Review of Different Technique to Enhance Heat Transfer Rate of Hot Gas Carrying Turbine Stack

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Abstract—the exhaust system of gas turbine is directly connected to high temperatures as they form the path for the hot gases. It consist of only bigger size of duct which having very short life span as there is lot of restriction provided to the flow of hot gases in terms of bents and height of it in order to reduce the noise level. Hence gases traveling more time in this section as compare to other part of gas turbine. So that those area need to be modify during design phase, here even distribution of heat along the entire exhaust system is necessary for improving life span of the elements in the exhaust system.

Keywords: Exhaust system, Heat transfer enhancements, Tube inserts, Heat exchangers.

Nomenclature:
y= successive distance between two adjacent twist, w= width of twisted tape, p= pitch of wire coil, d= wire diameter of coil, y/w= twist ratio (TR), p/d= pitch ratio, TT= twisted tape, D= tube diameter, δ=dimple depth, a=dimple print diameter, CD= Converging diverging tube, e/D= effective roughness factor, ST = lateral distance between adjacent dimple, SL = longitudinal distance between adjacent dimple.

I. INTRODUCTION

The main objective of exhaust system of gas turbine is to direct the path for the flow of hot gaseous and reduce noise level produced by the gas turbine. The turbine stack is normally of two types one is absorptive type and other is reactive type. In case of absorptive type of turbine stack sound wave get absorbed in to sound absorbing material and it is converted into heat and absorb by that material only. In case of reactive type turbine stack numbers of baffles plates are arrange alternately to damp the sound wave. For both the types of exhaust system, uniform distribution of heat is important. But because of high temperature of exhaust gaseous some area undergoes in thermal failure which reduces life span of exhaust system. So without affecting primary structure of the current system we will modify the same for uniform heat

II. LITERATURE REVIEW

In the Article from HRS technology [1] the author reported that one of important factor controlling heat transfer is the resistance to heat flow through the various "layers" that form the barrier between the two fluids. The driving force for heat transfer is the difference in the temperature levels between the hot fluid and cold fluid, the greater the difference the higher the rate at which the heat will flow. The resistance to the heat flow is formed by five layers as follows:

1. The inside "boundary layer" formed by the fluid flowing in close contact with the inside surface of the tube.
2. The fouling layers formed by deposition of solids or semi solids on the inside surface of the tube.
3. The thickness of the tube wall and the material used will govern the resistance to heat flow through the tube.
4. The fouling layer formed by deposition of solids or semi solids on the outside surface of tube.
5. The outside boundary layer formed by the fluid flowing in close contact with outside surface of the tube.

By number of experiment it is found that during turbulent flow heat transfer rate is more as compared to the heat transfer at laminar flow; but turbulent flow develop only at high speed for that we have to make rough surface which result pressure drop and high speed which make flow turbulent hence erosion of tube are more at that high speed, so there is need to generate the turbulent flow at less speed which only possible by changing their internal structure so it will not generate high pressure drop as well maintain the turbulent flow for that they design shallow spiral structure for inside surface of the tube. Which result at low speed al so turbulent flow is achievable.

In the article from orbit coating [2] the authors reported that there are normally two type of oxidation occurs in case of automobile silencer. One is because of high exhaust temperature and second is because of acidic nature of exhaust gaseous when it cools down. So if we use only steel for manufacturing of silencer body it will not survive from oxidation. To fix that problem they suggest to use aluminized steel (aluminum coated steel) for silencer body. Hence the aluminum coating present on the steel resist the acidic oxidation of silencer body.

Mehmet Avcu et. al. [4] carried out thermal analyses of the exhaust system. For that they used CFD Analysis (anasys CFX 12 model). They make a modification for wet type of silencer in that they design four different type of geometry in first geometry the inlet of cooling water are 90_0 with single inlet and in second geometry they use same 90_0 with two inlet for cooling water. But in third and fourth geometry they use 45_0 of inlet pipe with single and double inlet for cooling water. In Wet-type silencer model for single and perpendicular inlet condition they got mean temperature 73 °C , for double and perpendicular inlet condition they got mean temperature 57 °C. For Wet-type silencer model for single and 45° inclined inlet condition they got mean temperature 106 °C and for double and 45° inclined inlet condition they got mean temperature105°C. From that it is found the Wet-Type Silencer Model for Double and Perpendicular inlet Condition is more effective.

