# Study of Various Waste Heat Recovery System

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***Abstract-*** *The progressively worldwide downside concerning speedy economy development and a relative shortage of energy, the Non-ox furnace exhaust waste heat and environmental pollution has been additional emphasized heavily recently. Out of the entire heat provided to the furnace, close to, 30 to 40% is converted into helpful work; the remaining heat is expelled to the surroundings through exhaust gases, leading to entropy rise and high environmental pollution, thus it's needed to utilize waste heat into helpful work. The recovery and utilization of waste heat not alone conserve fuel (fossil fuel) but additionally reduces the number of waste heat and greenhouse gases dumped to the atmosphere. The study shows the review of various waste heat recovery system develops everywhere the globe. This paper is an effort tocover a completely different heat recovery system. During this paper design, analysis and experimental setups and their results also are mentioned.*

***Keywords***- WHRS, Heat exchanger, CFD, Kerns method.

## I. LITERATURE REVIEW

Manickam, M. et. al.[1] developed A model of a waste heat recovery boiler utilizing typical plant of-gas consisting of each gaseous and particulate combustibles. The model permits the calculation of temperatures of gas and particles inside the boiler and thus the probability of deposition onto the boiler walls. The model was applied to a typical waste heat boiler pure mathematics, and a typical o€-gas composition as well as a combination of combustibles (char) and non-combustible particulates. compounding within the burner region, char burnout and char particle temperature were analysed using the model. Combustion stability was additionally studied employing an easy Eddy break-up model that accounts for combustion dynamics and therefore the results compared with a Mixed-is-burnt model.

Zhang, G. et. al.[2] according to that in step with the heat balance of coke appliance, the key to an energy saving of coking trade was created clear. The technology of flue-gas heat recovery with radial heat pipe was introduced. Then its advancement was delineating. By giving an associate example, the appliance of the radial heat pipe in coke-oven verified that the technology obtained obvious economic and social benefits, that place on has sensible value and popularizing prospect.

Jouhara, H. et.al.[3] reported that the bulk of the energy demand in the industrial application was primarily used for heating functions. Recovering waste heat may contribute to an important reduction in cost and greenhouse emission. The author has targeted on to design an innovative heat recovery system and it factory-made and tested. The Flat Heat Pipe (FHP) was designed to recover the warmth by radiation from hot steel rods throughout the producing cooling method. The FHP system was composed of stainless-steel heat pipes connected by a collector at an all-time low and a shell and tube top header. The thermal performance of the FHP was investigated by testing the system at two positions from the barrier of the wires conveyor. The quantity of the energy recovered additionally the} operating temperature of the FHP was also reported. The experimental results showed that the warmth transfer capability of the FHP is powerfully influenced by the hot supply temperature. The operating temperature of the FHP ranged between 80°C and 60°C whereas the surface temperature of the FHP reached a most worth of 160 °C. The FHP was able to recover heat up to 15.6 (kW) for a water rate of flow of 0.38 kg/s and a hot provide at 450°C. It will be determined from the results that the FHP may even be a promising technology for waste heat recovery in associate trade with several challenges like extreme temperature provide. The Flat Heat Pipe (FHP) was designed to recover the heat by radiation from hot steel rods throughout the producing cooling technique. It had been determined from the results that the FHP is an associate innovative technology for waste heat recovery from industrial applications with high efficiency.

