Energy Audit of Compressor System

Singhal D K

ABSTRACT

In most of the paper mills, compressed air is used for instrumentation such as pneumatic cylinders, actuators, I/P converters, P/I converters etc. Additionally, air is also used for process applications such as tail feeding, cleaning of water filters etc. The present work indicates how an energy audit can be used to optimize the system for minimum power consumption

INTRODUCTION

Compressors are used for producing compressed air for instrumentation, process air (cleaning of air filters of DG sets, cleaning of filters of high pressure water showers etc), and consume several times of normal energy requirement if compressed air system is not in order. It is therefore, important to periodically audit the compressor system and evaluate the performance as a system and not as equipment.

The present work is based upon a case study where audit was done to minimize power consumption.

Original System

The original system consisted of three compressors, out of which two compressors were connected to the main load, and the third one was standby. Compressor 1 had a relatively higher pressure setting than compressor-2, thus ensuring operation of compressor-1 at most of the time. In case pressure drops below the setpoint value of comopressor-2, it started automatically, and pressure was maintained within desired range.

Earlier mill had faced a problem of pressure dropping due to electrical problem in compressor-2, which resulted in unloading of press roll and touch roll while the paper was running. It could have resulted in damage to press and MG felt also. To avoid such problems in future, the mill had installed a pressure switch in the main compressed line header connected to a hooter, which would sound in case of low pressure to alert the machine operators.

Initial Investigations

To begin with time tantalizers (hour meters) were installed on the three compressors. It was observed that the total run hours for the compressors were to the tune of 32-36 hours a day. From the maintenance department, there was a complaint of frequent compressor failure. On the basis of their records, MTBF (Mean Time Between Failures) was found to be between 35-42 days. It was also observed that the pneumatic elements such as regulators, clutches failure was also high, requiring nearly 10-15 regulators, and 5-7 clutches replacement in a month. The mill had tried various brands for achieving good life of these as failure of these elements resulted production loss at times.

So far, no air dryer had been installed, and mill was seriously considering installation of air dryer of suitable capacity to avoid production loss due to above problems.

Modified System

Modified system employs use of four compressors, as indicated in figure1-

1. Compressor-1 is used for rewinder and pulp mill.
2. Compressor-2 is used for paper machine.
3. Compressor-3 is used as and when required for dandy roll pneumatic shower, cleaning of DG sets air filters and such misc. activities.

Features of the Modified Compressor System

Load Distribution

Load has been distributed in order to maintain high degree of reliability, trouble free operation and well-distributed operation. Other compressors have been connected to paper machine compressor, it being most critical one. It must also be indicated that when the machine runnability is fairly good and constant, the compressor running is quite steady, and any reduction in machine runnability, results in increased cylinder operation and hence increased air consumption.

Similarly, the rewinder and pulp mill have been associated to a separate compressor. Depending on diameter of reels to be made, the number of rewinder cylinder operations varies. Similarly, the pulp mill operation is affected by the quality of waste paper resulting in variation in batch size and hence number of batches and finally air consumption.

The operation of dandy roll is made only in selected qualities of paper and hence is more uncertain. Dandy roll has been linked to a separate compressor. Also filter cleaning etc. misc. jobs are being taken up with the same compressor. As different jobs except the dandy shower operation do not follow a definite trend, hence estimation of air utilization percentage is difficult.

Usage Monitoring with Hour Meters

The compressor usage monitoring is done with the help of hour meters installed at individual compressors. The hour meters are of 220V design and of electromechanical type. These have been connected to the compressor motors input supply position. A small 2A fuse has been provided to ensure limiting the phase current in case some fault occurs with the hour meter resulting in increased motor current and hence unnecessary motor tripping.

Installation of hour meters has given several distinct advantages. Long back before installation of the same, there were no instrument air needed in pulping section, and all the air needed was for paper machine and rewinder section. The total running hours were to the tune of 32-36 hrs a day.

Chandpur Enterprises Ltd.,
Noorpur Road, Chandpur-246725
Dist. Bijnor, (U.P.)

