrigerants, so obtained are found to have their improved thermal, physical properties over the conventional refrigerants. In this study,alumina (Al2O3) nanoparticles will dispersed in refrigerant R134a ,R717 and R744 to improve its heat transfer performance. After conducting experimental study, it is expected that performance of the system will be improved. The improvement in coefficient of performance (COP) will be maximum (7.5 to 8.5%) .[1] The nanoparticle materials are usually of metal, non-metal and their oxides, which enhance the heat transfer performance of base fluids. Hence, there is large scope of its application in heat transfer area.

Literature Review

In the current research paper I have done detailed literature survey for types ,properties of Nano- refrigerants, its production method, applications in refrigeration system with good and bad effect .Complete research review done for the last ten years in the field of nano-refrigerants.

Table 2.1.Summary of Research Review for Nano-Refrigeration systems

Year	Researcher	NP	Size, nm	Nanofluids	Results & Concluding Remarks
2012	LiuYang	-	-	-	20 types of nanoparticles mixed pairwise orthogonally with 10 types of dispersants are added in ammonia-water, respectively, to observe the dispersion stability of suspension.
2014	Coumaressin, T., Palaniradja, K	CuO	10 to 70	R134a + CuO	Refrigeration system performance is better with Nano- refrigerant.
2014	Hussen, H.	TiO2	20	R22 + (MO+ TiO2)	Refrigeration system performance is better with nanorefrigerant. Compressor work reduction 13.3 % &12 % increase in COP.
2014	Zhang, F., Jacobi, A.	Al2O3	40	Water+NP	Higher the NPC higher the wetting of surface. Surface roughness increases with NPC.
2015	Behabadi, M., et al	CuO	40	R600a + (POE RL68H +CuO)	Nearly 83% HTC at 1.5 NPMFL & 1 NLMFR increases as compare to pure refrigerant.
2015	Vandaarkuzhali S., Elansezhian, R.	CuO, ZnO, Al2O3	50	R22+ (de-ionized water+NP)	Air conditioning system with CuO nanorefrigerant is found to be more efficient than ZnO & Al2O3 nanorefrigerants.
2016	PRAVESH KUMAR KUSHWAHA	Al2O3	25	R134A+AL2O3	It was observed that there is more temperature drop across the condenser forthe nanorefrigerant (12.37% – 10.88%) compared to refrigerant R134a. Similarly, a gain of 5.0 % and 10S% was obtained for evaporator temperature. An improvement inCOP was also observed during the investigations (1.17% – 9.14%).
2018	Atul Bhattad	All Nanorerigerants	-	-	Application of nanofluids in the refrigeration, heat pump and air conditioning systems in different roles (refrigerant, lubricant and secondary fluid)is reviewed
2019	Oluseyi O. Ajayi	Al2O3	-	Al2O3+R134a	The outcome revealed that the Al2O3 nanoparticle enhanced the performance ofthe refrigeration process with better efficiency.
2020	Faizan Ahmed	Al2O3 use as secondary working fluid		-	A maximum COP of 6.5 was achieved for nanofluid inlet temp 40^0C at mass flow rate80 g/s and Vol Conc.by 15%.
2021	Reza Bakhtiari	TiO2-Graphene	-	TiO2-Graphen-Water	Study proposed correlations to predict thermal conductivity of TiO2-Graphene/H2O
2021	Faizan Ahmed	Cu and Al2O3	-	Cu and Al2O3+Water	For the highest volume fraction of 5%, Al2O3 nano-fluid was found to enhanceo the COP by a maximum of 22.1% while Cuexhibited a more significant enhancement by 29 %

Nano refrigerants Production Methods

The preparation process of nano-refrigerant is the most critical but important step as it affects the stability and properties of nanofluids. Preparation of nanofluids requires some uniqe methods for stable and uniform solution with negligible cluster,lump and depositions problem. Nanofluids which can be used as a secondary fluids in the refrigeration system are produced by dispersing metal, metal oxides, non-metals of nano-size in the base fluids such as water and brine. Commonly used methods for making of nano-fluid: single step method and two step method. Nanofluids preparation is a basic and main important step in experimentation requiring four guidelines
1) Dispersability of nanoparticles 2) Stability of nanoparticles 3) Chemical compatibility of nanoparticles 4) Thermal stability of NF. In refrigeration systems, preparation of nano-lubricant is comparatively easier than direct reparation of nano-refrigerant, as only few refrigerants are available in liquid state at atmospheric pressure. Nanoparticles as per required size,sh ape and type are dispersed in base fluid after precise weighing on electronic balance. Stirring is done in a mechanical stirrer for some period followed by ultra-sonic vibration technique to form one stable nanofluid. Surface active agents and/or dispersants are generally not used.[9] Other than these methods Nanoparticles can be produced from mechanical attrition, pyrolysis, gas condensation, chemical precipitation. Methods like dc plasma jet and dc arc plasma, radio frequency induction plasmas, chemical synthesis, gamma rays and laser ablation are used. Inert-gas condensation is frequently used to make nanoparticles from metals with low melting points. Depending upon application (properties) & cost, specific manufacturing technologies are chosen.

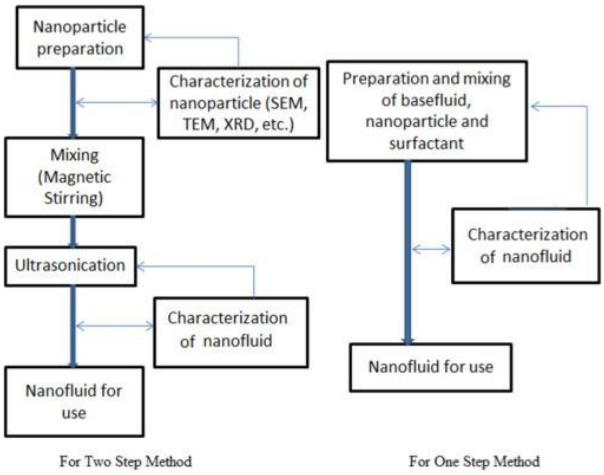

Fig.3.1 Nano-refrigerant preparations Methods[9]

Properties of Nano-Refrigerants

Comparative study was done for different properties of most commonly used nano-refrigerants such as thermal conductivity, viscosity, electrical properties, specific and surface tension and freezing characteristics.

Table 4.1.Summary for effect of different properties at various operating conditions [10]

Refrigerants/ Effect of Properties at various operating conditions	Al2O2+R134a	Cu+R134a	Al2O3 / R141b
Thermal Conductivity	K= 283–308 K, Φ= 5 v%; u= 5 m/s, Φ= 1–5 v%, mass flux= 100 kg/m2 Thermal conductivity enhancement is higher for smaller diameter and larger aspect ratio of Carbon NanoTube. Smaller dia means the more thick interfacial layer and the greater in value of K enhancement	Φ= 1–5 v%, D= 20 nm, T=300–325 K Maximum improvement of 43% has been observed at 325K and 5 v%.	T= 5–30 °C, Φ = 0.1–0.4 v% &0.5–2.0 v% respectively, Thermal conductivity increaseswith the increase in nanoparticle volume fraction and temperature. It increases by 1.6
Viscosity	T= -25 K, Φ= 5 v%; u= 5 m/s, Φ=1–5 v%, mass flux= 100 kg/m2 Viscosity increases with the increase in particle volume fraction and decrease in temperature; increased by 13.68% for same temperature.	Φ= 1–5 v%, D= 20 nm, T= - 25 K in temperature due to weakening of intermolecular adhesive force	T= 5–30 °C, Φ = 0.1–0.4 v% &0.5–2.0 v% respectively, Viscosity increases with theincrease in particle volume fraction and decrease in temperature.
Electrical Properties	Surfactant: SDS, Φ = 0.01–2.0 wt %, T= -25 K Electrical conductivity increases with increasing particleconcentration and temperature.		
Specific Heat	T= -25 K, Φ= 5 v% Densityincreases and heat capacity slightly decreases by using nanorefrigerant; heat capacity increases with temperature. COP increases by 2.6% & 3.2% due to effect of specific heat and density respectively.	Φ= 1–5 v%, D= 20 nm, T=-25K Density increased with the increase in particle volume fractions and decrease in temp	T= -25 °C, Φ = 0.0–0.4 v% Density increases with the increase in particle volume fraction and decrease in temperature.

Limitations

The use of nanofluids seems very attractive but its application can be obstruct by so many factors like poor long term stability,high pressure drop, high pumping power, low specific heat, sedimentation and high production cost.

Future Scope

From Research review it is seen that by using only single type nanoparticles is studies to make particular type of Nanorefrigerants but using mixture of different types of nanoparticles dispersed in base fluid is to be studies in future. Also with base fluid as natural refrigerant ammonia, Industrial refrigeration system, flooded refrigeration system need to focus. Nanoparticles which improve lubrication to reduce compressor wear & tear,

Conclusions

In this research review paper different types of Nano refrigerants, their Preparations methods discussed in details. With this also spread light on detailed study of their thermophysical properties and effect at different operating conditions reviewed. Also studied some of its limitations to the different application. As very little research is done in this area and its need to do further work so for the research scholar future scope in this area also have been discussed.

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COMPARATIVE STUDY BETWEEN WATER YIELD AND CONSUMPTIVE USE: A CASE STUDY OF KHATAV TALUKA

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ABSTRACT

Water management is crucial in arid and semi-arid regions to maintain a sufficient and reliable water supply. The semi-arid Khatav taluka in Maharashtra, India, has an average annual rainfall of 554 mm. The various authors have used conjunctive usage of surface and groundwater for water resource management in such water-stressed areas. The purpose of this study is to correlate and estimate water yield and consumption in irrigation commands for the Khatav taluka. The SWAT (Soil and Water Assessment Tool) model was calibrated and validated using the SUFI-2 algorithm in the SWAT-CUP program to meet the desired aim. The SWAT model's actual evapotranspiration values were compared to those obtained using the modified penman method (MPM). The meteorological data from the IMD (India Meteorological Department) was utilized to process the SWAT model for the period (2000-2014). The results show that, average curve number for the research region is 86.81, and evapotranspiration was 461 mm. It was also discovered that the research area suffers from salinization since the rate of evaporation exceeds the rate of precipitation. This research aids in the identification of potential salinized areas as well as the forecasting and management of future water demand. Researchers and decision makers will be able to use the study's findings to manage and allocate water resources in a sustainable manner.

Keywords:*Consumptive use, SWAT, Calibration-Validation, water resource management, Khatav.*

Introduction

The agriculture sector is most water consuming sector (Ewing, 2011)worldwide. The water available on earth surface is mostly saline (about 97 %) and only 3% water is fresh and again it is available in different forms. So, negligible volume of water available on earth surface to fulfill all kinds of needs. In 21th century (2020), the global population is about 7 billion and in 2050 it will be about 9.7 billion according population survey by United Nations.As population is increasing tremendously, the urbanization and expansions of agriculture is at its peak. To fulfill food demands for such huge populations all countries throughout the world expanding their agriculture sectors so water demand also increased (Singh, 2012)and some countries already faced water stress and zero water situations. In addition to this, climate change also imparts the negative impact on water resource management(Singh, 2014; Singh & Panda, 2012). To alleviate the water scarcity issues and to plan sustainable irrigation most of researchers from the globe are emphasizes conjunctive use of surface and groundwater (Singh, 2010; Vedula et al., 2005; Venot et al., 2010), stormwater management (Bressy et al., 2012; Luell et al., 2011) and rain water harvesting (Adler et al., 2011; Amin & Han, 2011).In India due to uneven distribution of rainfall and due to poor irrigation management some areas of country have water shortage issues while other regions have the water logging and secondary salination issues. The rapid urbanization, hasty population and climate change are the important parameters which affects and accelerate the water scarcity issues (Singh, 2012). Indian government has launched the river linking project to ensure the perennial water availability in rivers. Also the government emphasizes to practice the sustainable irrigation methods. The consumptive use is an indicator which shows the net amount of water being utilized by plant throughout its life span. The study of consumptive use and water available is also important to estimate the water requirement and accordingly plan and develop the water resources(Tian et al., 2015).

Starr & Levison(2014)studied the consumptive use for different crops for Whiteman's creek watershed in Canada. The authors introduced the concept of virtual water (VW), blue water term was used for ground or surface water and green water is nothing but soil-water. The authors carried a study over a 398

km^{2}watershed and summarized the conclusions indicating crops and their respective consumptive use. Behera & Sharma(2014) carried a study to estimate the water use efficiency of wheat crop. Authors carried a field experiment on different resource conservation technique and the results shows water use efficiency under furrow irrigated raised bed was more than conventional flat bed. Bennett & Harms(2011)estimated the water required by crops and respective crop yield. Authors carried an experiment for major irrigated crops in Southern Alberta, mathematical model was developed to estimate water use and crop yield. The results of work were more encouraging and those were used by water managers and economist to develop the water resources in Southern Alberta.Birhanu et al., (2019) conducted an experimental work in Southern Mali to manage rainfed agriculture in semiarid region and also to study the effect of landuse pattern on the consumptive use of water. The authors carried an experimental analysis over the period of 34 years (1980-2014) and results were more encouraging and helpful for water management.

The objective of present work is to correlate the water yield and consumptive use for Ner watershed. The SWAT model and Modified Penman Method (MPM) was used to achieve the set objective. The meteorological data for period (2000-2014) was used, for MPM data from India Meteorological Department (IMD) for same duration was used.

Study area

The present study was conducted at Ner watershed located near Ner village in southern part of Satara district of Maharashtra state, India. The Ner village is 36 km east from Satara city (Fig.1). The average elevation of study area is 800 m and it lies in latitude 17^{0}43' N and Longitude 74^{0}18'E. The total area of Khatav taluka is 1358 sq.km, out of this small watershed (10792 ha) near to Ner dam was considered for study. The study area has been categorized as semi-arid (CGWB 2017) and has average annual rainfall 554 mm. The study area is mostly dry and receives its major portion of rainfall from return monsoon (October-December). Daily variation in temperature was observed as maximum temperature 44^{0}C in month of May and minimum 8^{0}C in December. The average wind speed observed in study area is 7.4 Km/hr.

The population of Khatav taluka as per last known census (2011) is 2,75,187 and population of Ner village is 2000. The Ner dam and Yerala river are the two important water sources of study basin. Ner dam is medium scale project having 154.10 km^2 catchment area, 0.5 TMC gross storage capacity. The landuse of study area shows mainly agriculture (7598 ha) (Fig.4) then urban area and bare land. The main crops were observed in study area namely Soyabin, Jowar, Onion and Sugarcane

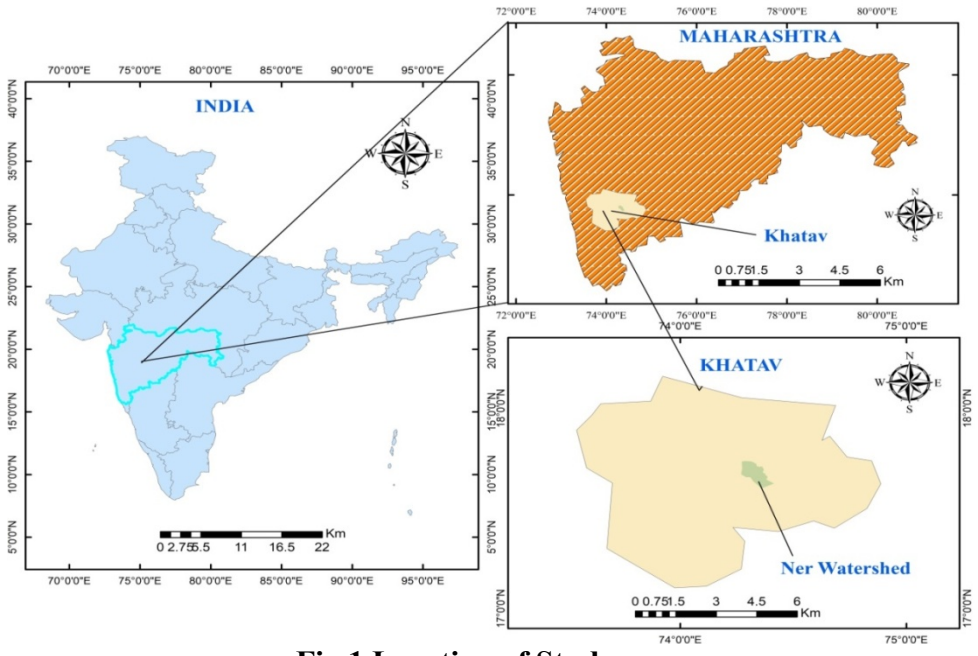


Fig.1 Location of Study area

Materials and Methods

Forpresent work, the objective was to correlate the water yield and consumptive use (C_u) or Evapotranspiration (ET). To estimate evapotranspiration two methods were used, the hydrological model SWAT developed by US agricultural department and Modified penman method (FAO)were used (Fig.2). The gridded meteorological data for period (2000-2014) was used to process SWAT model, the actual landuse and irrigation data was collected from Ner irrigation department.ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) global module (003) was used to obtain digital elevation map from NASA web site (search.earthdata.nasa.gov) and used for delineation process.

SWAT model

SWAT (Arnold et al., 1998)model was developed by United States department of agriculture.