V S Naveen J et.al.[4] has done CFD simulation and according in the paper that, the extremely competitive metal production and power generation industries, the distinction between energy recovered and energy wasted typically determines the distinction between profit and loss. A waste heat boiler was one amongst the devices usually utilized to recover energy from extreme temperature furnace gases, extracting a major fraction of waste energy. Waste Heat Recovery Boiler (WHRB) was the representative example of energy improvement during this age of renewal and energy saving. They capture the waste heat from method systems and used it for alternative heating process that ultimately increase the potency of the plant. However, the operating stage of WHRB was difficult as style is ready looking on site constraints and it was expected to deliver high efficiency even once handling high rate and extreme temperature flows. CFD was wide accustomed investigate the flow pattern, pressure drop across ducting and particle trajectory within numerous instrumentation. CFD has accustomed address issues with existing geometrical or performance errors like an erosion of duct material due to ash particles, flow non-uniformity at tube bundles entry. Such issues could lead to lower efficiency of the instrumentation. Therefore, CFD was to supply insight among the behavior of the system and contribute to breakdown the matter.CFD helped in rising the flow pattern by an arrangement of baffles, flow separators at required locations within prescribed pressure drop across the system, up particle separation efficiency. among the works, CFD was wont to analyze & improve flow distribution among the WHRS,that boosts the thermal efficiency of the boiler, correct distribution of particles to avoid erosion of the tubes and improvement among the pressure drop in WHRS. Pure mathematics and mesh were created in Hypermesh & T-grid. The analysis was conducted to follow advanced CFD software system tool, Fluent. Fluent has been applied extensively worldwide for various engineering applications. Fluent solves numerically the Navier-Stokes equations (the elementary fluid dynamics governing equations). The separate section modelling is completed by DPM point in time approach.

Huang, F. et. al.[5] has reviewed a Low-temperature industrial waste heat is a very important heat supply for industrial processes and utility services to scale back the consumption of fossil energy similarly as lower the danger of worldwide warming. during this article, a review of waste heat recovery e an important resolution of waste energy disposal is created to indicate the present standing of heat recovery potentials and also the potential technologies utilized in industries. The construct of industrial waste heat is outlined, potential sources of waste heat from industries are known and conclusions are drawn. Then, the technologies available for waste heat recovery are illustrated in terms of heat pumps, heat exchangers, heat pipes, boilers, refrigeration cycles, power cycles and heat storage according to the transfer mode of waste heat among the recovery method. The waste heat opportunities both in developed and developing countries are mentioned to work out the potential advantages of heat recovery additionally on creating a general survey of the event of heat recovery technologies globally. analysis of typical applications of industrial waste heat recovery in Asian countries and particularly in China is overviewed to point out the performance of this engineering in practice.

Thakar, R. et. al[6] has according to that, the Diesel Generating set (DG Set) that uses diesel was gaining quality in rural areas because it produces electricity for irrigation and agricultural functions. however, there have been numerous losses related to diesel that tends to cut back its efficiency and performance. Among these exhaust heat loss was a major loss that contributes nearly 33-36% and ends up in the waste of heat that might be recovered and a substantial quantity of primary fuel can be saved. within the literature, a survey had reviewed that exhaust gases from diesel having heat potential that would be recovered. within the paper, an attempt had been created recovering of waste energy of exhaust gas of diesel by putting specially designed device simply close to the inlet and outlet duct of the engine so energy from the exhaust was used for preheating the air passed to the engine. a straightforward counter flow shell and tube type device was styled and invented based on the output obtained from the initial design. The experiments were conducted with and while not out heat exchanger on a vertical, single-cylinder, 5 HP, cold start, water cooled, four stroke diesel functioning on high speed diesel fuel. The diesel engine with the incorporation of heat exchanger shows improved performance of the engine and additionally shown a reduction in smoke level. the heat exchanger designed for the aim of recovering the waste heat from the exhaust gases and to heat the inlet air to 1500C at full load by using this heat was operating satisfactorily. The inlet air heating improves the performance of the stationary diesel engine and lowers down the emission level. The effectiveness of heat exchanger was found to be 0.615 at full load condition.

