Energy Conservation Approaches for Small Paper Mills

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ABSTRACT

Many a times, people with small paper mills have a myth that energy conservation is mainly concerned with large paper mills. Adequate attention is normally not given to the existing equipments and systems, and installation of costly and imported items is considered an only way towards energy conservation. This paper indicates how the performance of existing systems can be improved to get better results.

INTRODUCTION

In a typical mill, it was decided to reduce the energy consumption. For the same, three major areas were identified.

1. Stock Pumping Systems
2. Vacuum System
3. VFD Application Areas, e.g. ID Fan, Fan Pump etc.

While a lot of information is available on other topics, relatively less is available on pumping of pulps, or suitable vacuum system.

It was observed that except a few, most of the pumps were procured from a local manufacturer; who could not furnish data for the pump characteristics. The mill was not interested in investing a big amount of money in procuring new pumps or vacuum pumps, or VFDs etc. due to slump in paper market and hence acute shortage of funds.

EXPERIMENTAL

Optimization of Pumping Systems

Of course, the first step was to prepare data available in the mill. The experimentation in a continuously running process plant is sometimes very difficult as the parameters are controlled by the process personnel, and it may take even several days to attain the desired parameters at which the data are to be taken. Considering the same, it was decided to study two pumps (Pump No.5 and 7). Both the pumps were having a 6" suction and " delivery size. While the pump 5 had a 6" size Tee on a 8" diameter and 500 mm long pipe connector directly to cheat, the 7 was directly connected with a 6" diameter 200 mm long streight through distance piece to the chest. The delivery pipelines were similar for both pumps.

In oder to maintain an effective and accurate data. digital ampere meter and power factor meter were installed in the main line to motors concerned. The installation of energy meters was considered, but observed that the least count of the meters was creating problem in getting accurate data. The flow rate was calculated by dividing the flow volume by pumping time.

This made it posible to collect accurate data on stock flow, pump running time, and load on the pumping system.

Theoretical Pumping Power Consumption

Power Consumed for pumping of pulp stock can be calculated easily as under-

Power Consumption per tonne of Dry pulp

$$(KW/Tonne)=9.81*H*(1+0.014*Cy.) *100/1000*Cy.$$

where, H is the height to which pulp is to be transferred in meters, and Cy. is consistency in percent. Here, we have assumed that the specific gravity of pulp suspension is given by (1+0.014*Cy.). To simplify the calculation purpose the pumps were selected with open discharge, so that the pressure at the delivery point is zero.

Actual Power consumption was calculated by the formula

$$\text{Power} = \sqrt{3} * V * I * \cos \phi$$

As in case of power meters normally used, measurement of energy consumption for short duration is not accurate. To maintain constant operating conditions, the precautions were taken that voltage or frequency does not fluctuate during experiments and it was decided to discard concerned data if such fluctuations occur during observation.

RESULTS AND DISCUSSION

Effect of Chest Level

To begin with, the effect of chest level was checked. For the same, the suction and discharge valves were kept full open and load (Amp.) and flow rates were measured. For four five minute intervals it gave the following results indicating that the chest level does not affect the flow rate or pumping energy. The authors cannot explain the reason for the same, and hope that further work in this area would reveal the reasons.

Effect of Suction Piping

Table 1 shows effect of suction valve opening on power consumption for pumping for stock pump No. 5.

Pump No. 5
Furnish: 100 % ONP
Freeness: 44 SR
Consistency: 2.8%

Table 1

S_V_OP, %	LPM	TPH	kW	U/T
100.0	2455	4.124	14.41	3.49
83.3	2421	4.067	14.25	3.50
75	2284	3.837	14.02	3.65
66.7	2090	3.511	13.29	3.79
58.3	1416	2.379	13.09	5.50
50	1256	2.110	12.70	6.02

On analysing this data, it is clear that a reduction in suction valve opening to 75% results in lowering of flow rate by 7% only and increases specific power consumption by 4.6% only. This indicates that further increase in suction line diameter will not yield in increased throughput or efficiency of pumping system. As a matter of fact, this was on the contrary of plant personnel opinions who thought if the pump were fit without suction line bend as in case of pump No. 7, it could have transferred more pulp and specific pumping power consumption would have been less.