Compressors Installation: Process Flow Sheet

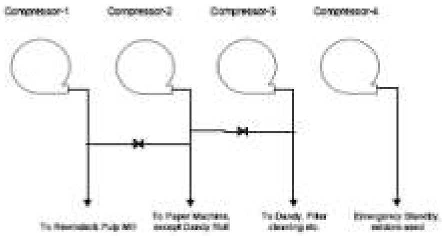

Figure-1

Annexure 1

1	Compressor-1						
2							
A3	**B**	**C**	**D**	**E**	**F**	**G**	**H**
4	**Cylinder**	**Number of Cylinders**	**Bore**	**Stroke**	**Volume**	**Daily Frequency**	**Theoritical Air Consumption**
5	**Rewinder:**		mm	mm	lit	Nos/Day	Lit/Day
6	Brake Shoe	1	100	125	0.98	60	117.75
7	Ejector	2	100	400	6.28	25	314.00
8	Chuck Lift/Lower	2	125	800	19.63	25	981.25
9	Press Lift/Lower	2	125	800	19.63	25	981.25
10							
11	**Pulper:**						
12	Pulper Dump Valve	1	150	400	7.07	20	282.60
13	Pulper Reject Valve	1	150	600	10.60	20	423.90
14	Fresh Water Fill	1	100	150	1.18	24	56.52
15	Back Water Fill	1	100	150	1.18	24	56.52
16	Back Water Fill (Lower)	1	100	150	1.18	24	56.52
17							
18	**TOTAL**				**67.71**		**3270.31**
19							
20							
21	Total Air Consumption	Lit/Day		=H18			3270.3
22	Utility Air Pressure	Kg/cm2g					6.0
23	Standard Air Flow	Lit/Day		=h21*(h22+1)			22892.17
24	Capacity of Compressor	Lit/min					1000.0
25	Theoritical Run Reqd.	Min/Day		=h23/h24			22.9
26	Actual Running	Min/Day					150
27	Overall Air Utilization	%		=h25/h26			**15.3%**

After installation of hour meters, daily readings indicated air generated by the compressors. This helped in monitoring air consumption and after taking a pipeline change program to minimize air leakages, this time reduced to 6-7 hours only. This was much better than expectations, and should have been an end to further modifications for reduction in air consumption.

But, soon it was noticed that now and then mechanical fitters observed a leak in pipeline, and that was more promptly attended, as the benefit of the same had to be reported by the hour meter. As a result, this time has further reduced to 4-5 hours only, in-spite of the fact that the pulper has been given air supply for operation of different valves.

Another advantage of the hour meters was that the shift wise monitoring of compressor operation was developed as a benchmark within the plant. Against the earlier practice of periodically checking the compressed air piping network for leakage, a routine of checking of earlier shift compressor run hours was started. Run hours within a predefined limit can be considered a system when compressor as well as all piping is healthy. Now every fitter initially checks compressor run hours for previous shift. In case the figure is normal (less than 1 Hour a shift), no action is required. In case it increases beyond 1.3 Hours, he is supposed to check pipeline leakages using soap solution, and reports any leakages to be attended during next shut. In case it increases beyond 1.6 Hours, the case must be informed immediately to maintenance incharge, along with pipeline leakage test as earlier.

Installation of Individual Headers

The compressed air network comprises of different sections for a single compressors. For example, the compressed air line from compressor one feeds rewinder as well as pulper. To minimize the pipeline frictional drop, different headers have been provided in different sections. Header works as a buffer, and as the air is required for some purpose, the requirement is partially met by the header.

It has been observed that the installation of headers has also helped in more retention time of compressed air within the piping network, thereby allowing more time for air to cool down, and thus absolute moisture in compressed air is reduced. Both, reduction in air consumption and increase in piping volume has been so beneficial that the pneumatic cylinder related problem has been nil over the past three years. Put apart the cylinders, not even a single seal kit has been changed due to moisture related problem with compressed air during past three years.

Loading & Unloading

A pressure switch based ON-OFF operation is being done in the plant. As the existing storage tanks, having a capacity of 300 Lit. each is equivalent to the air consumption for an hour or so, dP (differential pressure) between switch ON and switch OFF cam be maintained at a fairly low value of 0.5 kg/cm2. Thus, unnecessarily high pressure air is not generated and it leads to energy efficient operation. A further reduction of differential pressure will result in more frequent start-stop of compressors.

Elimination of Moisture

No moisture separator (dehumidifier) had been installed in the compressed air circuit. Initially, installation of air moisture separator was under consideration. But after reduction in air consumption, it was observed that the consumption of compressed air

Annexure 2

1	Compressor-2						
A2	B	C	D	E	F	G	H
3	**Cylinder**	**Number of Cylinders**	**Bore**	**Stroke**	**Volume**	**Frequency**	**Theoritical Air Consumption**
4			mm	mm	lit	Nos/Day	Lit/Day
5	Press Roll Loading	2	300	300	42.39	3	254.34
6	Touch Roll Loading	2	350	400	76.93	5	769.30
7	Primary Arm Locking	2	50	150	0.59	36	42.39
8	Primary Arm Loading	2	75	600	5.30	36	381.51
9	Secondary Arm Loading	2	100	800	12.56	36	904.32
10	MG Doctor Loading	2	50	75	0.29	6	3.53
11	**TOTAL**				**138.06**		**2355.39**
12							
13							
14	**Clutch**	**Pipes**	**Bore**	**Stroke**	**Volume**	**Frequency**	**Theoritical Air Consumption**
15	Couch Roll	1	20	25000	7.85	3	47.10
16	Press Roll	1	20	25000	7.85	3	47.10
17	MG	1	20	25000	7.85	3	47.10
18	Pope Reel	1	20	25000	7.85	10	157.00
19	**Total**				**31.4**		**298.3**
20							
21							
22	Total Air Consumption	Lit/Day		=h11+h19			2653.7
23	Utility Air Pressure	Kg/cm2g					6.0
24	Standard Air Flow	Lit/Day		=h22*(h23+1)			18575.8475
25	Capacity of Compressor	Lit/min					1000.0
26	Theoritical Run Reqd.	Min/Day		=h24/h25			18.6
27	Actual Running	Min/Day					150
28	Overall Air Utilization	%		=h26/h27			**12.4%**