In this paper Veeresh Fuskele, R. M. Sarviya [5] prepares experimentation set up for tube in tube type heat exchanger with new type of insert called twist wire mesh tape. On the same method various author performed CFD and mathematical approach unlike those current author shows the effectiveness of same insert by experimental set up for the Reynolds number range of 2000-12000. The experimental set up consist of tube with annulus; in that they used tube of 9.5 mm inner diameter and length of 1250 mm with annulus through which cooling water flows in counter direction with same flow rate except hot oil having different flow rate. Author used two different twist tape having twist ratio 5 and 7 separately which shown in figure 1 and 2.

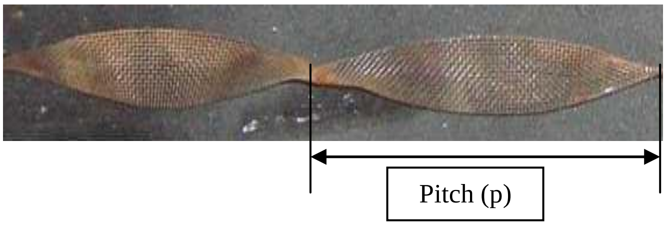

Fig.1 Twisted ape with twist ratio 7 [5]

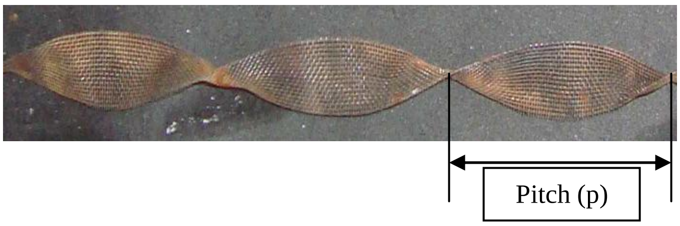

Fig.1 *Twisted tape with twist ratio 5 [5]*

For sensing purpose they used pressure gauge, rotameter, RTD temperature gauge which gives the different reading at various flow rate. From that they calculated modified heat transfer rate and frictional factor. And those calculated parameter compare with theoretical heat transfer and frictional factor on same Reynolds number. From that comparison they found new type of insert responsible to enhance heat transfer rate twice and friction factor increases four times of theoretical friction factor. This is just because of high degree of eddies which generate by twisted tape inside the tube.

R. Zimmerman et al.[6] discussed their study of two phase air water flow through horizontal pipe. The experimental study carried out to determine heat transfer coefficient and its connection to flow pattern and liquid film thickness at various flow rates of air and water. They are introducing highly compressed air in to water in order to form more turbulence in the pipe which result higher heat transfer coefficient at air entering section of pipe as compared to only water section. In this experimentation heat transfer coefficient calculated from the temperature measurement which was done by infrared thermograph method. On the basis of this study author conclude that as the velocity of air and water increases heat transfer coefficient increase and as the liquid film thickness increase heat transfer coefficient decrease. The film thickness is maximum at one side of horizontal pipe because of gravitation fore and uniform at vertical pipe so for more heat transfer that film need to be disturb in case of horizontal pipe in order to mix the water present at boundary layer in to center position water which only possible by multiphase flow with greater velocity.

A. G. Matani , Swapnil A. Dahake [7] discussed experimental study of new type of inserts such as single twisted tape, double twisted tape and wire coil with twisted tape and without twisted tape. Those are only for the purpose of vortex flow generation inside the horizontal tube. In case of horizontal tube boundary layer thickness is more at lower half of tube as compared to the upper half of the tube this is just because of gravitational force. This uneven boundary layer thickness causes un uniform heat absorption from the surface of heat exchanger. Whose ultimate result high surface temperature at lower surface and poor efficiency of heat exchanger. Hence for making uniform heat distribution we need to disturb the lower boundary layer in horizontal pipe for that purpose author develop vortex flow by introducing some insert and those are as follow
1) Twisted tape (y/w = 3.5, 2.66, 2.25)
2) Double twisted tape (y/w=3.5, 2.66)
3) Wire coil (p/d = 1.17, 0.88).
After the experimentation author conclude that all the tube with insert are giving better efficiency over the tube without insert and out of all the insert wire coil insert having higher Nussle number for the same range of Reynolds number.