Jouhara, H. et.al.[7] reviewed in waste heat recovery technologies and applications that industrial waste heat was the energy that was generated in industrial processes that were not placed into any sensible use and lost, wasted and drop into the atmosphere. recovering the waste heat was conducted through numerous waste heat recovery technologies to produce valuable energy sources and reduce energy consumption. The author has done a comprehensive review was fabricated from waste heat recovery methodologies and state of the art technologies used for industrial processes. By considering the heat recovery opportunities for energy improvement within the steel and iron, food, and ceramic industries, a revision of these practices and procedures were assessed. The analysis was conducted on the operation and performance of the usually used technologies like recuperators, regenerators, as well as furnace regenerators and rotary regenerators or heat wheels, passive air preheaters, regenerative and recuperative burners, plate heat exchangers and economisers and units like waste heat boilers and run around the coil (RAC). Techniques were thought of like direct contact condensation recovery, indirect contact condensation recovery, transport membrane condensation and additionally the utilization of units like heat pumps, heat recovery steam generators (HRSGs), heat pipe systems, Organic temperature unit cycles, similarly because the Kalina cycle, that recover and exchange waste heat with potential energy content. moreover, the uses of recent rising technologies for direct heat to power conversion like thermoelectric, electricity, thermionic, and thermophotovoltaic (TPV) power generation techniques are explored and reviewed. throughout this regard, the utility of all technologies and usage of each technique with relevance their advantages and disadvantages are evaluated and described.

Shrivastava, A.[8] has given within the paper that, thermal energy storage (TES) unit has become an integral a part of thermal energy conservation. because the name implies, the device simply stores heat once energy from the source is available in excess, and releases identical once energy from the source falls in need of the necessity. By doing, therefore, such devices deliver energy across the temporal barrier, creating thermal energy obtainable for extended operating hours of solar thermal power plants (STPP). High energy density and stable operation for a long period are desirable qualities which can be found in latent heat thermal energy storage (LHTES) system. to use the advantage of LHTES, the foremost common design reportable within the literature is shell-and-tube type latent heat thermal energy storage (ST-LHTES) systems with phase change material stuffed in shell side, whereas (heat transfer fluid) HTF flows within the tubes (or vice versa). this chapter offers an in depth classification of ST-LHTES systems supported geometry, orientation and relative position of PCM and HTF in a device at the side of the classification of phase-change materials. Numerical modelling of heat transfer phenomenon is given beside some simulated results for increased PCM, clearly describing the coupling between PCM and HTF domain. numerous heat transfer enhancement techniques and constant quantity analysis are mentioned with challenges and future scope.

Woolley, E. et. al.[9] has reported that globally one-third of energy consumption is as a result of the industrial sector, with up to fifty percent ultimately wasted as heat. not like visible material waste, waste heat (WHE) is often tough to spot and evaluate each in terms of quantity and quality. therefore by having the ability to know the supply of waste heat, and also the ability to recover, there is a chance to reduce industrial energy prices and associated environmental impacts. A waste heat recovery framework is developed to supply makers with a four step methodology in assessing production activities in facilities, analysing the compatibility of a waste heat source(s) and sink(s) in terms of exergy balance and temporal availableness, choosing acceptable heat recovery technologies and decision support based on economic advantages. The economic opportunity for industrial energy recovery is demonstrated in an industrial case study. The relevance of the framework for wider industrial application is mentioned.

Zhang P et.al.[10] has reported that waste heat of high temperature exhaust flue gases is widely distributed in several industrial processes. Recovery of waste heat is of nice significance to energy saving and property. during this paper, a unique high temperature device with hybrid improvement technologies is planned to enhance waste heat recovery efficiency supported the cascade recovery and utilization technique. the algorithmic rule for HTHE structural design and optimisation is developed and verified according to the experimental results. Heat transfer and pressure drop performance of the proposed HTHE are estimated by using the algorithmic rule. The results show that the effectiveness of the proposed HTHE will increase because the gas temperature will increase and the mass rate of flow decreases. The average effectiveness of the proposed HTHE and temperature of preheated air is 12.5% and 85.8°C over those of traditional HTHE with extra 70.0% and 22.0% pressure drop on air and gas sides, severally. The structural optimisation of the planned HTHE is distributed and it shows that the optimized HTHE has higher heat transfer capability and comprehensive performance under identical pressure drop, increasing effectiveness by 12.6% while not enlarging pressure drop compared with the non-optimized HTHE.

