Exploring Productivity Enhancement Option for Pulp and Paper Industry in Pakistan

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***Abstract*: Pulp and paper industry is one of the most energy intensive industries worldwide. Drying process consumes major part of energy in pulp and paper industry. Hence the objective of this research work involves finding out potential of energy saving in drying section. The methodology of retrofitting (improvements in existing technologies) is adopted for the dryer section, since pulp and paper industry is a capital intensive industry and inducting new technology requires huge capital cost. The data is collected from a local pulp and paper integrated industry. Potential energy savings and equivalent productivity enhancement are obtained by incorporating process improvement. The retrofitting for conventional multi cylinder drying section includes optimization of air flow rate, temperature, and optimization of humidity through the application of closed hood dryer system and installing heat recovery system to preheat air going in the dryer section. For the discussed retrofitting for dryer section, the total energy saving potential found is 2.48 GWh which is around 18% of the total energy use of 13.58 GWh by the paper mill per annum. Also, the equivalent productivity enhancement through the energy saving is around 17% (6.5k tons per anum or 18 tons per day) of the total annual production of 40k tons. The payback period for the suggested retrofitting for the paper mill is approximately 11 months.**

***Keywords*: Paper Industry, Productivity, Energy efficiency, Sustainable development**

I. INTRODUCTION

The pulp and paper industry is listed among top 5 largest energy consuming industrial sectors [1] and therefore has higher potential for energy saving. The dryer section is the greatest heat consumer section of paper industry [2]. For the identified best practices, energy saving potential in drying section is about 15% of total energy in a selected mill [3]. Maximum energy efficiency is achieved when dryer hood is fully closed, air dew point is high and maximum possible heat is recovered [4]. The yields of investments in heat recovery systems are positive and result 12% decrease in fuel use and 24% decrease in CO2 emissions[5]. In economic perspective, it is a viable option to retrofit the existing paper machine rather than inducting new technology since a state of art paper machine can cost up to 400 million USD [6].

1.1 Dryer section of Paper industry

The technique of mechanical pressing by rollers is used to dry the pulp initially. The pulp is then passed through, while being in contact with, a number of heated rollers known as dryer section. The rollers are steam heated. The wet paper sheet passes in contact with heated rollers and is dried by evaporation of water vapor it contains. The drying operation is done in stages i.e pre dryer and post dryer. Size press process stage is in between the two drying stages. Coating of paper sheet is carried out in size press. The coating is carried out by applying a starch water solution to pre dried paper sheet increasing its moisture content. The paper sheet is then sent to post drying section to further remove moisture added during coating. After these two drying stages, the sheet is dried to 95%, approximately 5% moisture remains in the paper sheet, in usual cases.[7].

1.2 Close hood system for dryer section

Close hood dryer system is a mechanically constructed system having a roof, walls and is usually covered at the operating level of dryer section. The advantage of this system is that it controls temperatures and humidity inside the dryer section for optimum drying conditions which results in achieving higher energy saving [8]. The closed hood systems also offer technical viability of installing heat exchanger systems to increase thermal efficiency by recovering energy from heated exhaust air of dryer section and using it to pre-heat incoming air and process water. Also, close hood insulates the drying section, cutting the heat leakage to paper machine room, and maintaining a suitable constant temperature inside the dryer section [9].

II. RESULTS

The equations used here are taken from Ph.D. thesis by Jobien Laurijssen [3], and from “Heat exchangers” chapter from the Book titled as “Heat Transfer” by younus cengel [11].

$$WV_{pd} = ((100/Dm_{in}) - (100/Dm_{apd})) * Pm_{dry} \quad (1)$$

$$WV_{psd} = ((100/Dm_{psd}) - (100/Dm_{o})) * Pm_{dry} \quad (2)$$

$$WV_{total} = (WV_{pd} + WV_{psd})*1000 \quad (3)$$

$$E_{input} = H_{exhaust} - H_{supply} \quad (4)$$

$$Air_{used} = 1/ (W_{exhaust} - W_{supply}) \quad (5)$$

$$Q = U_{overall}*Area*(Temp_{steam} - Temp_{air}) \quad (6)$$

Heat transfer to the air around the paper sheet varies with the temperature of ambient air, as shown in equation (6). Hourly temperature data is obtained for a time period of one year (October 2018 to October 2019). By this data, temperature variation range is determined for the location where studied paper industry is based. The recorded least air temperature was 9^{o} C and recorded maximum air temperature was 42^{o} C. Also from the data, the time period of specific scale of temperature for a specific number of hours is determined for the total of 8760 hours of the year. Table below shows the rate of Heat transfer at various air temperatures of the obtained range with and without taking the effect of heat recovery:

Table 1: Heat transfer in dryer section at different ambient temperatures with and without closed hood heat recovery system