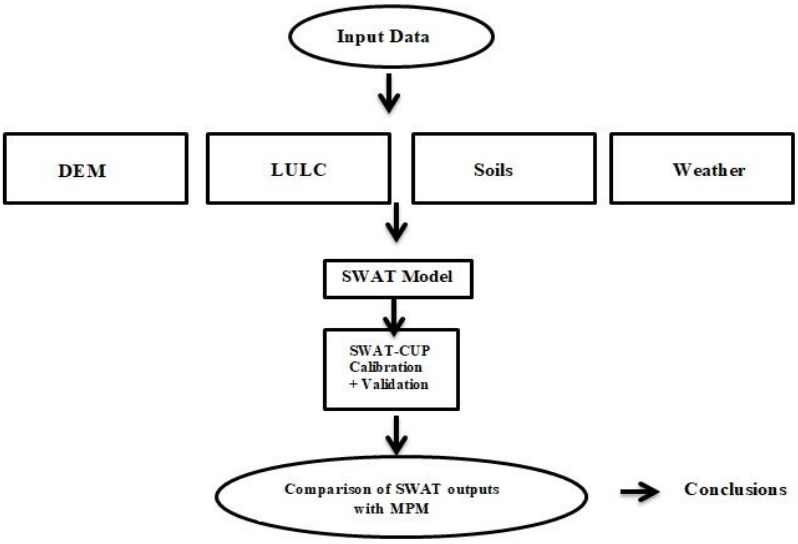


Fig.2 Methodology Used

It is a agro-hydrological, physical based, semi distributed simulation model mostly used for surface water modeling. The SWAT model has been used since last couple of decades for simulating runoff and sediment yield and to predict/estimate the impact of Land use/Land cover on hydrology of area (Fig.4). The model was used to estimate evapotranspiration and hence the water budgeting in study basins was easily carried out (Arnold et al., 2012). The model uses digital elevations of study area to analyze topographical features (Fig.3), soil map and meteorological parameters to process.

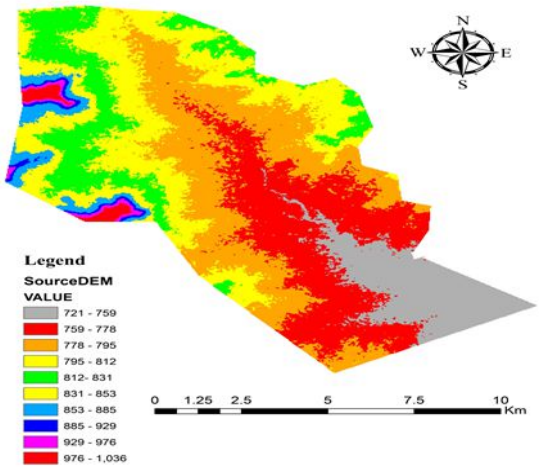


Fig. 3 Digital elevation model

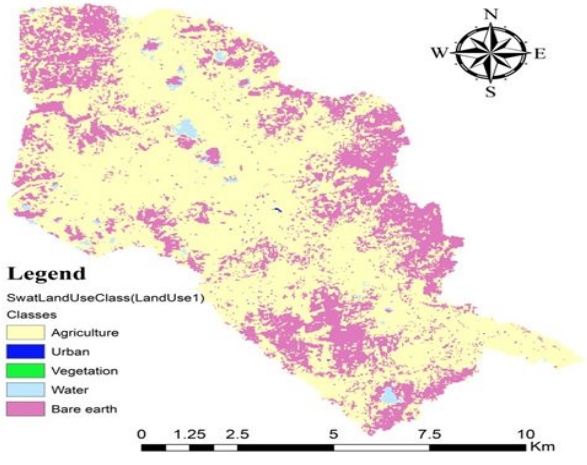


Fig. 4 Landuse map

Modified Penman method-

This is a better method to estimate evapotranspiration (ET_O) or Consumptive use (Cu) (FAO), if meteorological data like wind, relative humidity, solar radiation and maximum & minimum temperatures are available. The method uses almost all meteorological parameters and gives more accurate results. The formula for modified penman method is given as follows, eq. (1).

$$ET_0 = C[W.R_n + (1-W)\,F\,(U)(e_a - e_d)] \ldots\ldots\ldots [1]$$

Where,

ET_0 = Reference crop evapotranspiration (mm per day)

Rn = Net radiation in equivalent evaporation expressed as (mm/day)

W = Temperature altitude related weight age factor for the effect of radiation on ET_0.

F (U) = Wind function

U = Wind velocity in (Km/day) measured at 2m height

($e_a - e_d$) = Evaporation pressure deficit (m bar)

C= Adjustment factor (ratio of U day/Unight)

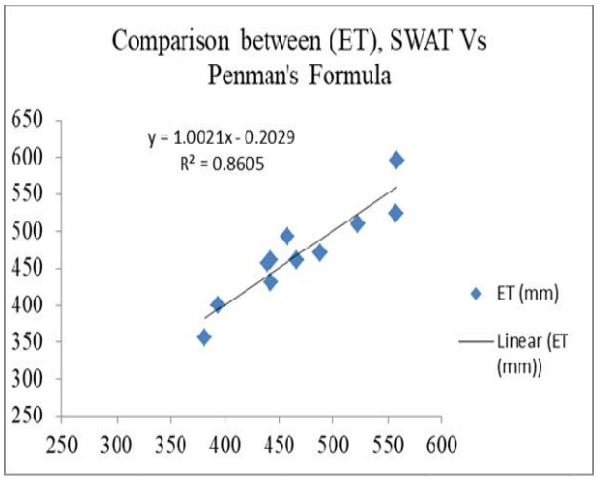
The Modified Penman's formula was used to validates the out comes from SWAT model. The evapotranspiration values obtained from SWAT shows good agreement with values obtained from MPM method.

Results and Discussions

In current study an attempt was made to correlate the water yield and consumptive use or evapotranspiration for Ner watershed, Khatav, Maharashtra, India. The methodology has been used; the SWAT model was run and calibrated for period (2000-2014). The evapotranspiration values obtained from SWAT model were validated by using Modified Penman method for evapotranspiration (Fig.6,7). The statistical parameter, coefficient of determination (R^2) yields (0.86), indicates acceptance of SWAT model. The graph between SWAT outputs and Modified Penman's formula (Fig.5), shows agreement between simulated and actual values. The water yield for study basin was calculated from SWAT model and can be used in future to plan irrigation. The hydrology of study area is shown in fig. (9), which elaborates many hydrological parameters for basins. The correlation between precipitation, water yield and evapotranspiration is shown in fig. (8).

Conclusions

This study was focused on water balance analysis of Ner watershed by using two powerful tools namely: SWAT and Modified Penman Method (MPM). The maximum crop water demand was observed at 2010 and it was 577 mm, similarly water yield at 2009 (657.39 mm) and Precipitation at 2009 (1270.2 mm) (Fig.8). The simulated values and observed values show good degree of fitness indicating acceptance of model. This study concludes that, SWAT model is highly efficient and can be used for similar watershed for water balance analysis study. The outcomes of this study will be helpful to researcher and decisions maker to solve the water shortage problems, also to design sustainable irrigation system.



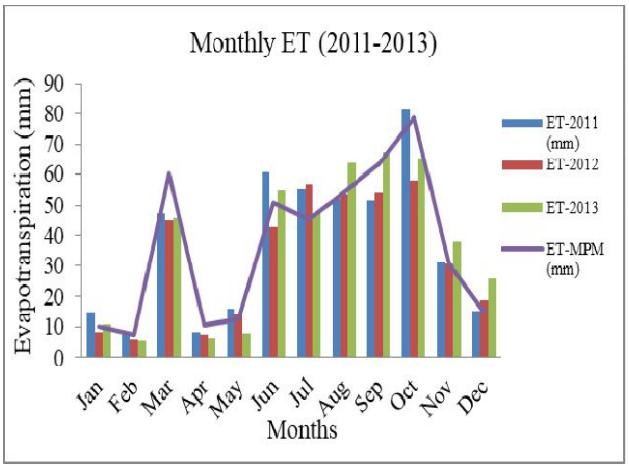


Fig.5 Evapotranspiration ComparisonFig.6Monthly Evapotranspiration

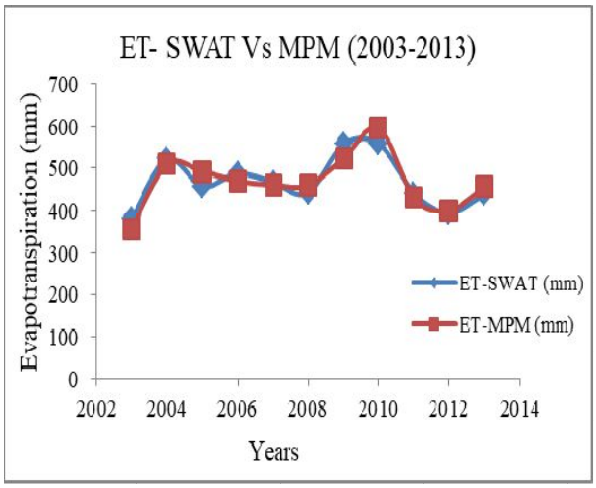


Fig.7 Evapotranspiration (2003-2013)

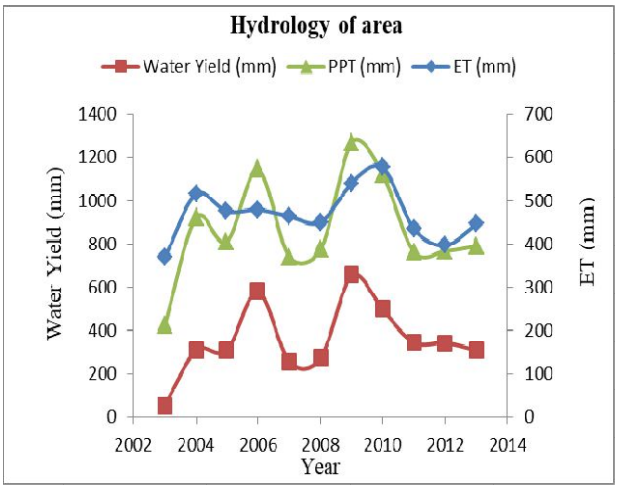


Fig.8Hydrological parameters

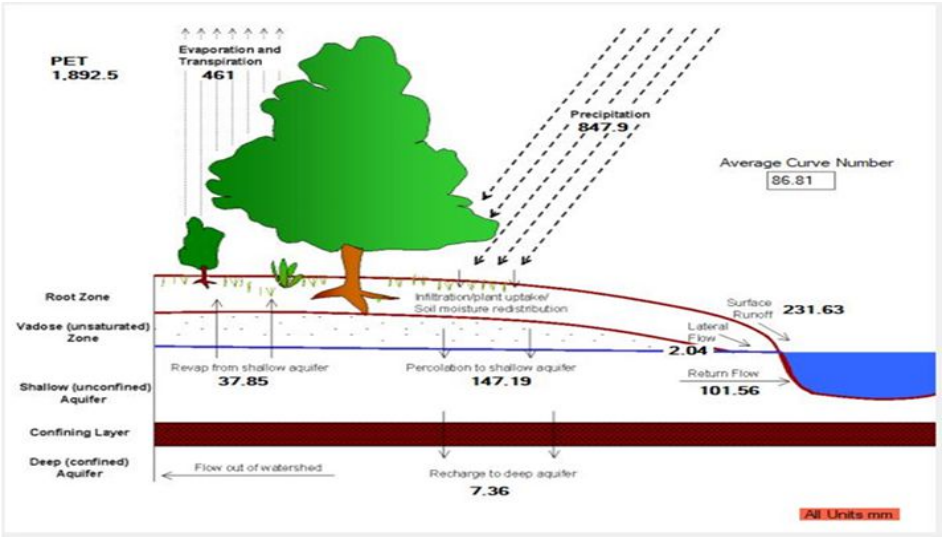


Fig.9 Hydrology of area-SWAT

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MODELLING AND ANALYSIS OF SPROCKET IN CAROUSEL SYSTEMS USING ANSYS

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ABSTRACT

Sprockets are extremely important part of the transmission of energy and movement in most of the industrial and manufacturing sector. They exist in different dimensions and materials. Here the sprocket is used in vertical carousel storage system which is mostly used as a space optimization technique in various industries. To efficient power transmission chain sprocket should be designed as per the requirement and loading conditions. This paper reviews the design of sprocket, analysis using FEA and using the results to select the material for the sprocket. The material used for the sprocket arenamely 16MnCr5- Steel and Grey Cast Iron. The analysis was done using Finite Element Analysis in Ansys R16.2 software. Comparison of stress and total deformation was done and on the basis of comparison optimum material for the sprocket was selected.

Keywords- *Carousel System; Optimum Space Utilization; Sprocket; Ansys (R16.2)*

1. Introduction

Stationary shelf storage system consists of shelves that goes from floor to a designated height. These are the most commonly used storage system because of their simplicity and the low-cost relative to its competition. But these systems come with some major difficulties. Items stored near to the top and bottom shelves are often hard to reach in order to unload the items. Anothermajor disadvantage is that heavy items cannot be stored in the top shelves because while unloading accident is prone to take place. Therefore, a solution to these problems is constructing a rotating shelves system, so that we can load the items wherever we want. A vertical carousel storage system occupies less floor space and instead utilizes more vertical space. The shelves or racks are rotated with the help of chain and sprocket drive and a suitable motor is used for supplying the power to the mechanism. The whole system is mounted on a solid frame structure. Roller chain drive is recognized to be one of the most effective forms of power transmission in mechanical systems. It has a basic feature with a constant ratio becauseof no slip-page or creep. Roller chain drive is generally suitable for the transmission under a slower speed due to its polygonal action and meshing impact.[1] Also, chain drives provide a high transmission efficiency of up to 98%. Chain sprocket is one of the important components of chain drive for transmitting power from one shaft to another. To ensure efficient power transmission chain sprocket should be properly designed and manufactured. There is a possibility of weight reduction in chain drive sprocket.[2] A sprocket is a profiled wheel with teeth, or machine gear-pieces, that work with a chain, track or other punctured or indented material. The name 'sprocket' applies for the most part to any wheel whereupon outspread projections connect with a chain disregarding it. Sprockets are generally used to transmit power with the help of a chain drive. The sprocket is an extremely imperative part in the transmissionof energy and movement. They exist in different measurements, teeth number and are made ofvarious materials. By and large sprockets are made of mellow steel.[3] Here, in this paper, wehave analysed the sprocket for 2 materials, 16MnCr5-Steel and Gray cast iron.

Methodology

1.1. Vertical Carousel Storage System

A 3D model of the vertical carousel storage system was built in Solidworks software as shown in fig. The dimensions are as follows height of 3000mm and base of 1500*1000mm. the storage system have in total 12 trays connected to the chain. The chain is mounted on the shaft which is driven by the induction motor. The material used for the frame and trays is AISI 1010 Steel, hot rolled. These systems can hold up to 30kg on one shelf, can reach over 10m tall, automation controlled, and

fully enclosed. The weight of each tray, frame and hole assembly was calculated to be 12.267kg, 96.281kg and 265.27kg respectively.

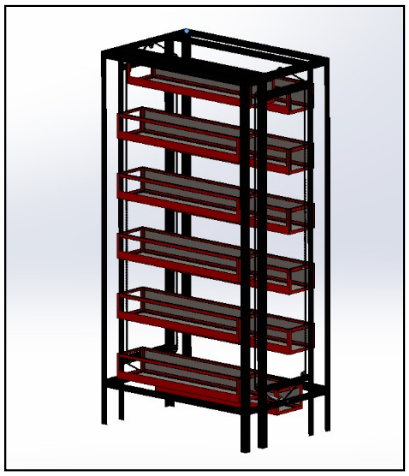

Fig.1. Vertical Carousel Storage System

2.2 Analysis of Sprocket

A 3D model of sprocket was built in CATIA software as shown in fig 1. The dimension of 3D model had pitch circle diameter 76.35mm, top diameter 86.033mm, roller seating radius 5.16mm, root diameter 66.03mm, tooth side radius 15.875mm, tooth side relief 2.38mm, sprocket thickness 9.625mm and overall thickness of body 40mm. The outer and inner diameter of spline shaft hole were 25mm and 22mm respectively. The geometry was saved in (.igs) format and exported to ANSYS software for finite element analysis. In the inputs we applied forces normal to the face of teeth which would be in contact with chain. Here we have 5 teeth in contact with chain and each tooth has force of 706.32 N acting on it. We have also applied angular velocity of 23.25 RPM. A fixed support is applied at centre of sprocket .

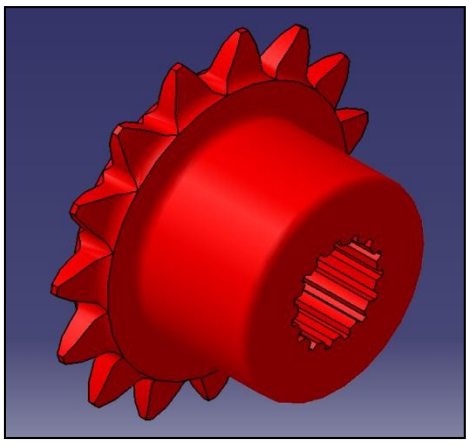

Fig. 2. 3D model in CATIA

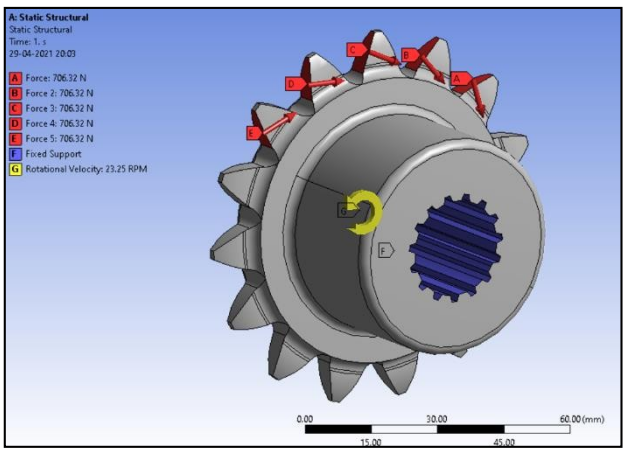

Fig. 3. Forces Applied on teeth andangular velocity

Table 1. Properties of Material

Properties	16MnCr5-Steel	Gray Cast Iron
Density(kg/m^3)	7700	7200
Young`s Modulus (GPa)	200	110
Poisson`s ratio	0.3	0.28
Bulk Modulus (GPa)	166	83
is to analyse Shear Modulus(GPa)	76.92	42.97

Ultimate Tensile Strength(MPa)	880	240
Ultimate Shear Strength (MPa)	1160	610

After the geometry optimization, two different materials were assigned to 3D model in ANSYS. The two materials considered for analysis were 16MnCr5-Steel and Gray Cast Iron.