Vizitiua, R.S. et. al.[11] has done CFD analysis. The analysis showed that the heat recovery system could be a possible solution for increasing the energy efficiency of buildings. The equipment was recovered a major quantity of thermal energy from low-temperature residual sources, that was used for heating or heat the domestic hot water needed within a building. Increasing the amount rate of flow of the secondary agent decreases the overall heat transfer efficiency. By deviating the flow through an exact path, the thermal energy recovered was found to be higher. Paraffin coated heat pipes were an honest improvement for the efficiency of the heat exchanger as a result of they operate over small temperature gradients. the flexibility of the paraffin to store thermal energy was additionally an important advantage due to the intermittent regime of the heat source. the prices of production, exploitation, and maintenance were comparatively small as a result of the equipment could be a passive device that does not need its pumping system. The PCMHE will reduce the energy needs of a building whereas decreasing the $CO_2$ emissions that even affect the surroundings.

Ortega-Fernández et. al. [12] has written within the case study that to search out a technological solution for heat recovery from the exhaust gases at extreme temperature exiting within the electric arc furnace of a steelmaking plant.

A thermal energy storage system supported a dual-media packed bed was planned as inexpensive and appropriate technology, employing a by-product made within the same plant, the steel slag, as filler material. the main objective of the system was to realize endless heat provide from the inherent batch operation of the steel furnace. This implementation strategy shows excellent benefits. Among them, the additional price of endless heat source was highlighted because it opens a good variety of applications for the recovered heat, not accessible for discontinuous sources. The obtained results have discovered the massive pressure drop values induced by the packed bed because of the essential design parameter. This development was associated with the massive quantity of discharged energy from the furnace, in conjunction with the short times for its capture and storage. Besides, the influence of the idle period, inherent to the batch operation of the furnace has additionally been investigated. during this case, the short time of static operation along with the thermal stratification behaviour have incontestible the negligible impact of this idle amount within the thermal energy storage unit operation. Finally, the analysis carried out has shown that, once an acceptable optimization method, efficiency values higher than 65th and 85th might be achieved for the cycle and filler material usage, severally. These values show the good waste recovery potential of the projected solution. It should be noted that the definition of the planning and operation parameters of an illustration plant, to be created in a steelwork, was the ultimate target of the bestowed work.

Liu, J. and Sun, F.[13] has done a coupled high-low energy grade flue gas waste heat recovery systems (CWHRS) are applied in power plants to enhance unit efficiency. during this study, to evaluate the rationality of waste heat recovery, the energy-grade balance coefficient (EBC) of the CWHRS was derived exploitation the theory using balance, exergy balance and energy grade balance. The inlet flue gas temperature (IFT) of the low-temperature economizer was defined because of the node temperature of the CWHRS. The optimal node temperature (ONT) was best once absolutely the worth of the EBC was the littlest. The exergy efficiency and EBC of the system put in on a supercritical 600 MW unit were calculated and also the result shows that the ONT of the system was regarding 1150C, the ONT reduced from regarding 1350C to about 1130C once the IFT enhanced from 3350C to 3800C and also the ONT decreased from concerning 1440C to about 1130C once the increased air temperature inflated from 100C to 350C. The node temperature is suggested as an adjusting parameter of CWHRS to confirm the result of waste heat recovery.