Air Temperature [ºC]	Rate of Heat transfer without taking effect of Heat recovery [Kwatt]	Rate of Heat transfer taking effect of Heat recovery [Kwatt]	Variation in rate of Heat transfer for the two cases [Kwatt]	Time that the specific temperature remained in one year [hour]	Variation in energy utilized in drying section [KWh]
9 ºC	1210	821	389	82	32.6×10^3
10 ºC	1198	815	383	110	41.3×10^3
11 ºC	1192	813	378	86	31.7×10^3
12 ºC	1182	809	372	146	54.9×10^3
13 ºC	1172	805	366	145	54.06×10^3
14 ºC	1162	801	361	263	93.6×10^3
15 ºC	1152	798	355	164	56.6×10^3
16 ºC	1142	794	346	188	66.7×10^3
17 ºC	1134	788	343	123	41.1×10^3
18 ºC	1124	784	335	155	53.2×10^3
19 ºC	1114	780	331	207	67.4×10^3
20 ºC	1103	776	326	199	65.7×10^3
21 ºC	1095	772	320	126	38.3×10^3
22 ºC	1085	768	314	206	66.3×10^3
23 ºC	1075	765	308	210	66.5×10^3
24 ºC	1065	763	302	366	108.6×10^3
25 ºC	1055	757	296	340	102.9×10^3
26 ºC	1046	753	291	450	128.4×10^3
27 ºC	1036	749	285	460	133.1×10^3
28 ºC	1026	745	276	560	153.6×10^3
29 ºC	1017	741	274	508	139.8×10^3
30 ºC	1007	738	268	470	124.4×10^3
31 ºC	997	734	262	404	106.1×10^3
32 ºC	987	730	256	422	107.2×10^3
33 ºC	978	726	248	332	83.8×10^3
34 ºC	967	722	244	326	78.4×10^3
35 ºC	957	718	239	340	81.4×10^3
36 ºC	947	714	231	318	73.3×10^3
37 ºC	938	710	227	320	73.3×10^3
38 ºC	928	707	221	304	66.2×10^3
39 ºC	918	703	210	200	43.4×10^3
40 ºC	909	701	207	134	27.5×10^3
41 ºC	899	697	202	35	7.31×10^3
42 ºC	889	693	196	61	11.8×10^3
				8760 hours per year	Total energy difference / saving = **2.48 GWh**

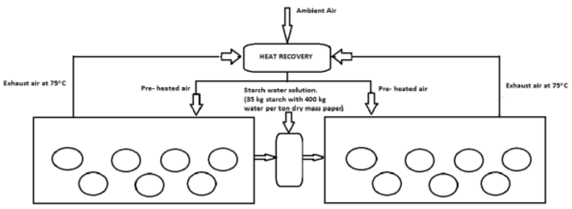

Fig 1: Flow diagram showing Close hood system for dryer section with heat recovery

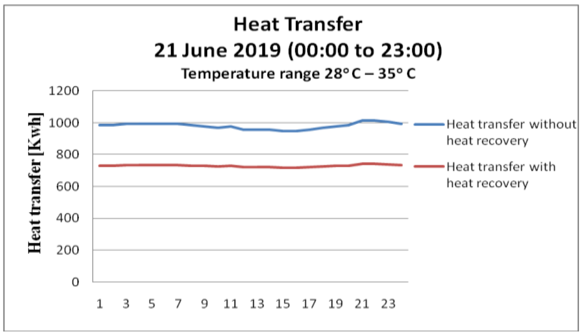

Fig 2: Heat Transfer in dryer section at different temperatures for 24 hours with and without Close hood and heat recovery

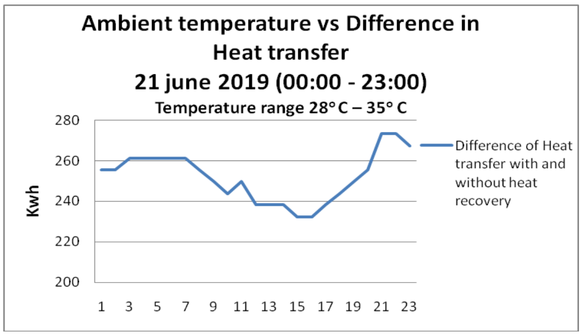

Fig 2: Variation in rate of Heat Transfer in dryer section at various temperature points for 24 hours.

III. CONCLUSION

The variation in rate of heat transfer from steam inside the heated cylinders of dryer section to the air around paper web is observed for different ambient air temperatures. It was found that the rate of heat transfer is decreased at higher air temperatures. The decrease in rate of heat transfer is actually the heat energy being saved in the paper mill's drying section. The temperature of ambient air is increased by pre-heating it with the indirect air to air heat exchanger device installed in the ventilation system of dryer hood. The humidity was assumed constant at 50% for ambient conditions since it has little overall effect on the heat transfer rate inside dryer section.The dryness of air has effects on paper drying and its quality which is not studied in this research work. The close hooded system for drying section in conjunction with the air to air heat exchanger device for the paper industry studied in this work showed a potential energy saving of 2.48 GWh that is approximately 18% of the total energy use of 13.578 GWh, per annum. The productivity enhancement obtained through the energy saving accounts for 17 % increase (6,539 tons per anum or 18 tons per day) in total annual production of 40,000 tons. Investment in retrofitting is around Rs. 11,000,000 (11 million Pakistani rupees according to one Chinese manufacturer's quotation) which gives a payback period of around 11 months.

Abbreviations

WV_{pd} = Water Evaporation in tons in pre drying section
WV_{psd} = Water Evaporation in in tons in post drying section
Dm_{in} = Dry content % in paper web coming in drying section
Dm_{apd} = Dry content % in paper web after pre-drying section
Dm_{psd} = Dry content % in paper web in post drying section
Dm = Dry content % paper web out
Pm_{dry} = dry mass in ton of paper web
WV_{total} = Total product water evaporation in drying section (kg)
E_{input} = Input energy in kJ/kg in air
Air_{used} = *Air used kg air per kg Water Evaporation*
$W_{exhaust}$ = *humidity of exhaust air kg water per kg dry air*
W_{supply} = *humidity of supply air kg water per kg dry air*
$U_{overall}$ = Overall Heat transfer Coefficient
Area = Heat transfer Area
$Temp_{steam}$ = Temperature of steam in kelvin
$Temp_{air}$ = Temperature of air in kelvin

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