2.2.1. Mesh Generation

The main purpose of finite element analysis is to analyse 3D model accurately. For this it is necessary to convert it into finite elements. The more are number of elements more is the accuracy. The meshing part was carried out and number of nodes formed were 575095 as shown in fig 2. The meshing was carried out in hex dominant manner, so most of the elements were quadrilaterals and few were triangles.[6]

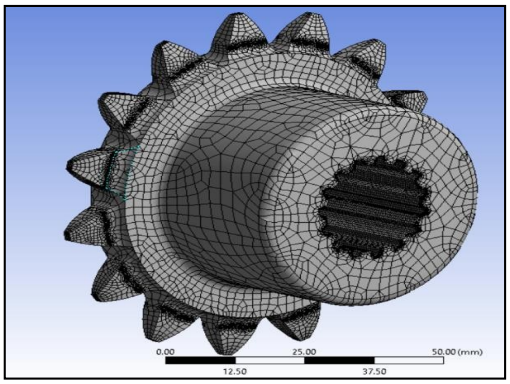

Fig. 4. Mesh Generation ofSprocket

3.Result

On the basis of analysis of sprocket, it was observed that sprocket made out of two different materials is safe as total maximum stress is within the limit of two materials which are Gray Cast Iron and 16MnCr5- Steel which are shown in fig. 5.a, 5.b and fig. 6.a, 6.b respectively.

Material 1: Grey Cast Iron

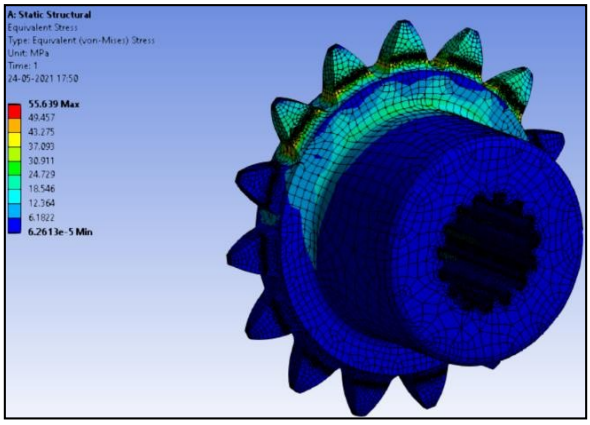

Fig. 6.a. Equivalent Stress for 16MnCr5- Steel
Maximum value is observed as 56.037 MPa

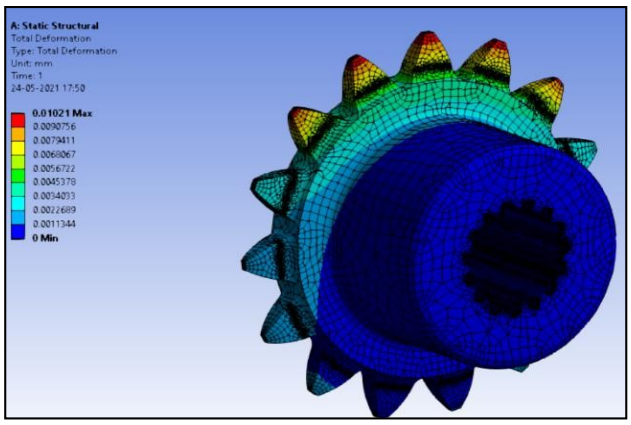

Fig. 6.b Total Deformation for 16MnCr5- Steel
Maximum deformation was observed as 0.0056711 mm

Conclusion

The sprocket was simulated and analysed by using finite element analysis software ANSYS. Grey Cast Iron and 16MnCr5-Steel were the materials selected for analysing the sprocket. Total deformation and Equivalent stress were obtained for both the materials. It can be observed from the results that the minimum deformation occurred in the case of 16MnCr5-Steel and minimum stress occurred in the case of Grey cast iron. It can also be noted from the results that the maximum value of stress and total deformation is almost equivalent and hence any one of the materials can be used for manufacturing the sprocket for vertical carousel storage system. For future works, simulation of the sprocket of same or different dimensions as compared to the model used in this paper can be carried out with different materials and the analysis of its performance at various conditions is possible.

Acknowledgement

We take this opportunity to express a deep sense of gratitude to our Head of Department and our Guide Dr. R.R. Chaudhari for cordial support, valuable information, resources & guidance which helped us in completing the task through various stages.

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DESIGN AND DEVELOPMENT OF PLANETARY GEARBOX TWO STAGE GEARBOX FOR AUTOMATED GUIDED VEHICLE

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ABSTRACT

Industrial automated guided vehicles are facing various problems and defects due to simple gear drive. The simple gear drive results in low torques and efficiency. In this paper a two stage Planetary gearbox is design for compact AGV's as per rated power and high torque to be transfer which will give high torque output and maximum efficiency. Also CAD model is made in Catia V5 software for further manufacturing process along with various calculations like gear ratios, velocity ratios, and torques ratios has been done. Simulation of output torque has been done on solid works with different speed inputs.

Keywords: *Catia V5, Solid works, planetary gears, gear trains, spur gears, Agv.*

1. Introduction

Planetary gear systems normally consist of a centrally pivoted sun gear, a ring gear, and several planet gears found between the sun gear and ring gear. Now, industrial applications demands high torque in compact (a high torque/volume) and light (a high torque/weight ratio) package. In planetary gears, torque density can be increased by adding more planets through multiple gear mesh points. This means a planetary gear with say three planets can transfer three times the torque of a similar sized fixed axis ―standard spur gear system.The applied load to planetary gears are distributed onto multiple gear mesh points means the load is supported by N contacts (where N = number of planet gears) increasing the torsional stiffness of the gear train by factor N. Hence it lowers the lost motion compared to similar size standard gear trains. High rotational stiffness is important for applications with positioning accuracy and repeatability requirements; especially under fluctuating loading conditions. Hence planetary gears are used for such applications in automation. Added inertia results in an additional torque/energy requirement for both acceleration and deceleration. The smaller gears in planetary system result in lower inertia. Compared to a same torque rating standard gearbox, it is a fair approximation to say that the planetary gearbox inertia is smaller by the square of the number of planets. Again, this advantage is rooted in the distribution or branching of the load into multiple gears meshes locations. In the next portion the objective of the project and methodology is explained.

1.2 Methodology

Firstly to start designing the gearbox the power obtained and output parameters from the motor is needed. The motor used is EMRAX 208 which is an AC synchronous motor with 3000 rpm. The maximum rated power output of the motor is 30 kW with torque supplied is 1.85 N-m. For achieving the desired acceleration and speed at the output of gearbox various calculations are done and thus the transmission ratio for the system can be obtained.
This arrangement gives the gear ratios of 3:1 or more and is relatively simple to implement. The design procedure for the gears is carried out in accordance with the design data book and the formulae's and procedures are referred from the standard books.

1.3 Research Objectives

1. To design a compact gearbox with two gears set for electric drive.
2. To perform various speed inputs on the input shaft for achieving various gear reduction ratios.
3. Determining the efficiency of the gearbox and output torque calculations.
4. Performance analysis on gears set to determine the design safety.

1.4 Research Questions

Based on the formulated research objectives, the research questions were drawn:

1. Does the planetary gearbox can be used for any type power transmission?
2. What is the efficiency of power transmission between spur gears and helical gears?
3. How the planetary gearbox does helps in reduce the backlash error?

2. Material Selected

Part	Material	Safe Stress N/mm^2	Brinell hardness number	Flexural endurance N/mm^2
Gears	Semi-steel	200	200	126
Carrier	Steel	245	150	252
Housing	Cast steel	196	240	420
Shaft	Alloy steel case	40	110	65

3. Gearbox Dimensions

The gear box is going to fit in the agv body withconnections with the electric drive so the available dimension for designing the gearbox have been taken from the model agv as shown in the figure. Accordingly the dimension of gearbox has been determined.

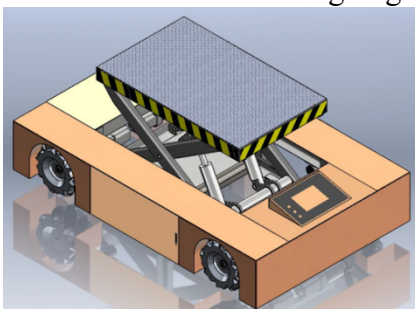
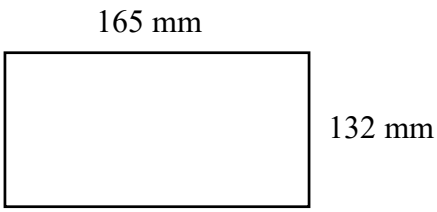


Fig. 1 Project AGV



Work volume available

Model dimensions:

Overall length of gearbox	135 mm
Output flange	156*156 mm
Stage housing diameter	132 mm

Design parameters of spur gears used

Gear	No of teeth's	P.C.D (mm)	O.D (mm)	Face width	Shaft dia	unit
Planet gear	50	50	52	10	15	6
Ring gear	100	126	130	12	-	2
Sun gear	25	25	27	10	12	2

Lifetime calculation of ball bearings

1. Radial load: Fr= 306 N
2. Speed of output shaft: n = 1000 rpm
3. Distance between ball bearings: a = 8 mm
4. Distance between ball bearing A and radial load: b = 14 mm
5. Ball bearing NSK 608 DU:
6. Dynamic load rating C = 3300 N
7. Static load rating C0= 1370 N

Calculation

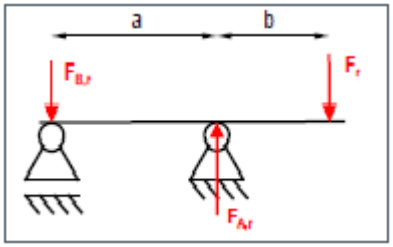


Fig.2 Load sketch for bearing life

- Radial load @ A: FA,r= Fr·(a+b)/a = 306·22/8 = 841.5 N
- Equivalent load: P = FA,r= 841,5 N
- Lifetime: Lh10= (C/P)3·106/n/60 = (3300/841,5)3·106/100/60 = 10000 h

4. Determination of Reduction ratio for each stage.

The reduction ratio for the given composite arrangement is product of ratios of each stage. Total reduction ratio, R = R1*R2*R3*……Rn … (1) Where, R1, R2, R3 …Rn represents the reduction ratios of each stage of gear train connected in composite. For easier computation it is preferred that the planetary gear ratio shall be an exact integer (3, 4, 6 ...) the reduction ratio in planetary gear train is determined as below:-

$$\text{Ratio} = \frac{\text{P.C.D of Ring gear} + \text{P.C.D of Sun gear}}{\text{P .C.D of Sun gear}}$$

$$\text{Ratio} = \frac{Z2 + Z3}{Z2}$$

For stage 1,
Ratio = R1= 5. Similarly for second stage R2= 5. And R3 for intermediate reduction =

Z1+Z2/Z1= 5 therefore total reduction comes to be = **15.504**.

5. Development of gearbox components

Construction of gear box:

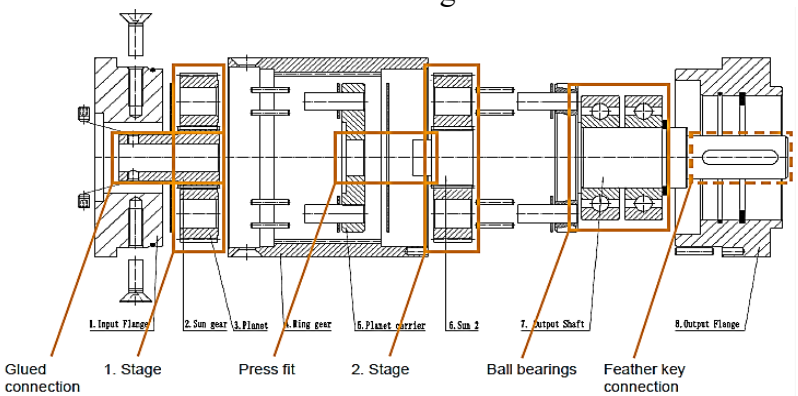


Fig. 3 Cross-sectional view of gearbox

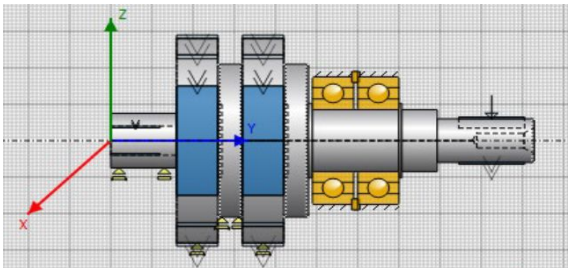


Fig. 4 Stage assembly with bearings

Assembly of gear sets:

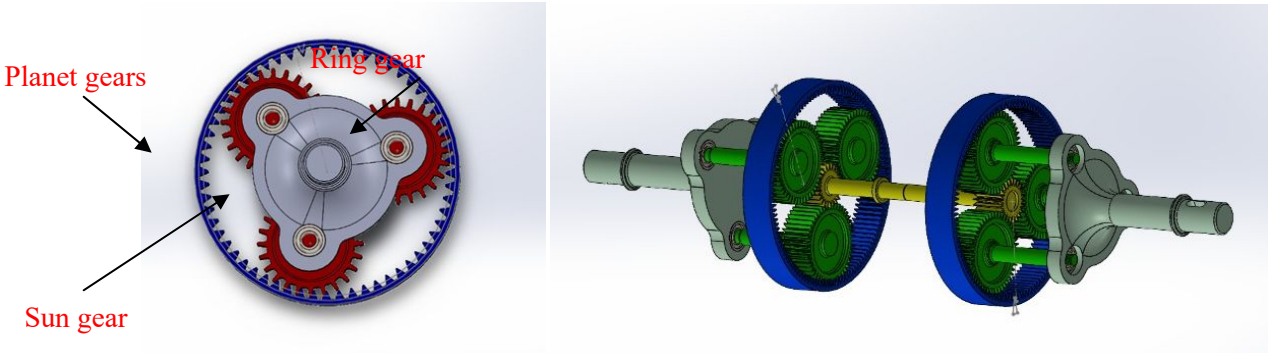


Fig. 5 Gear assembly of two stage with intermidiate shaft.

Planet Carrier and Output Carrier:

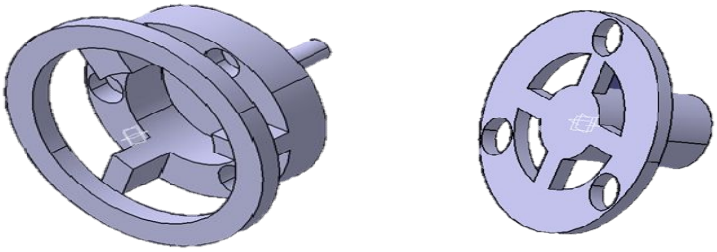


Fig. 6 Three planet gearscarrier

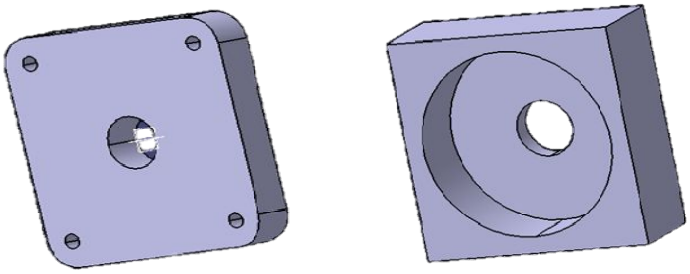


Fig. 7 Motor attachment and output flange

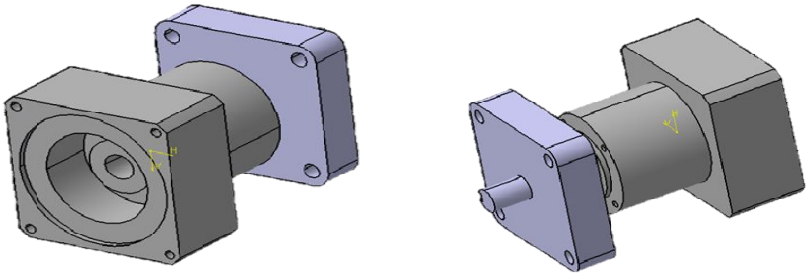


Fig. 8 Model Assembly of gearbox with front view and rear view

6. Calculated gear box specifications

The final made gearbox has been simulated for various input parameters and tested for minimum and maximum load conditions and accordingly the standard specifications have been determined as follows.

Reduction ratio	-	15.504
No of stages	-	2
Rated output torque	Nm	24.6
Max. output torque	Nm	39.4
Rated input speed	Rpm	3000
Max input speed	rpm	5900
Backlash	°	0.52186
Efficiency	%	94.483
lifetime	h	10000
Max axial forces	N	430
Max radial force	N	1080
Gearbox inertia	Kg/mm^2	5.4002
Ambient temperature	°C	-15 - +90

Simulations and mathematical calculations

	Speed rpm	Torque N-m
Input	3000	1.85
	225.75	24.065

Bearing life	Lifetime/h
Bearing B1	40320.883
Bearing B2	10110.684

7. Results

1. The calculated static load on the tooth and the maximum or limiting load of wear are greater than the dynamic load, therefore the design is safe.
2. After simulation the reduction speed of output shaft is near to the threotical speed calculated.