Agathokleous, R. et. al [14] according to in work that, within the european union industrial sectors use 26th of the first energy consumption and are characterised by a great number of energy losses within the form of waste heat at completely different energy levels. Their recovery may be a challenge however additionally a chance for science and business. during this study, once a brief description of standard Waste Heat Recovery (WHR) approaches, the novel technologies under development within the I-Therm Horizon 2020 Project are present and assessed from an energy and market views. These technologies are heating to power conversion systems supported bottoming thermodynamic cycles.; heat recovery devices supported heat pipes. The waste heat potential within the EU has been calculable to be 300–350 TWh/year supported the energy consumption breakdown. this is often a crucial quantity of energy saving compared to the 3217.85 TWh energy consumption of 2016, such as greenhouse gas emissions saving moreover. concerning the value of the WHR technologies planned in I-ThERM, it is expected to own 25th additional cost over the traditional technologies, that is balanced by a major improved performance because of higher efficiency. the essential industrial sectors wherever the proposed technologies may be marketed are the iron and steel and cement industries. The potential market of the proposed technologies is mentioned in terms of the market of the standard technologies that may get replaced by the proposed ones. For the FHP system, there is no connected conventional system to check the size of the market, that the analysis is formed supported the industries with radiative heat losses. the most radiative heat is determined in iron and industry and also the size of the market is calculable based on production information in the EU and numerous assumptions. From the analysis, it turns out that 72 TWh/year of waste radiant heat will be potentially recovered from the iron and steel industry, that corresponds to 42.5 million tonnes of $CO_2$ that may be saved if the requested energy is covered by the recoverable energy.

Ahmad, F. et. al.[15] done a domestic chimney provides an exit to the hot toxic gases. The large portion of heat was lost to the surrounding by the exhaust gases. The present study deals to recover this heat and make it for useful purposes. There are many methods to recover this heat but the most important method is a heat exchanger, which transfers the amount of heat to the receiving medium or object. In the present study, the CAD model of a heat exchanger type chimney was created in Catia and analyzed by Ansys. The model was tested for two different types of material for material optimization. The result was compared and analyzed on the bases of temperature and stress distribution due to thermal loading condition.

Khalid, R. et. al.[16] has done a knowledge center waste heat recovery is an energy efficient and economically viable choice once the information center was close to different facilities. This study explores boosting the vapor from the knowledge center's two phase server waste heat employing a novel vapor re-compression system. The boosted waste heat contains adequate thermal energy to drive an absorption refrigeration chiller to get a stream of cold fluid. as an alternative, the chiller will be bypassed to use the boosted heat directly within the neighboring facility. These approaches are modeled to modify the estimation of energy saving and economic benefits under totally different cooling and heating loads. This calculation also indicates situations wherever the compressor should be by-passed, and also the server exhaust simply sent to the condenser for rejection to the ambient. The analysis was targeted on the waste heat recovery and re-use potential of a 1MW data center a middle size edifice within the vicinity. The paper focuses on two issues: 1) the efficiency of waste heat system, as well as neighboring, once boosted with the novel recompression system versus a turn key heat pump coupled with warm water cooling and 2) A comparison of the relative capital and operating expense of the two systems. The result shows that the novel recompression system has a lower price and a higher thermodynamic efficiency than a warm cooling system coupled to a conventional heat pump and use of novel waste heat recovery system is viable in areas with high electricity price.

Kostowski, W. et. al.[17] deals with waste heat recovery from a fossil fuel compressor station driven by a collection of seven gas engines. Attention is paid to waste heat from engine exhaust gases. potential choices of energy recovery include: a) direct heat recovery with optional thermal energy storage, b) conversion of waste heat to electricity via an ORC module or c) integration of gas expanders into the gas supply line in junction with waste heat recovery. choices for direct utilization of the recovered waste heat comprise a) provide of heat for the in-house demand of the cs object, b) provide of the heat of a bigger residential consumer c) supply of heat for an infatuated consumer, by choice located next to the cs. For external provides heat can be provided by pipeline or via a mobile PCM storage. The studied choices were connected with the possible pilot plant design bottoming one or two engines with a waste heat recovery system. For the potential pilot plant, the overall rate of waste heat recovery from the cs is low, starting from 3.1% to 11.6% for the studied cases. Effects connected only to the given engine represent between 19.3 and 41.4% recovery rate. at the same time, these effects are important for the studied consumers, having the ability to hide between 33.7 to even 98.1% of their demand from the waste heat recovery source. PCM storage includes a weak and non-uniform impact on system performance, looking on the profile of source and consumer. Direct heat recovery is suggested for a pilot plant, and also the recovered quantity of waste heat could reach 900 MWh/year from single-engine if operated continuously. Electricity generation could reach 530 MWh year (gas expander system) or concerning 300 MWh/year (ORC system), however, the latter should be suggested for more than one engine as a waste heat source.