Similar data was analysed for pump no.7, which was connected adjacent to the chest (Table 2).

Table 2

S_V_OP, %	LPM	KgPH	kW	U/T
24	785	1319	7.45	5.65
40	1817	2052	7.92	3.85
48	1708	2869	7.78	2.71
56	2160	3629	8.51	2.35
64	2160	3629	7.99	2.20
72	2356	3958	8.26	2.09
80	2849	4683	9.58	2.04
100	2959	4971	9.57	1.93

Pump No. 7
Furnish: 100% ONP
Freeness: 44 SR
Consistency: 2.8%
Delivery Valve Full Open (100%)

Here, it is interesting to note that the specific power consumption is of the order of 2.0-2.2 U/T, almost double against 3.5-3.7 as in case of chest 5 at increased suction valve openings. This indicates that the size of delivery pipeline is of more importance over here. With smaller pipe diameters, the friction loss is so high that the specific power consumption shoots up thus resulting in increased specific power consumption.

Effect of Delivery Valve

As indicated by the above results, the pipeline size of 6" was more suitable for lower power consumption, so further work was done only on chest pump No.7. In this case, the suction valve was kept full open and the delivery valve opening was changed. The data obtained were as shown in Table 3.

Pump No. 7
Furnish: 100 % ONP
Freeness: 44 SR
Consistency: 2.8%

Table 3

D_V_OP, %	LPM	TPH	kW	U/T
100.0	2900	4.871	9.57	1.96
92.0	2692	4.523	9.50	2.10
81.0	2356	3.958	9.50	2.40
71.4	2062	3.464	9.70	2.80
61.9	1868	3.138	9.97	3.18

It is as clear from above that with reduction in delivery valve opening to around 90%, the power consumption is not affected very much. But beyond that, the decrease in valve opening results in increased power consumption.

Another point to note over here is that the pumping power can go as high as double or even more than that if pipelines are not properly designed. As indicated by above data, a reduction level of upto 55% after modification of chest pump No.5 can be achieved. While this work was taken for planning in near future, the next thing was to decide the norms for power consumption in pumping.

We can divide power consumed by the pump in three parts, namely - 1). Power to lift the pulp suspension, 2). Power to counter the friction losses in the pipeline & 3) Power loss within pump & motor. The power required to lift the pulp suspension to a height of 4.4 M, as was the case, is 1.54 U/T. In this way, the losses due to friction etc are only to the tune of 25% . In other words, we can achieve a minimum of 1.54 U/T power consumption by reducing these losses to theoritically zero. This indicates that further effort to reduce power consumption may not be economically viable.

Further, the effect of consistency was considered. Specific pumping power in above case (Chest pump No.7) and pipeline friction losses at different consistencies can be calculated (Table 4). This table indicates the possibility to reduce the power consumption by increasing the stock consistency. The friction loss has been calculated on the basis of data given in Tappi Information Sheets (Tappi TIS 0410-14) for newsprint broke. This table indicates that an increase in consistency from 2.8% to 3.5% will result in a marginal saving of the order of 0.24 U/T only. As a matter of fact a higher consistency will be more useful for big paper mills due to increased effect of pipe friction losses which play a major role as the stock is transferred to a much longer distance.

Advantages

After the study was completed, the mill decided to replace the pipeline for the pump No.5 and it was achieved with a very less investment and a payback period of 30 days only. It was computed that for all the pumps, the power saving was to the tune of 10-12 kWh/t. The study also indicated that adopting a high consistency operation may not be a very viable solution for small paper mills, where the stock has to be transported to shorter distances.

Optimization of vacuum system

Most of the small paper machines are desiged to operate from ground floor on account of low capital cost. Many a consultants have suggested the author that for best results, the paper machine must be a first floor machine. On such machines, obviously, the vacuum elements would also be on a lower elevation from the plinth, and hence the discharge from these - the air water mixture will face restrictions to flow to the vacuum pump, which may have its suction even at higher elevations than the element itself.