8. Conclusion

The gearbox designed was checked for dynamic and wear load and stimulated for various speed inputs and thermal stress on Catia and Solid works. Thus it is preferred for manufacturing the two stage planetary gearbox for high output torques and speed reductions. For future works, it is recommended to stimulate the gearbox with different gear ratios and analyze the performances at various conditions.

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ENTROPY– EDAS APPROACH FOR THE SELECTION OF CONVEYOR BELT MATERIAL

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ABSTRACT

Belt conveyor is widely used conveyor system in industry. Belt is only moving element of conveyor system. Belt always experiences dynamic forces while in motion as well as impact forces at loading and unloading points. So, it is very important to select a proper material for belt for smooth and efficient operation. This paper presents multiple criteria decision making approach for conveyor belt material selection. Entropy method is utilized to calculate criteria weights. Evaluation based on Distance from Average Solution method is applied to select the best suitable alternative. Ten belt materials are evaluated using five criteria. Obtained results are very much similar to that of past researcher.

Keywords: *Conveyor Belt, EDAS, ENTROPY, Multiple Criteria Decision Making (MCDM).*

1. Introduction

Conveyor belt system is the most commonly used material handling equipment. They are quick in operation, more efficient and cheaper than other material handling equipment. Conveyors are usually used to transport bulky goods in mass quantity over a long distance. Variety of conveyors are available, in different designs as per requirement. Belt is the main member of any conveyor belt system. It is the only moving element, having direct contact with transporting material. Belt has high possibility of getting damaged during operation. Breakdown of conveyor system can disturb manufacturing schedule, resulting in loss of time and money. Therefore, selection of conveyor belt material is a crucial task. Variety materials are available in the market from rubber, nylon, leather to high strength Kevlar. Selection of conveyor is based requirements of industry, like process requirements, product requirements, speed, power requirements. Process requirement involves factors like transportation distance, space available, temperature etc. product requirement involves various factors related to product, like size and shape, quantity and weight of product. Cost is also one of the important criteria, as installing conveyor system requires huge investment. Evaluation based on Distance from Average Solution technique is used to rank alternatives and to select the optimum belt material alternative. Ten aramid materials are evaluated using five criteria. Criteria weights are obtained by applying entropy weight calculation method.

2. Review of Literatures

A study (Yazdani, Torkayesh, Gonzalez, &Otaghsara, 2020) proposed MCDM model to evaluate renewable energy sources. Entropy was used to find criteria weights and EDAS was applied to prioritize renewable sources. Ranking was compared with other methods and found close correlation with MABAC, WASPAS, COPRAS and MOORA. Nguyen, Dawal, Nukman, Rifai, & Aoyama(2016) presented an integrated fuzzy ARAS andAHP model for conveyor equipment assessment. Triangular fuzzy numbers were used to transform linguistic terms in AHP to obtain weights and then alternative weights were evaluated using ARAS method. Obtained results were similar to that of fuzzy TOPSIS method. Mitra (2019) applied EDAS method for selection of the best cotton fabric from thirteen fabrics. Sensitivity analysis was conducted by altering criteria weights. Comparison with TOPSIS and Thermal resistance ranking was made using spearman rank correlation analysis to state stability and robustness of method. A study (Karande& Chakraborty, 2013)assessed material handling equipment using utility theory approach. Four alternatives were evaluated using six criteria. AHP used to calculate criteria weights. Comparison was made with some other methods like VIKOR PROMETHEE, ELECTRE. Robustness of the method was checked using sensitivity analysis.A fuzzy AHP method for the selection of material handling equipment inFMS studied in (Kumar & Raj, 2016). Three different material handling

equipment were assessed against three criteria. Author also discussed some limitations of fuzzy AHP method. Fan, Li, & Wu (2019) used EDAS cross efficiency evaluation method for technology selection. Twenty-seven robots were evaluated using four parameters. Rank correlation result suggested that ranks obtained by EDAS and past researchers method were quite similar. An integrated approach, MACBETH-EDAS applied for evaluation of steam boiler(Kundakcı, 2018). Problem comprised of five boiler alternatives and six criteria. Among six criteria one was subjective criteria. Attributes weights were calculated using MACBETH technique and then weights were used to obtain ranking of alternatives using EDAS. Maksimović, Brzaković, Grahovac & Jovanović (2017) used EDAS approach for evaluation and the selection of appropriate transportation system at mine. Four different types of alternatives were analysed using five criteria. Almulhim (2020) presented Entropy and EDAS approach for the evaluation of insurance industries performance. Eight insurance performance indicators were used to analyse twenty-seven alternatives. Sensitivity analysis was conducted to examine robustness of the method. Vatansevera & Akgűl (2017) evaluated website performance using integrated entropy and grey relational analysis approach. Criteria weights were obtained using entropy and grey relational analysis method was applied to rank alternatives.EDAS technique integrated with fuzzy set theory for site selection problem applied presented by (Kahraman, Ghorabaee, Zavadkas, Onar, Yazdani &Oztaysi, 2017). Problem comprised of three alternatives and three criteria. Sensitivity analysis by changing weights was conducted to show the robustness of method. Chatterjee et al. (2018) proposed hybrid design of engineering (DOE) and EDAS approach for industrial material selection problem. Two real time material selection problems were solved to demonstrated proposed approach. Obtained results were similar with past researchers. Results indicated that the proposed hybrid approach was robust and very much suitable for solving material selection problems. Bhattacharya, Sarkar & Mukherjee(2004) applied analytical hierarchy process for evaluation of a conveyor belt material. The AHP algorithm was coded in FORTRAN language. Four material alternatives were evaluated using four criteria. Mathew &Sahu(2018) compared MCDM techniques for conveyors selection and automated guided vehicle selection. They considered CODAS, EDAS, WASPAS and MOORA for solving selection problems. Similarity in ranking was checked using spearman rank correlation coefficient method. Ranking was also compared with TOPSIS and ELECTRE methods. All methods produced similar ranking results. Entropy and TOPSIS approach presented for the selection of energy efficient materials (Bhowmik, Gangwar, Bhowmik & Ray, 2018). Nine various criteria were considered for the study. Nine energy efficient materials were evaluated.

1. MCDM Formulation

3.1 Entropy Method

The procedural steps for entropy method are as follows described in (Kahraman, Ghorabaee, Zavadkas, Onar, Yazdani &Oztaysi, 2017):

Step 1: Developa decision matrix by arranging alternatives row-wise and criteria column-wise. Let, there are n alternatives and m criteria. Therefore, n×m performance matrix can be obtained, where x_{ij} indicates performance rating of alternative A_i with regard to criterion C_j.

Step 2: Decision matrix (X) can be normalised for each criterion as:

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}, \qquad i = 1, 2, \dots, n \qquad (1)$$

Step 3: Evaluate entropy measure using equation given below:

$$e_j = -k \sum_{i=1}^{n} P_{ij} \ln(P_{ij}) \qquad (2)$$

where, k = Entropy constant which guarantees $0 \leq e_j \geq 1$ and can be calculated as:

$$k = \frac{1}{\ln(N)}$$

Step 4: The degree of divergence (d_j) of the average intrinsic information contained by each criterion can be calculated as:

$$d_j = 1 - e_j$$

Step 5: Weight for each criterion (w_j) is calculated as:

$$w_j = \frac{d_j}{\sum_j d_j}, j = 1, 2, \dots, m$$

3.2 EDAS Method

The Evaluation based on Distance from Average Solution uses two measures PDA and NDA solutions. Higher value of PDA and/or lower value of NDA represents that the solution is better than average solution (Yazdani et. al., 2020). Following is the procedure for EDAS as defined by Sudha (2019):

Step 1: Select alternatives and important criteria to construct decision matrix $D[x_{ij}]$.

Step 2: Obtain the average solution for each criterion using equation:

$$AV_j = \frac{\sum_{i=1}^{n} x_{ij}}{n} \quad (1)$$

Step 3: Calculate positive distances from average (PDA) solution using following formulae:

$$PDA_{ij} = \frac{\max\left(0, (x_{ij} - AV_{ij})\right)}{AV_j} \quad \ldots (2)$$

for beneficial criteria

$$PDA_{ij} = \frac{\max\left(0, (AV_{ij} - x_{ij})\right)}{AV_j} \quad \ldots (3)$$

for non-beneficia criteria

Step 4: Calculate negative distances from average (NDA) solution using following formulae:

$$NDA_{ij} = \frac{\max\left(0, (AV_{ij} - x_{ij})\right)}{AV_j} \quad \ldots (4)$$

for beneficial criteria

$$NDA_{ij} = \frac{\max\left(0, (x_{ij} - AV_{ij})\right)}{AV_j} \quad \ldots (5)$$

for non-beneficial criteria

Step 5: The weighted sum of PDA is obtained as:

$$SP_i = \sum_{j=1}^{m} w_j PDA_{ij} \quad (6)$$

Belt Material	MWT (N/mm)	CT (mm)	ME (kN/mm)	BW (kg/m2)	C (RS)
M1	63	2.5	23	11.7	2255
M2	80	2.6	27	11.8	2345
M3	100	2.7	31	12	2436
M4	125	3.5	37	12.8	3157
M5	160	3.6	44	16.2	3247
M6	175	3.7	49	16.4	3338
M7	200	3.8	54	16.5	3428
M8	225	4.2	60	16.9	3789
M9	250	4.5	66	17.3	4059
M10	315	5	80	17.9	4510

Table-1 : Initial Decision Matrix [1]

where w_j represents relative weight of j^{th} criterion.

Step 6: Calculate weighted sum for NDA using equation given below.

$$SN_i = \sum_{j=1}^{m} w_j NDA_{ij} \quad (7)$$

Step 7: Values of SP_i and $SN_i$are normalizedusing following equations:

$$NSP_i = \frac{SP_i}{\max_i(SP_i)} \quad (8)$$

$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)} \quad (9)$$

Step 8: Calculate appraisal score (AS_i) for all alternatives using following formula:

$$AS_i = \frac{1}{2}(NSP_i + NSN_i) \quad (10)$$

Where $0 \leq AS_i \leq 1$

Step 9: Rank alternatives in the descending order of the appraisal score. The alternative having the highest appraisal score is the most suitable choice.

4. Illustrative Example

This paper demonstrates the use of Entropy-EDAS approach for conveyor belt material selection problem. Athawale& Chakraborty(2010) applied AHP-TOPSIS approach to evaluate aramid materials for conveyor belt. Problem comprised of ten belt material alternatives, which are evaluated using five conveyor belt attributes. Maximum working tension (MWT), carcass thickness (CT), modulus of elasticity (ME), belt weight (BW) and cost (C) are the selected attributes. Among all above attributes, carcass thickness and cost are two non-beneficial attributes and remaining are beneficial attributes. Table-1 shows quantitative data for conveyor belt material selection problem.

4.1 Entropy Method

All selected attributes have different units, so their values are first normalized using equation (1). Using normalized values, entropy value for each criterion is calculated using equation (2). Then degree of divergence is obtained using equation (3). Finally, weights are evaluated using equation (4). All the obtained values are shown in Table-2.

Criteria	MWT	CT	ME	BW	C
e_j	0.9553	0.9896	0.9704	0.9942	0.9896
d_j	0.0447	0.0104	0.0296	0.0058	0.0104
w_j	0.4429	0.1034	0.2931	0.0571	0.1034

Table-2 : Entropy, Degree of Divergence and Weights

4.2 EDAS Method

Table-3 shows the average solution, obtained using equation (5). Then PDA for beneficial and non-beneficial criterion is calculated using equation (6) and (7), respectively. Similarly, NDA values are calculated using equation (8) and (9). Obtained values of PDA and NDA Then weighted sum of PDA and NDA are evaluated using equation (10) and (11), respectively and shown in Table-4.

. **Criterion**	MWT	CT	ME	BW	C
Average	169.3	3.61	47.1	14.95	3256.4

Table-3 : Average Solution

Belt Material	**SP_i**	**SN_i**	**NSP_i**	**NSN_i**	**AS_i**	**Rank**
M1	0.0796	0.4206	0.1383	0	0.0692	10
M2	0.0732	0.3525	0.1272	0.1620	0.1446	9
M3	0.0664	0.2766	0.1154	0.3424	0.2289	8
M4	0.0154	0.1756	0.0267	0.5824	0.3045	7
M5	0.0006	0.0480	0.0011	0.8860	0.4435	6
M6	0.0263	0.0113	0.0456	0.9731	0.5094	5
M7	0.1211	0.0177	0.2104	0.9579	0.5842	4
M8	0.2221	0.0432	0.3857	0.8972	0.6415	3
M9	0.3230	0.0628	0.5611	0.8507	0.7059	2
M10	0.5757	0.0951	1	0.7738	0.8869	1

Table-4 : Weighted Sum of PDA and NDA, Normalised Values, Appraisal Score and Ranking

Calculated weighted values are then normalized using equation (12) and (13). Using these normalized values, appraisal score is calculated by equation (14). These obtained values are shown in Table-4. Finally, alternatives are arranged in the descending order.

5. Results and Conclusion

Rank	1	2	3	4	5	6	7	8	9	10
AHP-TOPSIS	M10	M9	M8	M7	M6	M5	M3	M2	M4	M1
Entropy-EDAS	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1

Table-5 Comparison between Methods

In this paper, we applied Entropy and EDAS approach for the conveyor belt material selection problem. Problem comprised of ten material alternatives and five criteria. The criteria weights are evaluated using entropy technique and then those weights values are used to obtained ranking using EDAS method. M10 is the best alternative according to Entropy-EDAS approach. M9 is the second best alternative and M1 is the worst alternative. Entropy-EDAS approach gives very much similar results as that of obtained by Athawale & Chakraborty (2010) using AHP-TOPSIS approach. Both results are shown in Table-5.

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EXPERIMENTAL ANALYSIS OF GREYWATER BY HYBRID ELECTROCOAGULATION PROCESS

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ABSTRACT

Water is the most important and amazing substance on the planet, both qualitatively and quantitatively, and is vital to the health and survival of all living species. The present study examines the multifariousness of the electrocoagulation process for greywater treatment with the hybrid coalescence of Al-Fe-Al-Fe-Al-Fe-Al-Fe and DC power supply is utilized to provide a current density of at 6V, 12V, and 24V for 60 mins and increased to 90 mins. The outputs of COD for 6V, 12V, and 24V are 82, 33.98, and 17.34 mg/lt, turbidity with 10.6, 5.54, and 3.7 NTU and TDS with 471, 82.72, and 71 mg/It. As a result, under optimum condition, the operating cost for greywater treatment by EC using 8 Al-Fe electrodes was found out to be Rs. 62.57/m^3 and Rs. 61.75/m^3 for Fe-Al and Al-Fe combination.

Keywords: *Greywater, Electrocoagulation, Electrode Configuration*

1. Introduction

Water is considered as most important essential and remarkable substance that exists on the earth both in qualitatively and quantitatively[1,6].But it is overused and wasted which ultimately is of no use as it may contain undesirable substances during its flow and gets contaminated. Many times it is observed that people use improper way for disposal of dirty and filthy water which leads to insanitation [2,9]. With civilisation, urbanisation and hiking population growth fresh water demand increased so that need for wastewater treatment too [3, 11]. It has been observed in last few years that excess use of water resulted in water scarcity, which has given scientists and researchers a specific goal for introducing effective, economical and eco-friendly technology for wastewater treatment for reuse and recycle of wastewater generated from domestic and industrial areas [4,12]. Wastewater (WW) is water of no use at a point where it loses its initial properties and becomes undesirable for further use. Depending on water characteristics wastewater is combined form of greywater and black water. Greywater is untreated wastewater which is collected separately from sewage flow that generated from kitchens, bathrooms, floor washes and laundry areas [1,5]. Greywater is generally comprised of 70% of total consumed water, 30% of organic matter and 9%-20% of nutrients which is expected to be less than black water comprised of major part of organic matter [7,13]. Greywater has higher quality than black water due to its low level contamination and higher potential for reuse [8,11].In many countries like India greywater along with black water is treated in single treatment unit which ultimately increases load on that treatment unit for which scientists and researchers has conducted various researches and studies using different technologies for greywater treatment individually [1,9]. There has been many biological chemical and physiochemical technology came forward for treatment of greywater independently. Biological technologies like rotating biological contractors (RBC), sequencing batch reactor (SBR), constructed wetlands, up-flow anaerobic sludge blankets (UASB) with some innovative technologies like membrane bioreactors and reed beds gave good and effective results in removing objectionable from high strength greywater [14]. Many chemical treatments like coagulation, ion exchange, and granular activated carbon investigated which gave effective results in removal of organics and pathogens from the greywater but failed to meet reuse and recycle criteria for high loadings [19]. In recent years many technologies have been investigated and studied for greywater treatment of which physiochemical treatment like electrocoagulation gave effective and economic results in removal of turbidity, TSS, organics and surfactants from greywater compared to that of biological and chemical treatments due to its large required area and retention time [7].

1.1. Electrocoagulation

In recent years, the EC process has been proved to be an effective alternative for removal of objectionable from the greywater [3,21]. Greywater has been treated using various methods of which electrocoagulation is one of the new emerging methods which remove pollutants from water using electric current and electrodes. Electrochemical treatment got great attention for wastewater treatment due to its high effectiveness, low maintenance and lesser need for labour. It offers an alternative to the use of chemicals to break pollutants for easy removal from variety of waste water [10]. The EC process mechanism consists of three steps: electrode oxidation at the sacrificial anode, gas bubble forming similar to hydrogen bubble formation at the cathode, and flocs formation due to coagulation ferment a sludge blanket that is eliminated by the filtration process [8].