Li, T. et. al.[18] present the flue gas heat may be recovered by organic Rankine cycle (ORC) or Two-Stage series Organic Rankine cycle (TSORC) however, their comprehensive performance should be compared thoroughly. during this paper, ORC and TSORC are compared from thermodynamic and economic points of view. The technical indicators include the net output power, efficiency, thermal conductance, volumetric flow ratio, and also the economic indicators the electricity production cost (EPC), payback period (PBP) and rate of return on investment (ROROI). The results show that the TSORC will recover a lot of heat within the low-pressure stage from the heat source to decrease the irreversible loss between the heat source and the operating fluid in contrast with ORC, thereby enhancing the net output power and energetic efficiency however decreasing the thermal efficiency. However, from the economic purpose of view, the TSORC declines the EPC, PBP and ROROI because of that the increased investment is more than the earnings as a result of the installation of the second-stage evaporation. a higher flue gas temperature from 200 °C to 300 °C tends to boost the tech-economic performance of the TSORC. because the manufacturing price goes down over time, the TSORC can further improve its economic performance within the future.

Masud, M.H. et. al.[19] given in paper that, food waste is an alarming issue for the modern world. Drying is one among the oldest and best solutions for overcoming unessential food waste. However, most of the conventional drying consumes a major quantity of energy to get rid of water from food. On the opposite hand, there are many sources, that cause heat waste. good utilization of waste heat from sources as well as IC engine, turbine, brick oven and one thing like those would be an excellent solution to the energy consumption problem of food drying. there is no systematic theoretical analysis of waste-heat-based food drying system available within the literature. during this study, a comprehensive transport model of drying system using the engine's exhaust waste heat has been simulated. Utilization of a small lab-scale IC engine exhaust ends up in reducing about 1137.15 kg of carbon dioxide per annum that might be made from a conventional food drier of identical capability. additionally, low installation cost and payback period provide a promising rational solution of the drying system. The proposed system is additionally capable of reducing entropy to a considerable extent. Therefore, successful implementation of this proposed technique would supply a high-energy economical, inexpensive drying system along with ensuring green surroundings.

Masud, M.H. et. al.[19] given in paper that, the waste product is AN minacious issue for the fashionable world. Drying is one among the oldest and best solutions for overcoming spare waste product. However, most of the traditional drying consumes a major quantity of energy to get rid of water from food. On the opposite hand, there area unit several sources, that cause heat waste. good utilization of waste heat from sources together with an IC engine, turbine, brick oven and one thing like those would be an excellent answer to the energy consumption drawback of food drying. there's no systematic theoretical analysis of waste-heat-based food drying system accessible within the literature. during this study, a comprehensive transport model of drying system victimization engine's exhaust waste heat has been simulated. Utilization of a tiny low lab-scale IC engine exhaust ends up in reducing concerning 1137.15 metric weight unit of carbonic acid gas each year that might be created from a traditional food drier of constant capability. additionally, low installation price and payback amount supply a promising rational answer of the drying system. The projected system is additionally capable of reducing entropy to AN considerable extent. Therefore, the prosperous implementation of this projected technique would supply a high-energy economical, inexpensive drying system besides guaranteeing an inexperienced atmosphere.