C.Nithiyesh Kumar, P.Murugesan [8] review and discussed effect of various type of active, passive and combination type of technique in order to increase the heat transfer rate from the heat exchanger tube. They discussed 34 different type of twisted tape with different additional devices. On the basis of this review it is obvious the heat transfer rate of the plain tube with some insert can possible to improve with certain extent but investigation of pressure drop in such tube is important because it responsible to increase the pumping effort. Which normally generate because of such inserts.

S. Liu, M.Sakr[9] discussed their review on passive heat transfer enhancements in pipe heat exchangers. To create eddies in the fluids and destroy the actual boundary layer so as to increase surface effectiveness author suggested to use nine aspects. They suggested to use different type of surface feature such as Treated, Rough, Extended, surfaces and also suggested to use devices like displaced enhancement, Swirl flow, Coiled tubes, Surface tension, Additives for liquids, Additives for gases. In addition to that they discussed the effect of number of passive method to enhance heat transfer rate in horizontal tube. Under that method they discussed various devices with their experimental work and numerical work in order to identify the overall enhancement factor. From the observation of numerical and experimental method it found that the shape of insert are important because it al so offers the more frictional surface which result higher pressure drop. Hence the twisted tape is more preferable for laminar flow. If pressure drop is not big issue then it is useful in both laminar and turbulent flow. In all aspect the wire coil giving better enhancement factor with low pressure drop as compare to other devices. And remaining other passive devices such as swirl generator, conical ring and ribs are useful for turbulent flow.

Sandeep S. Kore et al.[10] investigate the effect of varying dimple depth which having constant print diameter on the heat transfer coefficient. And the ratio of δ/a is ranges from 0.2 to 0.4. Dimples are passive method of enhance the heat transfer coefficient. Which result thermal efficiency of heat exchanger are increases effectively. But then al so it how much effective if the size or depths of dimple are increases with constant dimple print diameter for that purpose author did the experimental investigations. In the experiment by keeping all the parameter constant they changing the test section of channel. They normally used three different depth of dimple test channel which having dimple depth 10 mm , 15 mm and 20 mm with 50 mm constant print diameter. The Reynolds numbers during investigation based on hydraulic diameter are ranges from 10000 to 40000. The channel height to dimple print diameter ratio and channel aspect ratio is 0.5 and 4 respectively. In the experimentation they found Nusselt number are increases for the range of δ/a ratio 0.2-0.3 but it decreases for the range of 0.3-0.4 and when it compare with the Nusselt number for the smooth surface channel it found 0.3 and 0.2 depth dimple channel having grater Nusselt number and it decreases for the dimple depth 0.4 for the same range of Reynolds number. The Nusselt number is higher for depth ratio 0.3 because of formation of stronger vortices, with more pronounced shear layer reattachment. It is also because of the ejection and local jetting of flow from the dimple of depth ratio 0.3 is stronger, which results in vortex pairs with stronger and more pronounced secondary flows. The depth ratio 0.4 having lower Nusselt number because it offers more resistance for the flow of fluid. Hence more amount of fluid get accumulated at that place which then acts as resistance to heat transfer.