2. Material and Method

2.1. Greywater characteristics and sampling

The characteristic of greywater depends on number of inhabitants, the age of inhabitant their lifestyle and living standards, quantity of chemicals used, residence time of greywater and water consumption patterns [3,4]. Greywater samples were collected from households at different locations. The greywater generated contributes mostly water from kitchen, laundries and toilets. Samples were collected with all care and stored at 4°C in polypropylene bottles until use and were analysed within 48 hours of collection. Before feeding electrocoagulation reactor with greywater, it is analysed and characterised in table 1

Table 1: Greywater characteristics

Parameters	Quality value
Colour	Blackish brown
Temperature	18-35°C
pH	5-12
TSS	557 mg/lit
Turbidity	252.8 NTU
TDS	1311 mg/lit
COD	460 mg/lit
Chlorides	726 mg/lit
Sulphates	263 mg/lit

2.2. Experiment setup

The treatment of greywater is carried in a laboratory scale batch reactor of size 30cm x 10cm x 20cm made up of glass material of thickness 0.5cm. An electrode sets of 8 aluminium and iron material of size 18.5cm x 5cm and thickness of 0.025cm. These electrodes were arranged alternatively and immersed in the effluent in set of 8 no's connected to Monopolar-parallel connection. The electrodes were supplied with DC power supply with variable voltages to run the rector.Subsequent to treating from electrolytic cell the water is passed from 2 cm hole opening at the 10 cm (H) through round channel bed having measurement 60 cm (H) with 12 cm (D) comprised of acrylic materials, with better sand of powerful size (0.2 to 0.4) mm at top followed by Granular coconut shell actuated carbon with rock of successful size (4.75 mm). The examinations were led with encompassing room temperature; greywater were delicately mixed at 100 rpm. The example was consistently observed at 60 min time stretch and went through 10 cm (H) of tank and last effluents were moved to filtration media by eliminating the accelerated flocs with stream rate 0.18 l/min persistently all through the cycle. The expulsion proficiency of every boundary was determined utilising condition [37].

2.3. Electrocoagulation procedure

Electrocoagulation reactor was fed with 4.5 litre of water which has aluminium and iron electrodes were used as hybrid combination and placed at a distance of 3cm in MP-P connection. Before feeding EC reactor greywater sample was stirred on magnetic stirrer for homogeneity to achieve high removal efficiency. A DC power supply is used to provide a current density of around 1 amp at 6V, 12V and 24V of voltages for 60 mins. Aluminium electrodes were used as sacrificial electrode rather than iron electrode, as residual ferrous ions are easily oxidises by air in EC reactor producing colour to water. Scum (colloidal particles) generated during process was removed by floatation, achieved by gas bubbles developed at cathode [16]. In EC process when electric current is passed through greywater in reactor, electrode metal

ions gets neutralised by ions of opposite electrical charges and makes pollutants unstable. Pollutants turns into stable precipitate on reaction with coagulant formed in water itself. Clear water is separated and sent to filtration tank [20]. After 60 min of process another batch of sample was processed at varying pH values for another 60 mins at 6V, 12V and 24V [15]. The EC process was carried at controlled room temperature and conditions required by it. During EC process samples from EC reactor was taken at regular intervals and analysed.

3. Results and discussion

EC process performance depends on many operational parameters such a pH of greywater, voltage and current density applied to EC reactor, conductivity of greywater, electrolysis time, type and size of electrode, arrangement of electrodes, distances between electrodes etc. are studied and investigated that factors influencing EC process are linked to (i) working condition like voltage or current and residence period, to (ii) greywater characteristics like pH, turbidity etc. and to (iii) specification of EC device and electrodes [32]. Experimental results are shown in table 2.

3.1.Effect of applied voltages and operating time

During entire EC process, current density and voltages along with operating time are most important parameters for controlling reaction rate inside the EC reactor. From table 2, it is investigated that Greywater when treated in different connection modes at different voltages for regular interval of time, shows hike in removal efficiencies. It was observed that increment in voltages hiked floc formation and increased removal efficiency.

Table 2: Experimental results for Greywater treatment by Electrocoagulation.

No. of sample collected = 10 Current density = 1.2 Amp Connection mode = MP-P Hybrid combo. = Al-Fe- Al-Fe- Al-Fe- Al-Fe							
Parameter	**Initial value**	**6V**	**% Removal**	**12V**	**% Removal**	**24V**	**% Removal**
pH	7.4	-	-	-	-	-	-
TSS (mg/lit)	557	212	61.93	29.79	94.65	14.6	97.38
Turbidity (NTU)	252.8	108.6	57.04	5.54	97.81	3.7	98.53
TDS (mg/lit)	1311	471	64.07	82.72	93.69	71	94.58
COD (mg/lit)	460	82	82.17	33.98	92.61	17.34	96.23
Chlorides (mg/lit)	726	72.9	89.95	25.11	96.54	12.9	98.22
Sulphates (mg/lit)	263	48.15	81.69	25.64	90.25	19.33	92.65

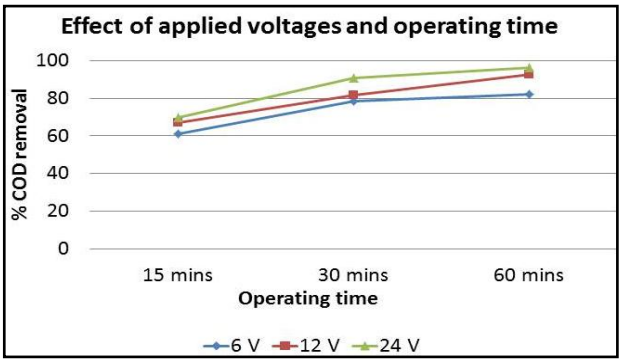


Fig.1: Effect of applied voltages and operating time.

However, after certain value of voltage dissolution of anode electrode stopped so as floc formation and also removal efficiency decreased with reasonable operating time, shown in fig.1 [24, 25].

3.2.Effect of electrode material

The EC reactor is constituted electrodes which plays a key role during EC process therefore it is given more concern. For best EC performance it is important to select appropriate electrode materials which are responsible to carry out all reactions in the rector [12]. There are many materials used as electrode of which electrodes typically made of stainless steel, iron and aluminium were given more attention as these electrode materials are economical, readily available and non-toxic resulting preferable efficiencies in EC process

[17, 33]. Hybrid combination of aluminium and iron electrode has proven best duo in giving maximum percentage of COD removal due to their reliability and availability [2]. Some studies have also proven that aluminium electrode individually can give higher removal efficiencies rather in any combinations [26]. Aluminium electrode is considered as pH neutraliser as it increases pH of greywater when it is acidic and decreases the same when greywater is alkaline and let performance go smooth [2].

3.3.Effect of electrode combination

The type of electrode influences the EC performance [35]. Generally, Aluminium and iron electrodes are utilised as electrode material due to their facile availability and non-toxicity. The tests performed utilised 8 aluminium and iron electrodes each arranged in Al-Fe and Fe-Al order in the prospect of high COD abstraction efficiency [35]. It was investigated that the entire EC process runs around the anode and the highest abstraction efficiency gained is thoroughly dependent on the type of material placed at the anode. Fig2 shows that the Al-Fe coalescence of 8 electrodes gave the highest COD abstraction efficiencies than the Fe-Al amalgamation.

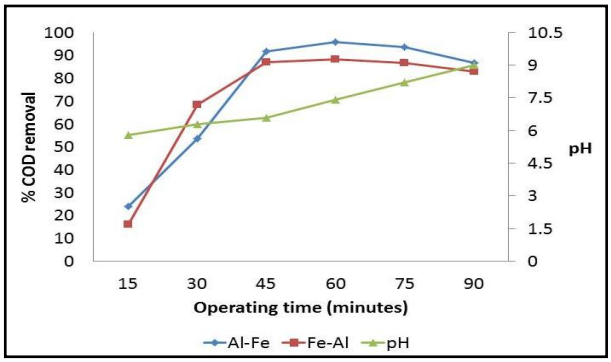
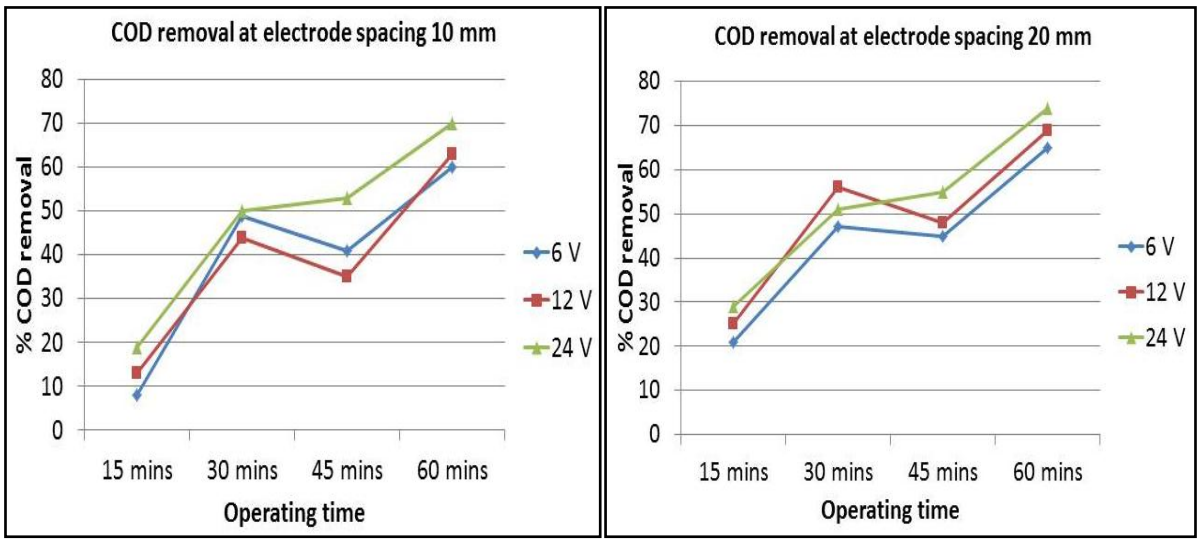


Fig.2: Effect of electrode combination over pH values during EC process.

3.4.Effect of electrode arrangement

Mostly aluminium and iron electrodes when placed individually or in amalgamation at certain distances gave good abstraction efficiencies. It was additionally investigated that when inter-electrode distances are incremented, i) ohmic loss in concern of both anode and cathode over varying voltages and ii) resistance to mass transfer becomes more immensely colossal which decelerate the process of charge transfer and electrode oxidation [34].



(a) (b)

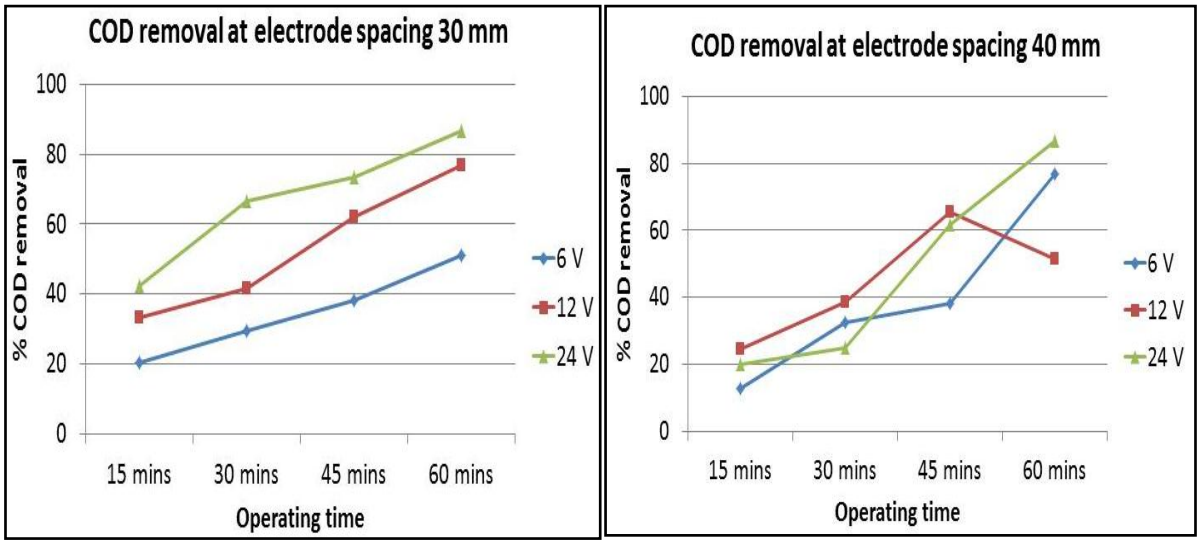
Also, increased inter-electrode distance forms a gelatinous aluminium hydroxide film over anode increasing resistance which minimises charge transfer [34]. Therefore, inter electrode distance is kept at inappropriate lower side to diminish energy consumption and raise removal efficiency [32].

It is also ensured that electrodes must not touch each other to avoid conductance in reactor. Several tests were conducted for electrodes at distances of 10 mm, 20 mm, 30 mm and 40 mm. From the performed experiments it was investigated that electrodes kept at minimum distance of 30mm from each other gave good

COD removal efficiencies than others within 60 mins of electrolysis time (shown in fig.3)

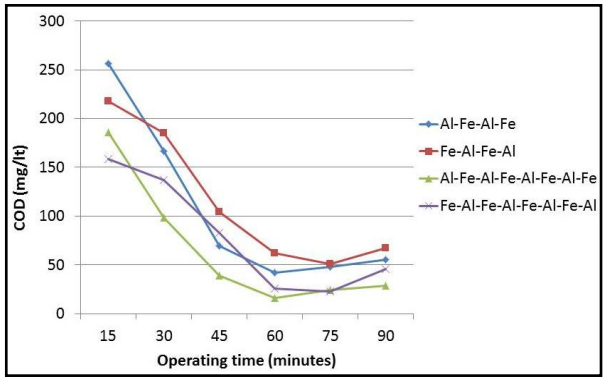
3.4 Effect of electrode configuration

The efficiency of EC process is strongly related to electrode dissolution and large amount of metal ions production which is supported by increased number of electrodes [34]. From studies it is investigated that Ohmic loss or increased resistance can be avoided/eliminated by increasing number of electrodes. Therefore, number of electrodes and their configuration plays an important role in getting higher removal efficiency in EC process. Generally,4 to 8 numbers of electrodes used and are arranged in two types of configuration: i) Monopolar and ii) Bipolar mode of connection. According to various literature studies Monopolar-parallel mode of connection gave best results than other mode of connections. Tests were carried out using 4 and 8 number of electrodes connected in Monopolar



(c) (d)

Fig.3: Effect of applied voltages and electrolysis time on COD removal at electrode spacing 10 mm,20 mm, 30 mm and 40 mm.

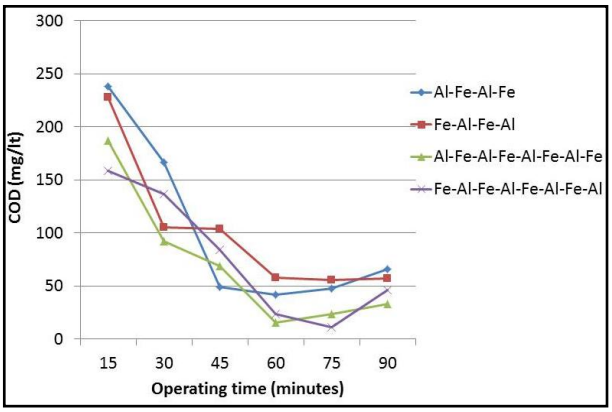


(i)

and bipolar mode of connections. From the tests it is investigated that i) electrode configuration of polarity had no such effects on sacrificial electrode consumption and ii) increased number of electrode results in higher removal efficiency percentages (shown in fig.4).

3.5 Effect of pH

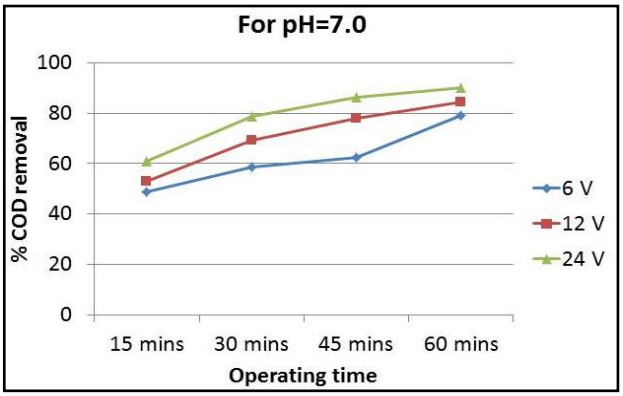
EC process is confined with pH of greywater as it shows varying results at different pH values. In order to examine the effect of pH Greywater was treated at different pH values [27]. Generally, during EC process pH of greywater tends to increase due to hydrolysis and oxidation of electrodes [25]. For Al-Fe combo of 8 electrodes, the percentage of COD removal was highest at pH value of 7.2 which is close to neutral. It was observed that greywater at low, neutral or slightly alkaline pH gave favourable



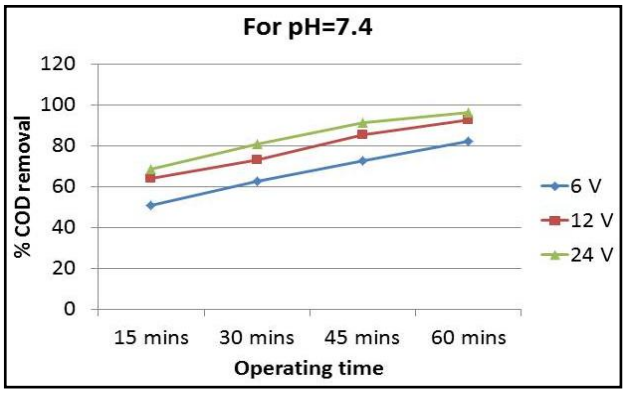
(ii)

Fig.4: Effect of electrode combination for (i) MP-P and (ii) BP-P mode of connections.