Mateu-Royo, C. et. al.[20] has present that a high quantity of industrial thermal energy remains lost because of the shortage of competitive solutions for energy revalorization. Facing this challenge, this paper presents a unique technology, supported a reversible High-Temperature heat pump (HTHP) and Organic Rankine Cycle (ORC). The projected system recovers low-grade waste heat to come up with electricity or helpful heat by consumer demand. compressor and expander semi-empirical models are considered for the reversible system computational simulation, being HFC- 245fa the operating fluid selected. The inbuilt volume ratio and Internal heat exchanger (IHX) effectiveness are optimized to achieve the most energy efficiency in every operating condition. although HFC-245fa exhibits energy performance attributes, its high global warming potential (GWP) is a difficulty for global climate change mitigation. Hence, multi-objective optimization of the environmentally friendly operating fluids butane, Pentane, HFO-1336mzz(Z), R-514A, HCFO-1233zd(E) and HCFO-1224yd(Z) has been carried out. The results show that the system proposed, operating with HFC-245fa, achieves a coefficient of performance (COP) of 2.44 for condensation temperature of 140 °C, operational in HTHP mode, whereas the ORC mode provides a net electrical efficiency of 8.7% at condensation temperature of 40 °C. Besides, HCFO-1233zd(E) and HCFO-1224yd(Z) are each appropriate alternatives for the HFC-245fa replacement. These operating fluids give a COP improvement of 9.7% and 5.8% and electrical net efficiency improvement of 2.1% and 0.8%, severally, compared to HFC- 245fa. This paper provides a reference study for more designs and developments of reversible HTHP-ORC systems used for industrial low-grade waste heat recovery.

Pelda, J. and Holler, S.[21] reported in paper statistically validates a unique methodology that quantifies, qualifies and spatially allocates the waste heat potential of waste material systems on an urban district level, altogether cases during which real information from the sewage system does not exist or is not publically available. The methodology is predicated on open data and open source technology and might be adapted to numerous forms of cities. The results, from the appliance of the methodology for an example city, show that the methodology robustly calculated the ways and wastewater volumetrical flow from wastewater sources to the wastewater treatment plant. The modelled system maps the sewage system accurately among areas that have a population density near the average. Despite little inaccuracies within the overall mapping, the methodology is in a position to present a decent estimation of spatially distributed waste heat from water flows of the sewage system within the example city.

## II. CONCLUSION

It has been identified that there are large potentials of energy savings through the use of waste heat recovery technologies. Waste heat recovery defines capturing and reusing the waste heat from different thermal devices (IC Engine, Refrigeration System, Boiler etc.) for heating, generating mechanical or electrical work and refrigeration system. It would also help to recognize the improvement in performance and emissions of the thermal system. If these technologies were adopted then it will result in enhancement is the efficiency of system and reduction in emission. The waste heat recovery from exhaust gas and conversion into mechanical power is possible with the help of Rankine, Stirling and Brayton thermodynamic cycles, vapour absorption. The use of CFD analysis is also useful to get the thermal performance of the system before fabrication. It saves the cost and time of fabrication and testing. For waste heat recovery thermoelectric generator is used low heat, which has low efficiency. It is helpful for the same amount of increases in thermal efficiency and reduction in emission.

## REFERENCES


[1] Manickam, M., Schwarz, M.P. and Perry, J., 1998. CFD modelling of waste heat recovery boiler. *Applied Mathematical Modelling*, *22*(10), pp.823-840.

[2] Zhang, G., Li, S., Jiang, H. and Xie, G., 2015, August. Application of Radial Heat Pipe to Heat Recovery of Flue Gas. In *2015 International Conference on Advanced Engineering Materials and Technology*. Atlantis Press.

[3] Jouhara, H., Almahmoud, S., Chauhan, A., Delpech, B., Nannou, T., Tassou, S.A., Llera, R., Lago, F. and Arribas, J.J., 2017. Experimental investigation on a flat heat pipe heat exchanger for waste heat recovery in steel industry. *Energy Procedia*, *123*, pp.329-334.

[4] Ducting, C., International Journal Of Engineering Sciences & Research Technology Cfd Simulation Of Flue Gas Ducting In Waste Heat Recovery Plant.

[5] Huang, F., Zheng, J., Baleynaud, J.M. and Lu, J., 2017. Heat recovery potentials and technologies in industrial zones. *Journal of the Energy Institute*, *90*(6), pp.951-961.