Another problem to the ground floor machine is the pipeline routing. It is not practical to have pipelines at elevations where these create restrictions to personnel doing their regular duties.

Installation of vacuum pumps below plinth level seems a simple solution to this problem and has been tried in many mills. It is considered to have an advantage of first floor paper machine at the cost a ground floor one. It, still, contains some serious bottlenecks, which need to be considered while designing the plant layout accordingly. First and of great importance is maintenance. Normally, the vacuum pump must have a free space equal to the length of its shaft on either side of the pump in the direction of shaft centerline. The drive motor is mounted with its shaft parallel to the vacuum pump shaft. In this way, a thumb rule is that the space requirement for an underground vacuum pump is roughly a square of 2.5 times the shaft length, yet the exact requirements will have to be as per manufacturer's recommendations. Thus the typical space requirement for some of the commonly used vacuum pumps in small paper mills is in Table 5.

Obviously, such a big area and that at a level below plinth is not practical as the availability of land is becoming lesser and lesser. Furthermore, at times, shift fitters may be reluctant to go every now

Table 4

Cy	%	2	2.25	2.50	2.80	3.00	3.25	3.50	3.75	4.00	4.25	4.5	4.75
U/T		2.39	2.18	2.01	1.86	1.78	1.69	1.62	1.57	1.52	1.48	1.45	1.42
Friction	M	0.48	0.60	0.73	0.91	1.03	1.21	1.39	1.58	1.79	2.01	2.24	2.49
Friction	%	11%	14%	17%	21%	24%	27%	32%	36%	41%	46%	51%	57%

Table 5

Flow Rate	Motor HP	Length	Width
10 m^3/min	20-30	2000	500
20 m^3/min	37-50	2800	500
30 m^3/min	50-75	3000	1800
60 m^3/min	100-125	3500	3200

and then and check the bearings etc and skip routine checking. This results in increase in avoidable breakdowns.

Another problem with underground vacuum pump installations is, though rarely, the leaking water from shaft seals and glands that accumulates around the pump, and is extremely dangerous to the running motor. There are many examples when motors installed in deep pits have short circuited due to water.

The Single Vacuum Pump System

The increasing power costs have forced papermakers to reduce the power consumption in all areas possible including the vacuum system. Today, many a paper mills is running only with a single vacuum pump only. This vacuum pump feeds wire part as well as press part at the same time. Quite often papermakers feel that with such a system break after the couch would result in reduced vacuum in the press part due to increased airflow through the felts. This affects the vacuum in the wire part also, and thus a reduced vacuum results in reduced sheet dryness, and hence difficulties in passing paper to the press part. Still, having a properly designed vacuum system can reduce this problem.

Wire Part Installation of Barometric Legs

Today all papermakers agree that the vacuum in the wire part flat boxes should be in increasing order. Installation of Lo Vac devices has also been made in some mills. Some other mills, which do not have such system, can easily go in for barometric legs. Against the myth that barometric leg requires a minimum length of 10M, these can be mounted of any length, as small as 1 M or even lesser. The only requirement is that the lower part of leg must always be submerged in a filled tank called seal pit (1). The barometric leg should be designed in such a way that the stock flow velocity in the leg is 2-3 m/sec. under normal circumstances. The length of leg depends on type of pulp used, temperature of stock, water removal from the element and vacuum requirement. The higher the vacuum requirement is, the longer should be the length of leg.

Individual Element Vacuum Control with Barometric Legs

Use of barometric legs is advanatageous in such a way that it ensures only a limited volume of air which can flow through the piping, while maintaining the desired low magnitude vacuum. If system needs more airflow to achieve that vacuum level, legs stabilize at a lower level of vacuum corresponding to existing airflow rate. In case the desired vacuum is achieved within the maximum air handling capacity of leg system, the vacuum does not increase beyond the design limit.

Seal pit is another important area of great importance. Optimum performance may be achieved if the clearance between leg bottom and seal pit bottom is at least 1.5 times pipe diameter, the maximum being 2ft. The clearance between the pipe and seal pit side walls should be more than one pipe diameter.