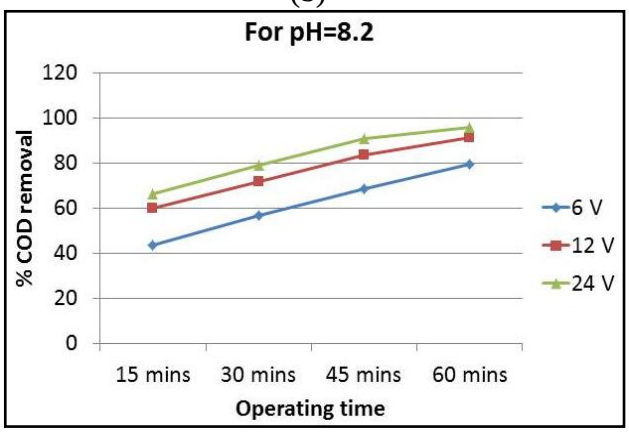
good removal efficiency and decreased the same when pH increased towards highly alkalinity [12,18]. From literature studies and performed experiments it was observed that when iron is used as sacrificial electrode (anode) it gave better results at lower pH values and aluminium as sacrificial anode stood still in giving good removal efficiencies even at higher pH values [35].



(a)



(b)



(c)

Fig.5: Effect of applied voltage and operating time at varying values of (a) pH=7.0, (b) pH=7.4, and (c) pH=8.2

4. Operating cost estimation

For the realistic operation of the EC process on a real-world basis, it is critical to be economical, and the major factor responsible for this is running cost [35]. The operating costs of the EC process include the cost of electrical energy used, the cost of electrode use, repairs, sludge disposal costs, and other fixed charges. The cost of electrical energy and electrode content is primarily used to calculate operating costs, and their calculations are shown below [35,36]

Operating cost = cost for electrical energy + Cost for electrode consumption .eq (1)

Electrical energy, $C_{Energy}\ (\mathrm{kWh/m^3}) = \frac{Uit}{V}$ ……..eq (2)

Where, U= average voltages (V); i= current (Amp); t= operating time (hrs); V=wetted volume of reactor ($\mathrm{m^3}$).

Electrode consumption, $C_{Electrode\ consumption}\ (\mathrm{kg/m^3}) = \frac{it\,M_w}{zFV}$ ……..eq (3)

EC	U (V)	CD (A)	C_{energy} KWh/m^3	$C_{electode}$ $kg\ Al/m^3$ $kg\ Fe/m^3$		OPcin INR $/m^3$
Al-Fe-Al-Fe-Al-Fe-	24	1	4.6	0.031	0.097	61.75

Al-Fe Fe-Al-Fe-Al-Fe-Al-Fe-Al-Fe-Al	24	1	4.9	0.0325	0.0981	62.57

Where, i=current (Amp); t=operating time (hrs); M_w=molecular wt of iron/aluminium (g/mol); z=number of electrons involved in the process (2 for Fe and 3 for Al); F=faradays constant (96485 C/mol); V= wetted volume of reactor (m^3).

Electrical unit price was taken as Rs 12.50/unit of kWh for the Nagpur area, December 2019 and price of electrode material were Rs 35/kg and Rs 135/kg for iron and aluminium respectively. On total during EC process 0.031 kg/m^3 and 0.097 kg/$m^3$of Al and Fe electrode respectively was consumed. From various studies and performed experiment it was observed that when 24 V of voltage is applied, all electrodes in Al-Fe and Fe-Al combination required less electrical energy of 4.6 kWh/m^3 and 4.9 kWh/m^3(using eq 2) respectively, to obtain higher current efficiencies, but it was observed that Al-Fe ordered electrodes consumed less electrical energy comparative to Fe-Al order electrodes [7]. As a result, under optimum condition operating cost for greywater treatment by EC using 8 Al-Fe electrodes was found out to be Rs. 62.57/m^3 and Rs 61.75/$m^3$for Fe-Al and Al-Fe combination.

5. Conclusion

The electrocoagulation technique has been accepted as an effective and reliable process for wastewater treatment, and it has also acquired significant interest in treatment applications due to its environmental compatibility, versatility, energy consumption, protection, selectivity, automation compatibility, and cost-effectiveness. The experimental study of electrocoagulation was conducted to analyse the feasibility of COD abstraction with aluminium and iron electrodes and to investigate the effects of the voltage applied, electrode spacing, and operating time on COD abstraction efficiency. The results betokened that coalescences of 8 aluminium-iron electrodes arranged in MP-P connection mode are efficient enough to give good abstraction efficiencies. The results show that electrode material and their arrangement along with current-voltage and operating time play a consequential role in the electrocoagulation process. The optimum COD abstraction efficiency of 96 % is achieved at 24 V of voltage and operating time of 60 mins with an electrode spacing of 30 mm for Al-Fe order with the operating cost of Rs 61.75/m^3. Conclusively EC process utilising opportune material, order, and coalescence of electrodes, is the most efficient process relative to simple, facilely managed, and economical for greywater treatment

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SMART COMPOST BIN USING SOLAR ENERGY

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ABSTRACT

The composting process has received much attention in recent years because of increase in volume of waste. This project report describe a wise way for the mitigation of the waste generation which is wise compost bin. The special features of the smart compost bin and its structure are also explained. Composting may be a microbiological anaerobic process. Smart compost bin could also be a system which comprises of several components like , metal and plastic detector, composting unit and outlet provision for produced fertilizer. The composting process is controlled by variety of things like temperature, moisture and oxygen content. If the temperature fluctuates during the composting period, the method are often adequately controlled just in case of any problem. Moisture content is that the factor which makes the nutrients bioavailable. To achieve success , we will need to provide the microorganisms within the system. this technique totally works on solar power . Smart compost bin can improve public area sanitation by returning vital nutrients to the soil. This project gives brief information on the composting for waste as a means of addressing the environmental pollution concerns. Composting has been used as how of recycling organic matter back into the soil to reinforce soil structure and fertility.

keywords: *design; realization; composting machine ; remote control; smart composter; sensors*

1. Introduction

1.1 General

Today solid waste management is one among the most important problems in the world. Around 50% of the waste in the world is organic waste. India ranks second in the world in terms of population; it produces more than 100 tons of solid waste a day. It is the mixture of both organic food waste and inorganic waste. Around 78% is food waste, which can be recycled. Some of them is land filled but it is not separated properly and it mixes organic and inorganic waste, which produces bad odour, and it'll spoil the soil. To manage the solid waste, it should be properly segregated at the source (houses). The organic and inorganic waste must be separated, the organic waste are often treated to form compost, and inorganic waste can be segregated and given for garbage collection. There are many companies who collect the garbage, segregate it and convert the organic waste into compost but as the waste is extremely high; they're unable to realize all the targets so it's better to compost reception . Composting is the decomposition of organic waste by microorganisms under controlled Conditions. Organic Waste, which forms a significant part of municipal solid waste, has caused increasing environmental concerns. By composting organic waste, we can preserve resources and produce a valuable byproduct that can be used as locally produced fertilizer. The existing composting methods and equipments have few challenges which are difficult to handle such as messy and smelly compost, timeconsuming process (3045 days), susceptible to insects and rodents and hard to clean. In addition, some of them release greenhouse gases. There are few automatic and high end compost bins but they are very expensive and not affordable. This project aims at designing a compost bin for Indian household kitchen also as other organic waste generated from the gardens and other resources, which is straightforward to use, odour free, economic in nature and visually appealing. Designed Compost bin consists of a separate chamber for compost starter, composting chamber consist shredder i.e. mixing blade works on the solar power , air exhaust with a filter and a output compost collection tray and also the outlet for liquid fertilizer is provided Neem and trash which Simple mechanism allows the user to maintain cleanlines.

1.2 Literature review

Composting isn't only a contemporary age matter, this practice took place while ago. The earliest records state evidence that before the introduction of recent sewage systems, the main fertilizers were animal manure and composts of garden and kitchen wastes. Composting existed 10 thousands years ago

through the Akadian empire which was located in modernday Iraq. When the citizens Analysis that their plants grew more better in area where there was manure they started mixing manure in their soil . The Past of composting also notice that early farmers in Scotland, during the Mesolithic (stone) Age , used to mix manure and vegetable compost in their soil. Moving to Ancient Asia, there is evidence that the stone tools found in Neolithic sites in northern china contained similar features as those employed by the Scottish farmers. The Greeks, Romans and Egyptians used composting too. In
Egypt, after observing the worms' composting abilities, Cleopatra enacted a law that states that anyone who removes earthworms from Egypt was punished by death. During the 12th century, the Handbook Kitab Al Falah & E. B. taylor written by Ibn AL Awam gave detailed information about composting and therefore the use of manure. . In 1943, Washington
Carver said "do make your own compost are often through with little labor and practically no cash outlay". Yet, composting was soon replaced within the early 20th century. Justus Von Liebig, a German scientist, proved in 1841 that the plants would be get nourishment from the chemicals. Therefore, the vegetables' and animals' waste mixture was replaced quickly by artificial fertilizers, which was the beginning of the methodology of farming. But like all the synthetic solutions, fertilizers had their opponents

1.2.Lmodern Composting

In 1905 sir Albert Howard announced the Indore method. After 30 years of research, Howard found the sole modern compost. It involves alternating layers of green, manure and soil until reaching the required height. The heap should be moist and turned regularly to satisfy the specified aerobic conditions, then the compost is prepared within the span of three months.
[Design of composting bin to convert aui's biomass to an organic fertilizer April 2017]

1.3 Objective of Project

The main objective of the project is to design a smart compost bin using solar energy having a capacity of 25 liters to carry out the composting of all types of biodegradable materials and to obtain good quality of manure.

2.Methodology

To review household survey of existing compost bin (Household and Industrial) various composting processes, and thus the interview are getting to be conducted with the users to understand the foremost problems in waste disposal and disadvantages of the prevailing compost bin. supported the Data collected in literature survey and ethnography research, the merchandise design specification is meant . to urge concepts 2D sketch is made on the merchandise design specification.

2.1 Ethnography Research

Ethnography research could even be a an area of literature survey. it's the study of the people and thus the merchandise in their environment and thus the way they use certain products.

2.2 Design Criteria

Frequency of use The biodegradable waste is input every day, so we'll use this bin for community

Use of Energy because the bin is completely works on solar energy, and hence there is no used electricity.

Product Handling The output product i.e. compost, should be in such a fashion that there should not be any inconvenience and it should be used easily for home gardening. •

Easy Process This composter is to be used by everyone and no need of any special skills for operating & maintenance it.

Product location: it should be Kept in either balconies or where Maximus sunlight is out there .

Product size: the size of the Smart compost bin would be ergonomic in nature and it'll maintain the standard modular kitchen dimensions followed in Indian kitchens. Depending upon the amount of the waste generated the size of smart compost bin may vary.

Odour free: The smart compost bin wouldn't give out any bad odour.

Low noise: its noise limit shall be limited within house only .

Aesthetics: As an integral a neighborhood of an urban household, the design language of the smart compost bin looks like other kitchen appliances. [Design and development of compost bin for Indian kitchen– International journal of waste resources 2018 DOI: 10.4172/2225211.1003]

2.3 Components of Smart compost bin

• **Solar panels**: Solar panels are the most source for the working of each component of bin. they're going to be provided along the suitable direction so on receive the optimum amount of sunlight. In India, there is an average of five to six hours of sunlight per day .

fig 2.1 Solar panels

• **Inlet provision**: Inlet are getting to be provided at the highest of the bin from where the organic waste is feed the bin.

• **Geared motor**: Geared motor are getting to be provided to rotate the shaft and thus the blades to required revolution per minute. Solar energy obtained by solar panel is used for the working of motor.

Fig 2.2 Geared motor

• **Shaft and Blade assembly** : Shaft provided is employed to revolve the blades about it's vertical axis. At one end of the motor shaft is connected. Other end of shaft is needle fixed at rock bottom on mesh. The blades will be provided on the circumference of the shaft which lessen the dimensions of the waste and fastened the composting process.

Fig 2.3 Blades with shaft

• **Blades with shaft** predicament sprinkling arrangement: so on maintain the favourable temperature for the composting process, the recent water are going to be sprinkled inside the bin with the assistance of sprinkler. • • **Screen:** Solid compost and liquid fertilizer are going to be separated by screen.

Fig 2.4 Screen

• **Collecting pan** :- It will be provided to collect the solid fertilizer for further use

• **Outlet provision: -** Outlet will provide to convey the collected liquid fertilizer to the required place.

3. Design and Procedure

3.1 Compost bin model design

The compost bin made up of mainly three parts. The top unit is a solar system and hot water storage system, second unit is the composting bin part and the third unit is Compost and liquid fertilizer collection system.

3.2 Compost bin working process

Figure shows the composting process utilized within the compost bin designed for biodegradable waste. the tactic goes as follows

• The biodegradable waste is loaded within the composting unit

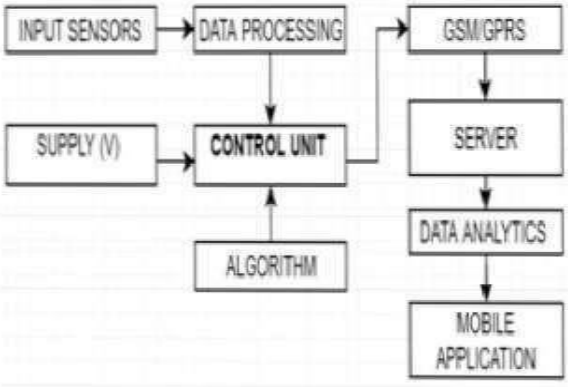
• Biodegradable waste is chopped finely with the help of cutting blade setup.

• Addition of compost maker means of microbes which start the composting process.

Fig3.1 smart compost bin

- Screens are provided at the lowest for separating liquid fertilizer
- The compost is then collected by the opening provided in side wall of composting unit
- Outdoor are provided to collect both solid and liquid fertilizers

3.3 Flow Chart of working process of Smart compost bin:



4.1 Conclusion

The proposed strategies for the management and disposal of degradable waste by composting with solar smart compost bin have shown practically in terms of organic matter mineralisation. Compost bin plays an enormous role in solid waste management in India as it is easy to use and price effective, are often implemented at lower rate. The new design of compost bin is aesthetically good looking, it's no odour, keep insects flies away from bin. supported the study, it can be conclude that composting is that the sole thanks to reduce or recycle the municipal solid waste and it effects less amount of pollution and more beneficial to environment also as economy as compared to this methods of collection and disposal. it's many benefits like reduce surface and water leachates, minimize landfill space, methane emission, pollution by burning of waste, transportation cost etc. It also reduce load on disposal units. Compost obtained by this could be used as organic fertilizer in agricultural field instead of chemical fertilizer also because of shredding of waste in bin fast process of composting takes place. The liquid fertilizer obtained are often directly used or stored which increases the yield of crop in natural way. Finally, it's conclude that the proposed alternative shall be sealed up in developing & urban areas to reduce and diversify the urban waste streams producing top of the range and balanced organic fertilizer with significant value.

4.2 Future Scope

- Based on few of the suggestions suggested by the advisors for future improvements of the compost bins, below are quite the very best of the day scope of the compost bin they are:
- Wheels are often added at the lowest so as that it's easily transportable.
- Blade setup are often made with multiple size for thick and thin .
- Composting area to be transparent. Blade setup are often removable
- Proper handle for movement of compost bin.

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STUDY OF MICRO HYDROPOWER SYSTEM FOR NAGPUR PENCH PIPELINE PROJECT

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ABSTRACT

Electrical energy consumption is increasing with advancing technology day by day. It's important for us to find out alternative source of energy generation which is reliable and renewable also it is important that it should be economical without any environmental side effect. Hydro power project such as micro hydro power projects and mini hydro power projects are best solution to this based on performance as well as design. This project tries to meet up the demand with alternative renewable energy source and compact design even with smallest and lowest available head. The main purpose of this study is to identify the utilization of unused potential energy of flowing water through Nagpur Pench pipeline project and generate the power in a green environment. The basic concept is to find the feasibility of planning the micro hydropower turbine on Nagpur Pench IV pipeline and generating power by using energy of flowing water which is unconsumed throughout the pipeline. The design is just on preliminary study and based on available data. It shows that for a head of 2 m and on installation of hydropower at every km, 37.08 MW /day energy can be generated. This study can be extended further to design hydro power projects on water distribution systems within the city area also. However, a detailed study is required in all aspects of hydropower generation projects.

Keywords- *Hydropower, Potential Energy, Renewable Source, Turbine Generator*

1. Introduction

Energy is the backbone for growth and sustainability of cities and nations. Hydropower is a most commonly used mature and cost competitive energy source which contributes about 85% of global renewable electricity. Hydroelectricity has more advantages compared to most of the other sources of electrical power because of its high efficiency, very low operating and maintenance cost, flexibility, high level of reliability and proven technology. The great variety in the size of hydro power plants allows this technology to adapt to both large, centralized and small scale urban distributed energy model needs. Due to development of small hydro turbines, it is possible to harness water power for onsite energy generation or domestic production or industrial and agricultural districts. These small tiny generating plants are classified as micro hydro, if they generate less than 100 kw of energy. Micro hydropower plants use hydraulic head of flowing water through pipeline or free flow conduits having low head to generate electricity as reported by Bhoi & Ali (2014), Marco (2015) and Talpur *et. al*(2016),

Today, small hydropower projects offer emissions –free power solutions for many remote communities throughout the world such as in Nepal , India , China, Peru as well as for highly industrialized countries like, United States. These micro hydropower systems can be deployed in municipalities, energy intensive industries and agricultural irrigation districts providing a consistent amount of clean and continuous energy at the same time helping in pipeline management and maintenance.