[6] Thakar, R., Bhosle, S. and Lahane, S., 2018. Design of heat exchanger for waste heat recovery from exhaust gas of diesel engine. *Procedia Manufacturing*, *20*, pp.372-376.

[7] Jouhara, H., Khordehgah, N., Almahmoud, S., Delpech, B., Chauhan, A. and Tassou, S.A., 2018. Waste heat recovery technologies and applications. *Thermal Science and Engineering Progress*, *6*, pp.268-289.

[8] Shrivastava, A. and Chakraborty, P.R., 2019. Shell-and-Tube Latent Heat Thermal Energy Storage (ST-LHTES). In *Advances in Solar Energy Research* (pp. 395-441). Springer, Singapore.

[9] Woolley, E., Luo, Y. and Simeone, A., 2018. Industrial waste heat recovery: A systematic approach. *Sustainable Energy Technologies and Assessments*, *29*, pp.50-59.

[10] Zhang P, Ma T, Li W-D, Ma G-Y, Wang Q-W, Design and optimization of a novel high temperature heat exchanger for waste heat cascade recovery from exhaust flue gases, *Energy* (2018), doi: 10.1016/j.energy.2018.06.216.

[11] Vizitiua, R.Ș., Burlacua, A., Isopescua, D.N., Verdeșa, M., Sosoia, G. and Lăzărescua, C.D., 2018. CFD analysis of an innovative heat recovery system.

[12] Ortega-Fernández, I. and Rodríguez-Aseguinolaza, J., 2019. Thermal energy storage for waste heat recovery in the steelworks: The case study of the REslag project. *Applied energy*, *237*, pp.708-719.

[13] Liu, J. and Sun, F., 2019. Node Temperature of the Coupled High-Low Energy Grade Flus Gas Waste Heat Recovery System. *Energies*, *12*(2), p.248.

[14] Agathokleous, R., Bianchi, G., Panayiotou, G., Arestia, L., Argyrou, M.C., Georgiou, G.S., Tassou, S., Jouhara, H., Kalogirou, S.A., Florides, G.A. and Christodoulides, P., 2019. Waste Heat Recovery in the EU industry and proposed new technologies.

[15] Ahmad, F., Farooz, M., Saini, N.K. and Chauhan, V.S., Preliminary Design and Analysis of Water Boiling Domestic Chimney by Finite Element Analysis.

[16] Khalid, R., Schon, S.G., Ortega, A. and Wemhoff, A.P., 2019, May. Waste Heat Recovery Using Coupled 2-Phase Cooling & Heat-Pump Driven Absorption Refrigeration. In *2019 18th IEEE Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm)* (pp. 684-692). IEEE.

[17] Kostowski, W., Pajączek, K., Pociecha, A., Kalina, J., Niedzielski, P. and Przybył, A., 2019. Methods of waste heat recovery–A compressor station case study. *Energy Conversion and Management*, *197*, p.111837.

[18] Li, T., Meng, N., Liu, J., Zhu, J. and Kong, X., 2019. Thermodynamic and economic evaluation of the organic Rankine cycle (ORC) and two-stage series organic Rankine cycle (TSORC) for flue gas heat recovery. *Energy conversion and management*, *183*, pp.816-829.

[19] Masud, M.H., Islam, T., Joardder, M.U.H., Ananno, A.A. and Dabnichki, P., 2019. CFD analysis of a tube-in-tube heat exchanger to recover waste heat for food drying. *International Journal of Energy and Water Resources*, *3*(3), pp.169-186.

[20] Mateu-Royo, C., Mota-Babiloni, A., Navarro-Esbrí, J., Peris, B., Moles, F. and Amat-Albuixech, M., 2019. Multi-objective optimization of a novel reversible High-Temperature Heat Pump-Organic Rankine Cycle (HTHP-ORC) for industrial low-grade waste heat recovery. *Energy Conversion and Management*, *197*, p.111908.

[21] Pelda, J. and Holler, S., 2019. Spatial distribution of the theoretical potential of waste heat from sewage: A statistical approach. *Energy*, *180*, pp.751-762.