All of the barometric legs of the wire part may either be submerged in a common seal tank or separate tanks may be installed for different legs. Separate seal pits give an advantage of better control of vacuum in increasing order in the suction boxes. For paper machines where vacuum adjustment is frequently required owing to different qualities of paper being produced on the same machine, the design of seal tank can be developed to have a controlled level, thereby controlling vacuum in suction boxes. An example has been shown in Fig.1. Note that by opening allowing the overflow from top pipe we may reduce vacuum in the concerned vacuum element, and by opening the lowest overflow line valve, we may increase vacuum.

Many operators face problem of seal pit water suction by the drop legs. If it happens, it is a clear indication of high vacuum in the header. Once the header vacuum is controled either by throttling the valve or by bleeding some air into the system, the problem can be solved.

Air Water Separator

The basic function of air water separator is to eliminate water going to vacuum pump alongwith air in order to reduce load on vacuum pump. Furthermore, absence of process water helps vacuum system to produce a steady non-pulsating vacuum. A typical problem often faced by the papermakers ia airlocking of extraction pump resulting in increase in level of water separator, thus resulting in failure of separation of air and water and hence increased load on vacuum pump. Modification of the extraction pump delivery pipeline

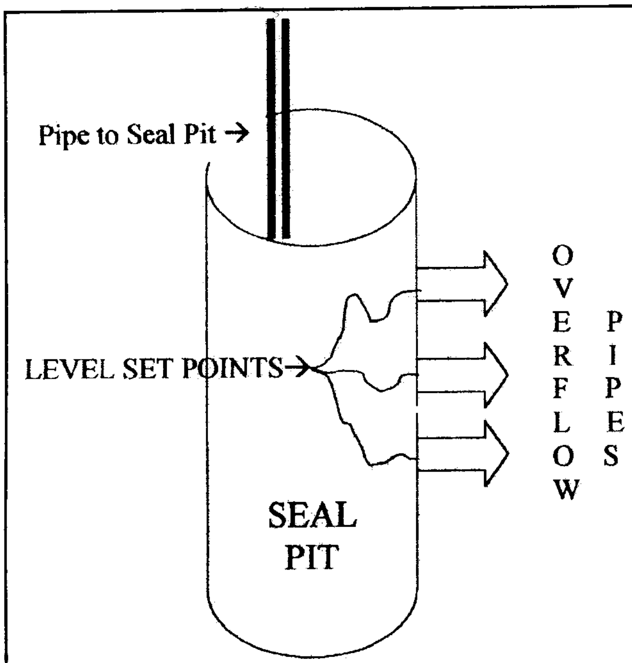

Fig. 1 Multi Level Overflow Pipes For Level Control of Seal Pit.

is required so that it first goes upwards by about 1 ft above the extraction pump top level, and then turns downwards - NRV and control valves being in upward line - is a good solution to this problem. No equalizing line is required with this system.

It is also necessary to check whether proper separation is taking place or not. Supplying fresh water for sealing purpose, and checking the return seal water suspended solids can easily put a check on it. A suspended solid level equal to zero indicates good separation process. If back water is being used the equal value of both inlet and outlet water suspended solid levels indicates good separation.

Vacuum Pump

Normally, ground floor machines are slow speed machines. A slight overlook at vacuum control results in increase in airflow through the vacuum pump. Increased airflow rate means drop in vacuum which is often misunderstood as low efficiency of vacuum pump. On low speed machines producing low grammage paper in particular, initial low vacuum removes maximum water; increased vacuum in consequent suction boxes removes relatively lower quantity of water, and sometimes further increase in vacuum does not remove any water. Furthermore, as the sheet dryness increases, its air porosity also increases resulting in decrease in restriction to flow of air. Now this increased airflow through the wet web results cooling of the web through evaporation of water thus resulting in reduced press efficiency. A reduced web dryness may adversely affect the machine runnability at wire part, but on low speed machines, normally machine runnability is not affected as the web has sufficient strenth even at slightly lower dryness.