2. Literature Review

The literature suggests that the factors like flow rates, head of discharge, corrosion effect, material properties, water's chemical and physical properties etc. mainly affects the design of hydroelectric power units. The material for turbine blades should be alloy materials since turbine blades are constantly exposed to water and dynamic forces, so they need to have high corrosion resistance, strength weld ability and low density. The carbon composite alloy materials satisfy this criteria. Generally, 'Austenitic steel' having 17% to 20% of chromium and 'Martensitic stainless steels' are used. Stainless steel alloys provide low density which is important to achieve higher efficiency because lighter blades rotate more easily.

The turbine blade angles, thickness, and number of blades also affects the power generation ability and efficiency. Even though it is totally dependent on design requirements still in most of the cases it is seen that a turbine

having six number of blades and 45º turbine angle of blocking system gives maximum torque. Also, if blade thickness of 10 mm will be used it will be more efficient turbine (Fig. 1 & 2).

Prasetyo (2018) suggested the factors affecting flow rates, as viscosity, density, and temperature of fluid. In addition to length and inner diameter of pipe, internal roughness of pipe, number and types of valve fittings, blends, entrance and exit position of pipe work also affects flow rate. The corrosion and degradation due to friction also affect the performance of the pipeline.

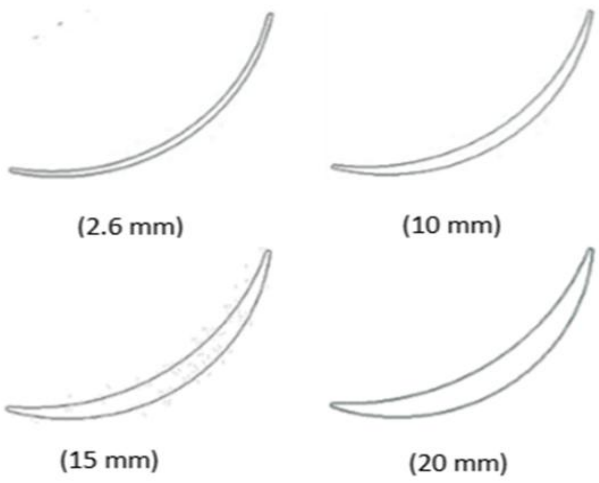
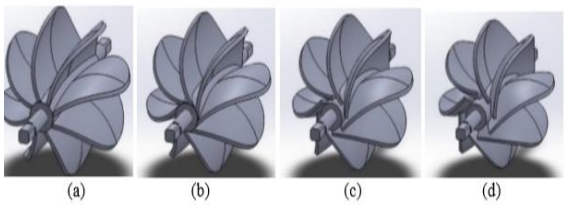
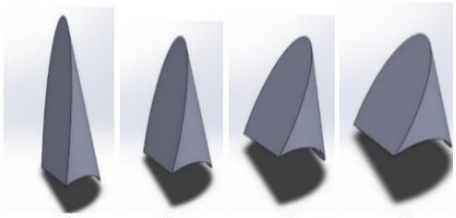


Fig. no 1:- Variation of Blade thickness



Figures 3. Turbine blade bucket angle of (a) 5°, (b) 10°, (c) 15°, and (d) 20°



Figures 4. Turbine angle of blocking system of (a) 20°, (b) 30°, (c) 40°, and (d) 5

Fig no.2: - Value of highest torque

An overview of the different types of in-pipe hydro systems available on the market and their possible applications at the urban and building scale and the benefits achievable in terms of energy production compared to other renewable such as photovoltaic and wind systems reported by Du *et. al* (2017)

Lucid Energy, INC developed the concept that electricity can be generated by installing hydrodynamic turbines inside the pipelines. The presence of turbine reportedly doesn't slow the water flow rate significantly, so there is no impact on pipeline efficiency. They generated average 1100 MW hours of energy per year which enough to power 150 homes.

The turbine is the most important component of hydro-system where water is converted into the rotational force that drives turbine and generate energy. A machine for producing continuous power in which a rotor fitted with blades is made to revolve by moving flow of water. The shaft from the turbine goes up into the dynamo or generator. When the water moves across the turbine blades, it will rotate the shaft by rotating the shaft and, rotating the copper coils of the dynamo. As the copper coils spin within the magnets, energy is produced called electrical energy. For maximum efficiency the turbine should be designed to match your specific head and flow. Purdue ECT Team (2012) suggested the sectional part of the hydro system as shown in Fig. 3. The system is connected 4 turbines and each turbine is attached with generator where it converts the rotational energy from turbine into electricity. In this turbine, generator and its complementary units are essential parts.

3. Experimental Model

In order to study the possibility of hydropower generation a model as shown in Fig. 4 was constructed in 1inch pipe (25gallons/min), 1 dynamo (6 to 12 volts), and 2 LEDs (1.8 to 3 volts). The flow was allowed to take place through pipe and tests were performed. With the available head in the building, the power was generated and LED was blown.

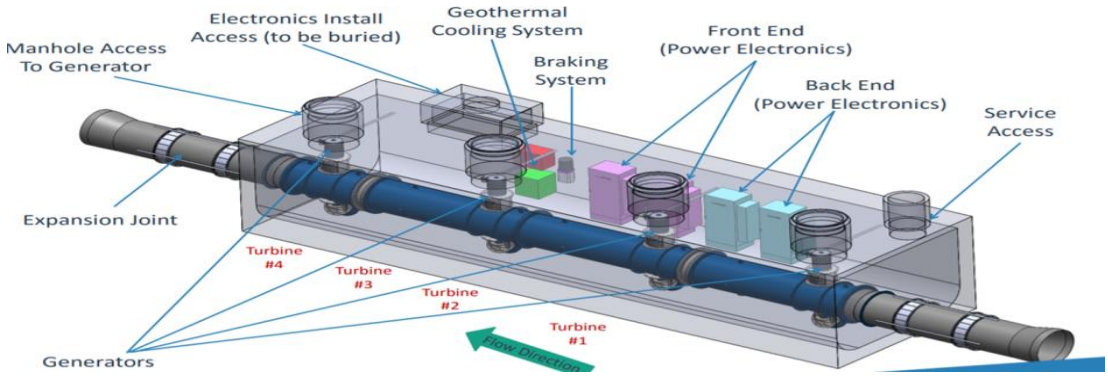
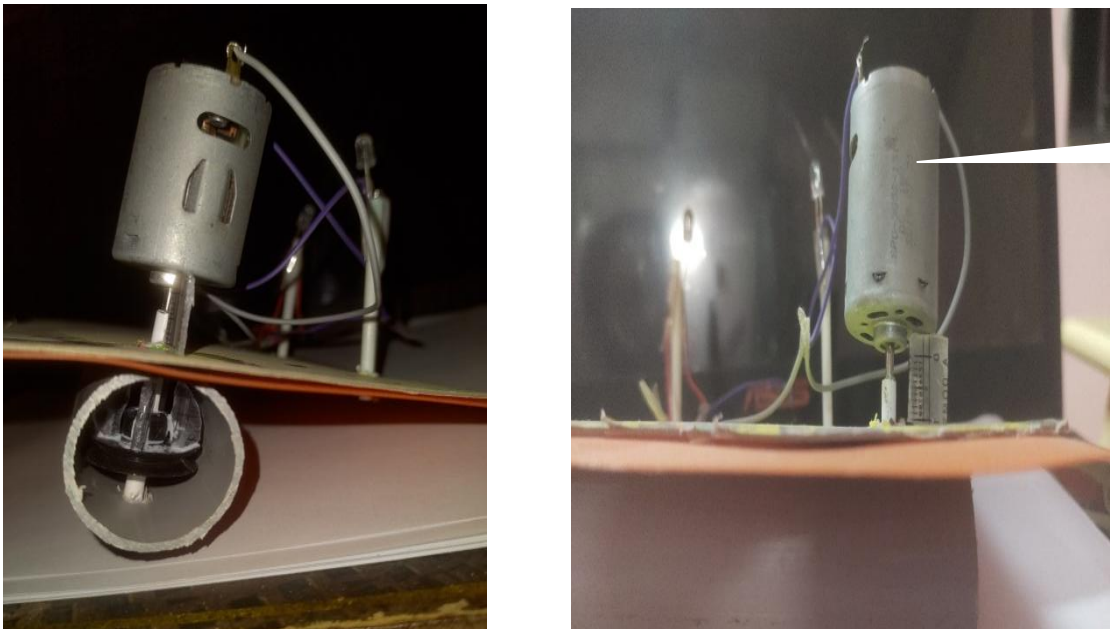


Fig no.3: - Lucid arrangement of turbines (Purdue ECT Team (2012)



(a) Set up of Turbine and LED system **(b) LED blown during flow through pipe**

Fig no.4: - Experimental Model of Test Setup

The experiment was carried out with 50% discharge through 1-inch pipe and for 30º, 45º and 60º blade angles. The maximum output was found for 45º blade angle using turbine having 6 rotatory blades and the results are tabulated in Table 1 and Table 2.

Table 1 and Table 2 shows the power generation at ground floor and 1st floor. The current was measured with the help of a multimeter and discharge was measured volumetrically. Fig. 5 shows that as discharge increases the power generation also increases.

Table 1: Ground floor test location with 45º blade

Sr. no	Discharge (cm3/sec)	Current (mA)	Voltage (V)	Power Generated (mW)
1	0.1	12	2	24
2	0.11	14	2.2	30.8
3	0.13	16	2.4	38.4
4	0.15	17	2.5	42.5
5	0.16	18	3	54
6	0.17	20	3.3	66
7	0.18	22	3.5	77
8	0.19	25	3.9	97.5
9	0.19	27	4.2	113.4
10	0.20	32	4.5	144

Table 2: First floor test location with 45º blade

Sr. no	Discharge (cm3/sec)	Current(mA)	Voltage(V)	Power Generated (mW)
1	0.1	18	2	36
2	0.11	20	2.2	44
3	0.13	23	2.4	55.2
4	0.15	25	2.5	62.5
5	0.16	30	3	90
6	0.18	36	3.3	118.8
7	0.2	42	3.5	147
8	0.23	50	3.9	195
9	0.24	56	4.2	235.2
10	0.25	62	4.5	279

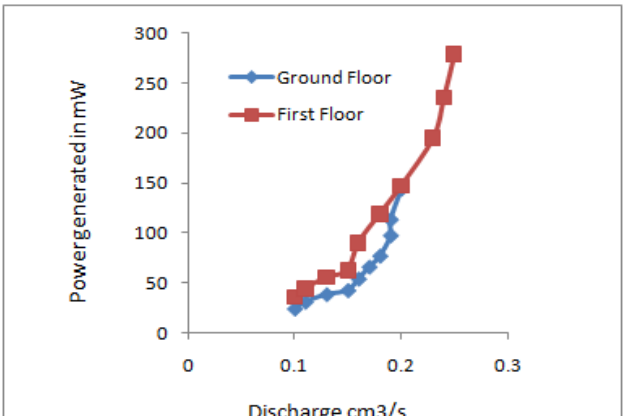


Fig no. 5 – Discharge vs Power Generated

4. Proposed Nagpur Pench Pipeline Hydro Power

The Pench to Nagpur pipeline known as Pench IV pipeline is shown in Fig. 6. This pipeline supply raw water to Nagpur city. It is 27 km long pipeline and has capacity of 115 MLD.

Fig no.6: - Nagpur-Pench Water Pipeline

Power generation

The study was carried out to check the feasibility of hydropower generation from this 27 km long pipeline which carries 115 MLD water. The data available was very limited and hence assumptions were for certain factors to calculate the power generated.

It was presumed that the head of water available at 25 turbine stations is 2m. The average efficiency of the turbine was assumed as 65%. The loss of 1MLD water was considered due to other losses. The calculated loss of water at each turbine i.e.

Loss for 25 turbines = Input - Output

=115 – 114 = 1MLD

$$= \frac{1x10^{6}x10^{-3}}{24x60x60}$$

= 0.01157 m^3/sec

Loss for Single turbine = $4.628x10^{-4}$ m^3/sec

At 50% discharge P =0.65*9.81*0.66*2

= 8.4 kW/sec

At 70% discharge P =0.65*9.81*0.93*2

= 11.86kW/sec

At 85% discharge P = 0.65*9.81*1.13*2

= 14.41kW/sec

The above calculations show that as discharge changes the power generation through pipe line hydropower changes.

Table 3: Power Generation through 25 turbines

Sr. No.	Original discharge (m3/sec)	Frictional losses	Discharge obtained	Average head (m)	Efficiency in %	Max power in kw
1	1.33	0	1.33	2	65	16.96
2	1.33	4.6280×10-4	1.3295	2	65	16.95
3	1.33	9.2560×10-4	1.3290	2	65	16.94
4	1.33	1.3384×10-3	1.3286	2	65	16.94
5	1.33	1.8512×10-3	1.3281	2	65	16.93
6	1.33	2.3140×10-3	1.3276	2	65	16.93
7	1.33	2.7768×10-3	1.3272	2	65	16.92
8	1.33	3.2396×10-3	1.3267	2	65	16.92
9	1.33	3.7024×10-3	1.3262	2	65	16.91
10	1.33	4.1652×10-3	1.3258	2	65	16.90
11	1.33	4.6280×10-3	1.3253	2	65	16.90
12	1.33	5.0908×10-3	1.3249	2	65	16.89
13	1.33	5.5536×10-3	1.3244	2	65	16.89
14	1.33	6.0164×10^{-3}	1.3239	2	65	16.88
15	1.33	6.4792×10^{-3}	1.3235	2	65	16.87
16	1.33	6.9420×10^{-3}	1.3230	2	65	16.87
17	1.33	7.4048×10^{-3}	1.3225	2	65	16.86
18	1.33	7.8676×10^{-3}	1.3221	2	65	16.86
19	1.33	8.3304×10^{-3}	1.3216	2	65	16.85
20	1.33	8.7932×10^{-3}	1.3212	2	65	16.84
21	1.33	9.2560×10^{-3}	1.3207	2	65	16.84
22	1.33	9.7188×10^{-3}	1.3202	2	65	16.83
23	1.33	10.1816×10^{-3}	1.3198	2	65	16.83
24	1.33	10.6444×10^{-3}	1.3193	2	65	16.82
25	1.33	11.1072×10^{-3}	1.3188	2	65	16.81
					TOTAL	429.13

Table 3 shows that if 65% efficiency of the generation is considered, the power generated for 2 m head at all 25 turbine station may be 429.13 KW.

Power generation per day

If the power generate for 24 hrs, the power generation for 24hrs will be 429.23x60x60x24 = 37.08MW

5. Result

Based on the assumptions and privileged power generation for standard circumstances, the Nagpur-Pench pipeline will prove to be source of hydro power generation of the tune of 37.08 MW per day. If it is presumed that power consumption of 100 units per month of a single house, then about 11124 houses per month will have electricity economically.

6. Conclusion

Harnessing of renewable energy sources is essential to meet the ever increasing electricity demand and also to minimize the impact on the environment by reducing the use of conventional sources of energy. From the work and analysis carried out , it can be concluded that

1. The hydraulic turbine in the water pipeline can generate the electricity.
2. The simple model analysis shows that the power generation increases with increase of discharge.
3. The Nagpur-Pench water pipe line will be a great source of hydro power generation and unutilized energy can be trapped economically.

7. Future Scope

The work carried out is preliminary based and indicative that water pipelines may become the source of power generation. The detailed work on availability of head, location for turbines and cost estimation need to be carried out. Similar to the main water pipe line, even within a city area network of water pipelines exists, This network can also be utilized for power generation after detailed study..

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EFFECT OF NATURAL AND SYNTHETIC FIBERSON STABILIZATION OF EXPANSIVE SOIL

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ABSTRACT

Expansive soils are some of the most widely distributed and costly geologic hazards. They have been called the "Hidden Disaster" in the construction world, and result in millions of dollars in ongoing treatment, and repair of homes, commercial structures, roads, and underground infrastructure throughout the country each year. In an attempt to make them more feasible for construction purposes, numerous materials and techniques have been used to stabilize the soil. In this study, the additives and techniques applied for stabilizing expansive soils will be focused on, with respect to their efficiency in improving the engineering properties of the soils. This paper is focusing on the stabilization of soil using natural as well as synthetic fibers with various percentage. Jute will be added in the soil as natural fiber whereas waste rubber fiber (Shrewd Tyre waste) is used as synthetic fiber. Stabilization is the process of modifying the properties of a soil to improve its engineering performance and used it for a variety of engineering works. This study examines the potential of soil stabilization with jute fiber when it is cut into roughly 30mm lengths as stabilizer. The varying percentages like 5%, 10%, 15% and 20% of pieces of jute & waste rubber fiber were used and mixed it with soil. The laboratory tests such as California Bearing Ratio (CBR) test, modified proctor tests and direct shear strength tests have been conducted to observe the change in engineering properties of soil.