Iftikarahamad H. Patel et al.[11] discussed experimental method in which they determine the surface effectiveness of dimple pattern plate for the heat dissipation problem. For that purpose they employed two different types of dimple pattern plates. In which one plate having inline pattern of dimples with dimple density 204 in number and other plate having staggered dimple pattern with dimple density 187 in number. In this paper they using aluminum plates of dimension 400x72x6 mm^3 which having inline and staggered dimple pattern. During the experimentation all the boundary condition of experiment are constant except test plate in channel section. Hence same experiment is repeated for two different test plates with different flow rate of air in channel section. On the basis of experimental reading for two plates at different flow rate of air in channel they used to plot graph for Reynolds number Vs. Nusselt number. And it indicate the staggered dimple pattern channel plate having more surface effectiveness for heat dissipation problem as compared to inline dimple pattern plate. This is because Nusselt number is higher due strong vortices formation in staggered arrangement i.e. turbulence is more in case of staggered arrangement. But in case of inline arrangement of dimple flow of air following straight path between the two neighboring row of dimples which result thicker boundary layer in that portion as compare to the portion over dimple row but it not happened in case of staggered arrangement hence inline pattern having Nusselt number greater than smooth surface plate but not more than staggered dimple pattern.

R. L. Edlabadkar et al. [12] investigate experimental result with computational analysis result. For that purpose they use CFD method. In that all preprocessor activity done in Gambit Preprocessor and analysis are performed in FLUENT with laminar viscous model. In the analysis they examine fin of three categories which is made of steel and mounted on the steel plain plate of dimension 2.1 m × 0.5 m × 0.45 m. the categories of fin are as follow.
1) Vertical plate with horizontal fin
2) Vertical plate with vertical fin
3) Vertical plate with V type fin
a) 60° V fin
b) 90° V fin
c) 120° V fin
For comparison purpose all the fins having same surface area and boundary condition. The base plate and fin having same temperature and they kept temperature difference between surface and atmosphere is 150°C for all fins. After the analysis it is clear experimental data are approximately matched with CFD data with +/- 10% error. And CFD analysis al so shows 90° V type fin is more effective over the other fin. This gives base plat heat transfer coefficient 6.26w/m^2k. It is because 90°
V fin offers fewer obstacles for flow disturbance in the upside region and most effective high heat transfer region in the downside region of the base plate. It observed that out of all type of fins partition maximum heat transfer achieved in case of 90° V-partition plates as compared to other.

Satish G. Kandlikar et al. [13] study the effect of roughness on heat transfer by experimentation method. Under the study they kept the value of Reynolds number much below i.e. 2300 with single phase flow in channel with small hydraulic diameter.

For changing the roughness of inside surface of tube acid etching method was employed during experimentation. They used two stainless steel tubes of 1.032 cm and 0.62 cm of inner diameter which acid treated to provide three different effective roughness values for each tube. The Reynolds number range for the test was 500-2600 for 1.032 cm tube and 900-3000 for 0.62 cm tube. The effective roughness (e/D) for

1.067 cm diameter tube is 0.0025, 0.00178 and 0.00281 and for 0.62 cm diameter tube is 0.00355, 0.0029 and 0.00161. From the experimentation found that the effect of varying roughness from 0.00178 to 0.00225 on heat transfer of 1.067 cm tube was insignificant but for 0.62 cm diameter tube roughness plays significant role. From that it found the tubes of small diameter i.e. less than 0.62 cm is more effective with increasing the effective roughness factor. From that it is clear if tube diameter increases then for same roughness value as that of small tube it gives the low heat transfer rate; hence as tube diameter increases roughness value also have to increases to maintain the effectiveness of tube for heat transfer rate.

In this paper N. Katkhaw et al. [14] studied effect of inline and staggered arrangement of ellipsoidal dimple on heat transfer from the flat plate. They perform experiment for that with different dimple pitch. In case of staggered arrangement they was used dimple of dimple pitch (S_T/S_L) 1.25, 1.11, 1.00, 1.33, 1.67 and similarly in case of inline arrangement they used dimple of dimple pitch (S_T/S_L) 1.00, 1.25, 1.89, 0.8, 1.00 and 1.11. The value of S_T and S_L for various dimple pitch shown below.