Modeling A Vacuum System

A vacuum pump develops a particular vacuum depending on its characteristics and actual airflow through it. For a particular flow rate, we may be sure to get that particular vacuum. Now, at the paper side of clothing, the vacuum is zero, i.e., vacuum increases towards vacuum pump and is maximum at the vacuum pump itself. Quite often, papermakers face a problem of lack of vacuum control, where the vacuum in any element increases rapidly while opening the vacuum control valve, and reaches to its maximum at only 20-25% of valve opening. To understand why it happens, we should first take a close look at the vacuum system. Basically, vacuum in an element is due to resistance to airflow through the web and fabric (wire or felt) and ease of airflow through the pipings. Broadly speaking, the vacuum piping could be divided into two parts Control valve and Piping beyond header. Now, let us consider that the control valve is fully closed. Theoretically, we may consider that the pressure drop across the valve is maximum and that across pipeline is zero. On slight opening the control valve, pressure drop across this reduces to some finite value and that across pipeline increases. The total pressure drop across the system, of course, decreases. In case the pipeline is overdesigned, there exists a possibility that the total pressure drop across control valve and pipeline reduces, but, at this time the resistance to air flow through the web and fabric reduces due to void opening inside the web. Also, increased vacuum means more volume of air has to flow through the pipeline, and thus increased pressure drop through the system does not allow vacuum element to have extremely high vacuum levels.

Using Suction Blowers

The wire part elements, dry suction boxes in particular, have a significant open area and thus high flow rate of air is to be handled. In a particular case, on a newsprint machine running at 170 mpm speed, with 3.2 m deckle, the wire part vacuum pump (driven with 75 HP motor) was successfully replaced with a suction blower driven by 20 HP motor. Of course, the after couch dryness reduced by 1%, against what newsprint machine running at 170 mpm speed, with 3.2 m deckle, the wire part vacuum pump (driven with 75 HP motor) was successfully replaced with a suction blower driven by 20 HP motor. Of course, the after couch dryness reduced by 1%. Against what was thought, the steam consumption for drying was reduced. The reason behind this is that the dry suction boxes act as a porous plug for the air passing through wet paper web. During air passing through web, some of the water in the web gets evaporated taking heat from the web itself. This result in cooling of web. Due to low temperature of web and water in the web, the water viscosity increases affecting the pressing operation efficiency adversely.

Advantages

With the above information, the machine vacuum system was modified, and it was made possible to reduce the vacuum requirement for two vacuum pumps of 57 and 29 m^3/min at 660 mmHg driven by 125 and 75 HP motors respectively to one vacuum pump of 29 m^3/min and another of 10 m^3/min blower. In addition to above, these changes resulted in better runnability of machine and machine speed could be increased by 12-15%. The power cost itself reduced from 150 kWh/t to 60 kWh/t, i.e., to the tune of rupees 35 lacs per annum for a 25 TPD paper machine. Aslo, at the same time no noticeable increase in steam consumption was observed.

Installation of VFDs

To reduce power consumption in ID fans, blowers and fan pump etc., VFD installation has become very popular. Sometimes, mill may be reluctant to install a VFD because of high cost of the system. In such a case, satisfactory results were obtained without the same.

ID Fan

The installed ID fan was fitted with a 40 HP motor, and the operating load was 46 Amp. When contacted the suppliers, the cost of VFD was much higher than the mill budget. To reduce the RPM, the V belt pulleys were changed., and RPM reduced from 1440 to 900 only. This resulted in significant savings, with a payback of one week only, as the load was reduced to 19 AMP.

Later on, a new ID fan was procured with 20 HP motor, and slightly lower the operating capacity, which runs on 16 AMP load only. The investment in new ID fan motor, civil work etc. was less than half the cost of VFD.

Fan Pump

Encouraged by the earlier success, the fan pump RPM were reduced from 140 to 980. As the 980 rpm motor was not available, the motor was elevated, and instead of tyre coupling, V Belt drive was provided. The load on fan pump was reduced from 80 Amp. to 40 Amp., with a payback of 3-4 days on investment. While, in earlier operating conditions, the payback for VFD was to the tune of 3-4 months, after V Belt installation, it comes to 4-6 years or even more.

CONCLUSION

The installation of very costly equipments is not a must to move towards energy conservation. Small paper mills have significant potential for energy conservation, and can be achieved very easily.

REFERENCES

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