***Keywords**: CBR Test, Jute, Modified Proctor Test, Soil Stabilization, Waste Rubber Fiber etc.*

Introduction

Expansive soil is characterized by clayey material. Treating expansive soil is necessary because clay soil particles attract moisture and hold on to it, producing a swelling mass of soil and water. When the moisture dissipates from the soil, the particles come back together, causing a shrinking action of the soil mass. Think of how a sponge swells when it's wet and shrinks when it dries out. This swelling and shrinking of the clay and the associated movement it causes can result in severe damage to structures built on or in this type of soil. The concept and principle of soil reinforcement was first developed by Vidal (1969). He demonstrated that the introduction of reinforcing elements in a soil mass increases the shear resistance of the medium. Consequently, efforts for using fibrous materials such as natural fibers, coconut (coir) fiber, sisal, palm fibers, jute, flax barely straw, bamboo and cane as reinforcing elements were stated. The performance of a soil-fiber mixture depends not only on the individual properties of the constituents, but also on the compatibility between the fibers and soil. The interface between reinforcement and matrix constitutes the contact area of the elements in the blend and is essential for the transmission of mechanical tensions from the matrix to the reinforcement. In the present work we have made an attempt to study the effect of natural and synthetic fibers on soil stabilization on various proportions and also to check the compatibility of these fibers with expansive soil sample.

Literature review

Akshat Malhotra et.al. [2014]
Demonstrated the potential of HDPE plastic waste on the UCS of soil. In a proportion of 1.5 %, 3%, 4.5 % and 6% of the weight of dry soil HDPE plastic (40 micron) waste was added. They concluded that the UCS of black cotton soil increased on addition of plastic waste. When 4.5 % plastic waste was added, 287.32 KN/m2 soil strength of the soil was obtained which was more than untreated soil.
Rajkumar Nagle et.al.[2014] Analyzed that the result of the CBR demonstrated that inclusion of waste plastic waste material in soil with appropriate amounts improved strength and deformation behavior of sub grade soils. The waste plastic material taken as 2%,4%,6%,8% by dry weight of each soil sample and corresponding to each plastic content and unsoaked CBR tests were conducted in the laboratory.
Shiva Kumar et. al. [2014] The unconfined compressive strength for BC soil is

increased due to inclusion of plastic waste strips. The strength of soil increased up to addition 0.2% of plastic strips. Thus using of plastic strips is an economical and gainful utilization since there is scarcity of good quality soil for embankment fills

B. M. Patil et. al.[2013] The CBR value of mix of soil and RBI Grade 81 for different proportions was determined. The RBI Grade 81 added in 2%, 4%, and 6% by weight of soil. The CBR value of mix of soil and different industrial waste for different proportions was determined. The CBR value of mix of soil, RBI Grade 81 and different industrial waste for different proportions was determined.

Pragyan Bhattarai et al. [2014] Suggested that expensive methods for stabilization can be replaced by the reinforcement with plastic strips which will make the construction purposes economical and also make the proper arrangement of plastic waste conserving the various component of the environment. Their study showed a major increase in CBR value of soil reinforced with plastic waste.

Ibrahim Adewuyi Oyediranet. al. (2015) Carried out a research on strength characteristics of genetically different rice and coconut husk ash compacted shales. 2 to 20 % by weight of both Rice Husk Ash (RHA) and Coconut Husk Ash (CHA) were separately added to Okitipupa (SW) and Enugu (SE) shales with the subsequent determination of Plasticity Index (PI), Maximum Dry Density (MDD), Optimum Moisture Content (OMC), Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR).

Shwetha P. and Prasanna Kumar N. [2017] Conducted different tests were conducted on soil with varying percentage of coconut shell ash. From the obtained results, it was observed that addition of 0.4% to 0.8% of coconut shell ash showed maximum improvement of dry density and optimum moisture content and also angle of internal friction and cohesion.

Gandhi, K.S. [2012] Used bagasse ash as the additive which increase the stability of soil and decrease the swelling of soil. As bagasse ash is high in silica, calcium, and other minerals is provides the necessary homogenous mass for performing the required test. Different tests are carried out with varying percentage of bagasse ash to check the effect on swelling pressure and on basic properties.

Priti Mishra et al.[2014] Reported that the fiber inclusion in soil changes the behavior of wasterecycled product from brittle to ductile. The unconfined compressive strength increases with increase in fiber content.

Anjan Kumar et. al. [2009] Carried out study on use of fly ash with lime and cement for stabilization of expansive soil. The result shows that the maximum load carrying capacity is obtained for stabilized fly ash subbase compared to untreated fly ash subbase.

1.Materials & methodolgy

i) Black Cotton Soil

Black cotton soil is one of major soil deposits of India which is expansive in nature. Treating expansive soil is necessary because clay soil particles attract moisture and hold on to it, producing a swelling mass of soil and water. They exhibit high rate of swelling and shrinkage when exposed to changes in moisture content and hence have been found be most troublesome from engineering consideration. The rate of montmorillonite is more in black cotton soil which causes expansiveness and crack occurs in soil without any warning which is dangerous for construction.

Crumb Rubber Fiber

In recent decades, the worldwide growth of the automobile industry and the increasing use of cars as the main means of transport have tremendously boosted tire production. This has generated massive stockpiles of used tires. Extensive research projects were carried out on how to use used tires in different applications. Waste tyres need a larger storage space than other waste due to their large volume and fixed shape. In this project the rubber is used in the form of powder. These discrete crumb rubber fiber is used varying percentage like 5%, 10%, 15% with weight with soil.

Fig-1: Crumb Rubber Fiber Sample

ii) Jute

Soils which are stabilized with jute show greater extensibility and compressive strength and reduction in settlement. The jute is biodegradable and has no environmental hazard. In this paper jute fiber is used with varying amount and their effect was analyzed on shear strength. The jute was procured from the local market. The diameter of the jute fiber used was 20mm. These fibers were cut in the length of 25mm for conducting our research. Generally, jute fibers are available in threaded form. These are mechanically, woven fibers with very fine threads.

Fig-2: Jute Fiber Sample

Sample Preparation

a) Composition of specimens

Specimens of parent soil and sample treated with 5, 10, 15 and 20% waste rubber and jute fiber by weight of soil sample were prepared for each test to be conducted. Soil collected from the Deccan area of Maharashtra state where it also known as "Regur" whereas waste rubber fiber and jute fiber procured from local market.

Mixing

Oven dry soil was dry mixed with various percentages of additives. Sufficient quantity of distilled water was then added to bring the moisture content to the desired level. The mixturewas then manually mixed thoroughly with a spatula. All the specimens were kept in polythene bags for maturing for three days.

1. Test Carried Out:

To ascertain the effects and change in behavior of soils subjected to jute fibers, soil samples were subjected to varying percentages of jute fibers as reinforcement. These samples were tested by conducting tests such as modified proctor test, direct shear test and California Bearing Ratio test.

i) Liquid Limit

It is the water content at which the soil changes from liquid state to plastic state or minimum water content at which soil just begins to flow. It is the ratio which signifies the relative consistency of a cohesive soil in the nature state.

ii) Plastic Limit

It is the water content at which soil changes from plastic state to semi-solid state or minimum water content at which soil rolled into threads of 3mm diameter just crumbles. The water content at which a soil changes from a plastic consistency to a liquid consistency.

iii) Modified Proctor Test

Proctor compaction test is a laboratory method of test is to define the optimal moisture content at which a given soil type will specifically. To determine the optimum water content at which soil be able to get to its maximum dry density.

iv) CBR Test

The California bearing ratio is a penetration test for evaluation of the mechanical strength ofroad sub grades and base-courses. The test is performed by measuring the pressure required to penetrate soil sample with a plunger of standard area. The measured pressure is then divided by the pressure required to achieve an equal penetration on a standard crushed rock material.

4. Results and Discussion

i) Plastic Limit & Liquid Limit

Atterberg's limits tests were performed on normal soil samples. The results obtained were as follows; the Liquid limit (LL) & Plastic limits (PL) were calculated on normal soil which was 30 and 22 respectively. Subsequently liquid and plastic limit calculated for various proportions of waste fiber and jute fiber like 5%, 10%, 15% and 20%.

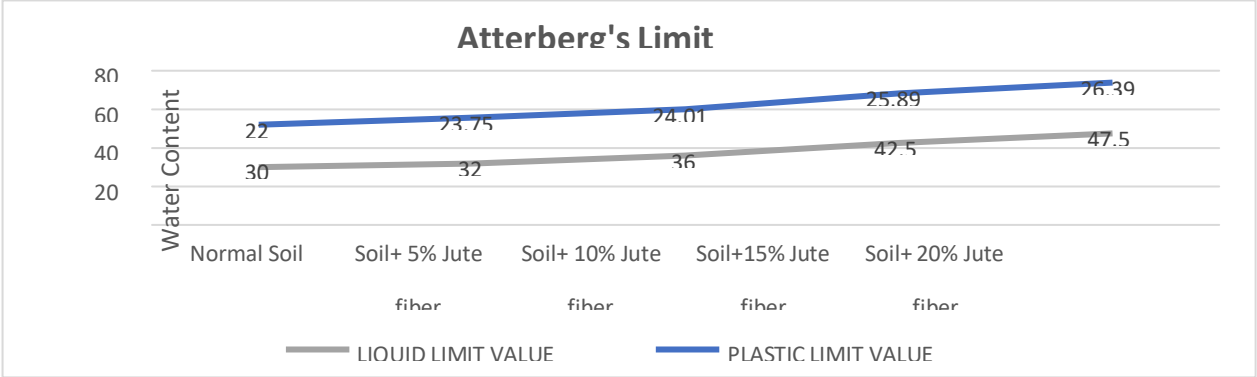

Fig-3: Atterberg's limits for soil sample of various percentage of jute

As far as mixing of jute in expansive soil with varying percentage it is observed from fig.3 that for normal soil, plastic and liquid limit are 22 & 30 respectively. On addition of jute fiberup to 5%, 10%, 15% and 20% value of plastic limit are 23.75, 24.01, 25.89 and 26.39 and that of liquid limit values are 32 at 5% and 47.5 on addition of 20% jute which shows great improvement in soil performance

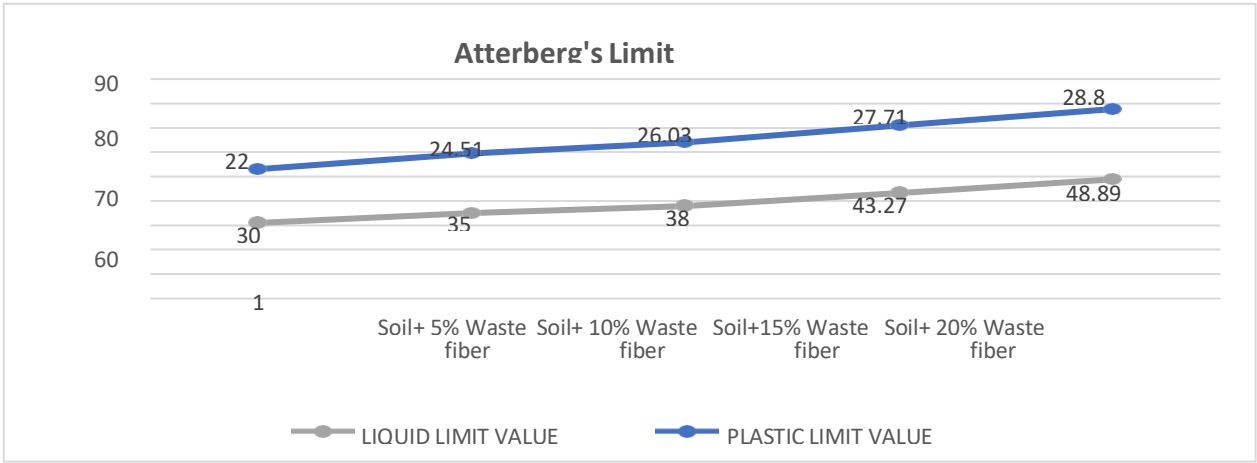

Fig-4: Atterberg's limits for soil sample various percentage of waste rubber fiber

Fig-4 demonstrates that on addition of waste fiber up to 5%, 10%, 15% and 20% value ofplastic limit are 24.51, 26.03, 27.71 and 28.8 and that of liquid limit values are 35 at 5% and 48.89 On addition of max. 20% waste fiber which shows better improvement

in soil performance than that of jute mixed soil.

i) MDD & OMC

Modified proctor test was conducted on reinforced soil samples at varying percentage s of jute fibers of 5%, 10%, 15% and 20%. The results obtained were as follows; by referring the graph in figure 5, for pure soil sample, MDD was observed 1.9g/cm^3. Soil sample reinforced with5% jute fiber, the MDD obtained was 1.62g/cm^{3}and 1.93g/cm^3 on addition of 5% waste fiber.

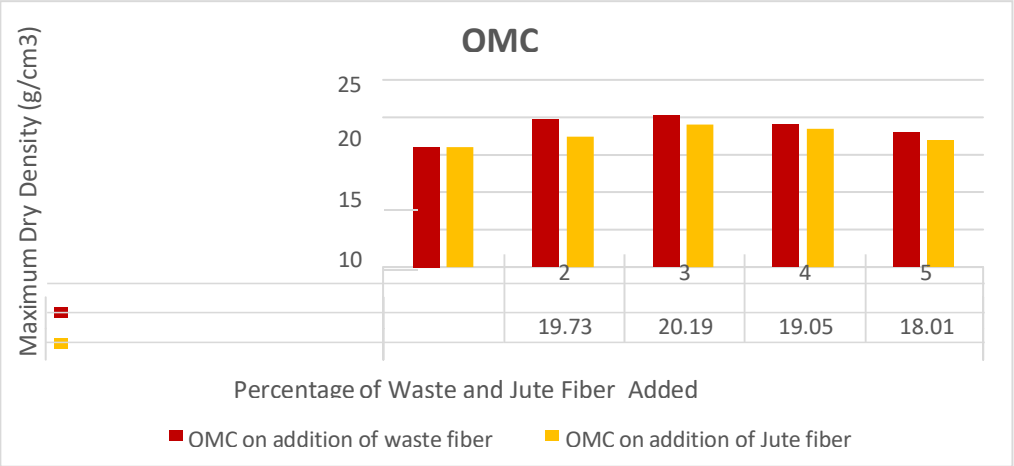

Fig-6: Comparison of OMC for different percentages of waste and jute fibers

CBR Value

CBR test was conducted on soil samples mixed with varying percentage of waste fiber and jute fiber. The fiber percentages varied from 5% to 20% for both waste rubber fiber and jute and 4 samples were tested for each. To understand the CBR values of waste and jute fiber soilsamples, the penetration values at 2.5mm and 5mm had to be observed. From fig-7, CBR value for normal soil sample is 2 which occurred without addition of any stabilizer. For 5% waste fiber, the CBR was 4.8 and that of jute fiber it is 4 at 2.5mm penetration. On addition of 10% waste fiber to the soil there is 22.50% increase in CBR value, similarly 27.50% of improvement in CBR occurs on 10% addition of jute fiber which is greater than waste fiber for the same. Further addition of 15 & 20 % of waste fiber to the expansive soil shows improvement of 19.04% & 27.42% respectively

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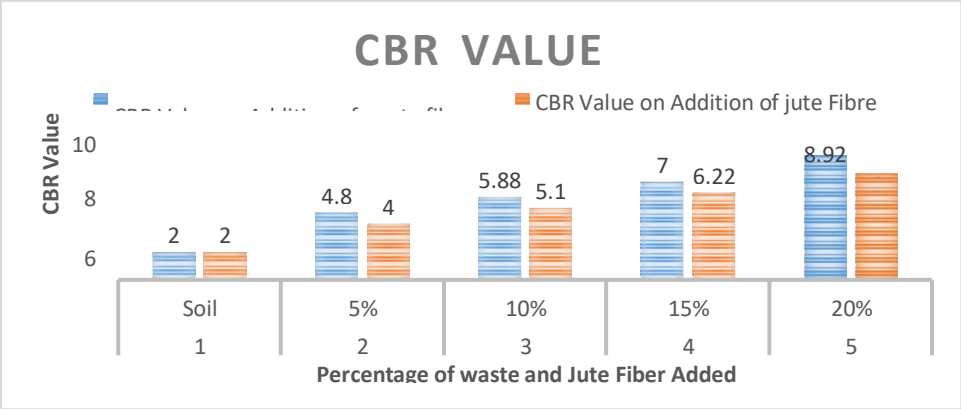

Fig-7: Comparison of CBR values for different percentage of waste &jute fiber

In case of jute fiber CBR value increased by 21.96% and 22.02% on addition of 15 & 20% jute fiber to the soil respectively. Therefore from the graphs, it could be inferred that the maximum percentage improvement in CBR was observed on 10%

addition of jute fiber as reinforcement.

5. Conclusion

The addition of jute fiber in expansive soil on varying percentages 5%, 10, 15% & 20% improves the value of plastic limit from 23.75 to 26.39 whereas liquid limit improves from 32 to 47.5 which is significant improvement in engineering properties of soil for better stability. Similarly, the addition of waste rubber fiber in expansive soil improves the value of plastic limit from 24.51 to 24.8 whereas liquid limit improves from 35 to 48.89 which is comparatively better than jute fiber for betterment of engineering properties of soil for againstthe stability. By comparing the results of modified proctor test, from fig-5 it is clearly observed that on addition 10% and 15% of waste fiber MDD shows a significant increment but with next addition of waste fiber its start decreasing and in case of jute MDD increases with every addition of jute from 5% to 15% but on the 20% mixture of jute it starts decreasing. From fig-7 demonstrated that expansive soil can be stabilize by using both waste rubber fiber and jute fiber where waste fiber can be preferred due to its better performance as a stabilizer. Results obtained from various test conclude that both waste rubber fiber and jute fiber has a great potential in soil stabilization but waste rubber fiber is more compatible with the expansive soil taken for the test.

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