TABLE I. ST/SL CHARACTERISTIC

No.	S_T	S_L	Arrangement	S_T/S_L
1	50	40	Staggered	1.25
2	50	45	Staggered	1.11
3	50	50	Staggered	1.00
4	60	45	Staggered	1.33
5	75	45	Staggered	1.67
6	40	40	Inline	1.00
7	40	45	Inline	1.89
8	40	50	Inline	0.80
9	45	45	Inline	1.00
10	50	45	Inline	1.11

The pattern of dimple surface for both staggered and inline arrangement are shown in figure 3 and 4. As shown in table 1 for staggered arrangement first and third they keeping S_T constant and S_L varying and for second, fourth and fifth arrangement S_L is constant and S_T is varying. Similarly in case of inline arrangement for sixth and eighth pattern S_T is constant and S_L is varying and for seventh, ninth and tenth pattern S_L is constant and S_T is varying. In case off staggered pattern when S_T is maximum up to 75 mm system shows significant effect as compared to flat plate but it not shows positive effect as compared to spherical dimple of same features. It happens because in case of ellipsoidal dimple of staggered pattern because the dimple structure establishes the less effective heat transfer area inside it and enhances the heat transfer rate at outside area. Hence if dimple arrange very close to each other then effective area offered by that structure is very less. In case of staggered pattern dimple rushes the plate surface so enhanced area between two dimple is very less when S_T is minimum hence S_T increases heat transfer rate al so increases up to certain value.

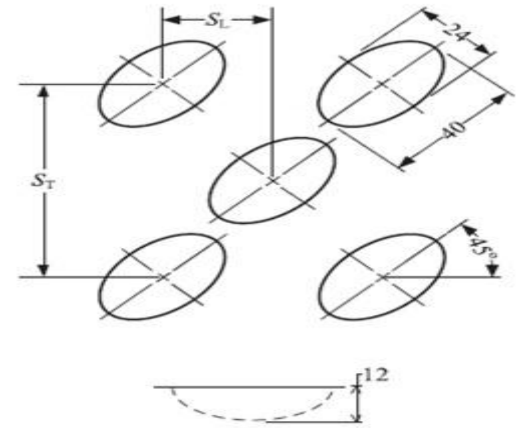

Fig.3 *Staggered* dimples [14]

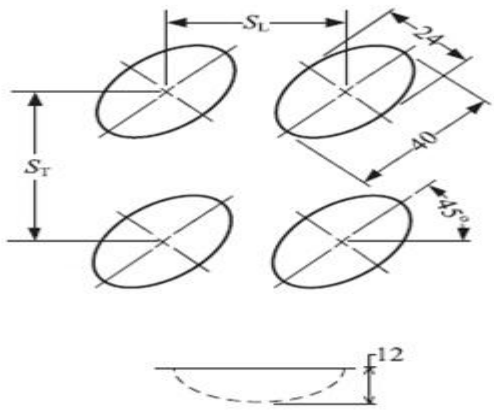

Fig.4 *Inline* dimples [14]

III. DISCUSSION ON REVIEW

To increase the heat transfer rate from the surface of the turbine exhaust system we have to focus on four parameter [1] such as thickness of solid deposition or semi solid on inner side, boundary layer thickness of fluid flowing at inner side, thickness of sheet metal wall, thickness of solid deposition or semisolid on outer side of silencer wall and boundary layer thickness of outer atmospheric air near to silencer wall. In our case we can't control on inner side deposition because exhaust always contain carbon partial, al so we can't make the inner flow more turbulent by adding extra baffle or perforated tube because inner structure is already design on the basis back pressure consideration which directly acted on turbine hence those modification may create more back pressure on engine. Hence we have to consider other three features such as wall thickness which we try to make thin as possible and problem because of outer deposition and outer air boundary layer thickness near to wall we can fixed by surface enhancement. As some author use various techniques for surface enhancement such as external fins [3] [12], dimple pattern with different features [10-11] but they used dimple pattern at inner surface of tube., they also use surface roughness to enhance outer surface for heat transfer [13], some author used shallow extended spiral feature at internal surface of tube [1],this all method are use for outer surface enhancement but to make inner flow more turbulent different type of twisted tapes used [5-9], and multiphase flow also used [6] to make flow more turbulent at inner side of tube. In our case we have to enhance outer surface which make outer flow more turbulent near to exhaust system wall for that we can use dimple pattern at outer surface of turbine stack, extended shallow spiral at outer surface, we also make outer surface more rough so flow become turbulent near to that wall. There is other option also available such as external spiral fin on outer peripheral of body.

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