elements (pneumatic cylinders, regulators, clutches etc.) reduced drastically compared to what it had been when the air consumption was more. Hence, the installation of moisture separator was not done.

Air Pressure Low Alarm

As the air is being used mainly for control purpose, a drop in compressed air pressure may create severe problems to paper machine as well as to product. For example, in case of low air pressure, below the holding limit for the touch roll, the same gets lowered while the paper is running. This may create damage to paper machine clothing as well as to some felt rolls. In order to avoid the same, a pressure switch has been installed on the main compressed air line with a hooter powered by 220V electricity supply, to raise an alarm if the pressure goes below a value of 6 Kg/cm2. In such a case, a connecting valve between the both compressors is opened manually, and the air supply pressure to machine is resumed. After the fault in machine compressor has been rectified, the interconnecting valve is closed again.

This system has saved at least twice during past five year period, when due to some electrical fault, compressor could not operate and air pressure decreased. In both that cases, possible loss of one hour production each time, in addition to possible damage to paper machine rolls and clothing, was successfully saved.

Upgradation Alternatives

For the purpose of energy conservation, different possible alternatives are discussed. Here, some comments are presented on different alternatives, possible advantages achievable with them and feasibility.

Installation of VFDs

Installation of VFD (variable frequency drives) if often suggested to be used for better energy efficiency, and better control over the generation process. As indicated above, the compressor operation is limited to only a couple of hours over a day. Thus, economically the installation becomes unviable. Instead, existing ON-OFF operation is running successfully, and the same should be continued.

In some installations, it has also been observed that continuous operation at much lower speed results in inadequate lubrication and hence failure of compressor system due to inadequate lubrication.

Installation of Air Dryer

In the original installation, dryer was not planned. Later on, planning was being done for an air dryer, but after audit and post audit activities, air consumption reduced drastically, and hence, the problem due to moisture in air was totally eliminated. Due to low air consumption, the process allowed so high a residence time in storage tanks and piping, that the air cools down and moisture is separated in FRL (Filter regulator lubricator unit) installed before each sub header in the plant. Furthermore, as the air generated at a relatively higher pressure than required in the process, pressure reduction results in reduction in relative humidity, and hence moisture does not appear as a menace in the system.

Hence, in the present case, installation of dryer is presently not recommended.

Reduction of Generation Air Pressure

The air pressure reduction is an energy conservation measure getting more attention as no capital investment is required in most of the cases. All one has to do is to set the pressure switch at a lower level, which needs just less than a minute. At lower pressure conditions, compressed air generation requires lower power consumption.

When the air pressure is reduced, air volume passing through the delivery pipeline, through filter of FRL units, and delivery headers increases and thus makes air retention time in distribution system lesser than that was earlier. Simultaneously, the process requires more volume of intake compressed air as expansion in FRLs is reduced. This leads to increased moisture levels in the compressed air system. It has been found that the increase in energy consumption for increasing the generation air pressure was very less than that required had an air dryer was installed. It must be indicated here that most air dryers use a fraction (typically 10%) of the compressed air to regenerate the drying chemical.

Now the compressed air is being generated at a pressure of 9 kg/cm2, and the mill is not facing any problem relating to moisture in air. Furthermore, since the quantity of the actual air needed by the process elements (cylinders, clutches etc.) is less, reduction of pressure is not advisable.

Running One Compressor as Main and Keeping the other as Standby

As the compressors running hour is only a couple of hours each, it may be suggested to put both the compressors in parallel-backup mode, with pressure settings in such a way that one of the compressors operate for all of air requirement of the plant. This scheme is running successfully in many a mill. The second compressor having a pressure setting at somewhat lower value in such a way that in case the main compressor fails due to any reason, the first starts working, and hence the operation would be more reliable.

In the present system, as the operation is limited to nearly 0.7-0.8 hours a shift for each compressor, the maintenance staff has been given two deadlines. In case the operation exceeds 1.3 hours a shift, the next shift fitter is supposed to conduct a leakage check on the piping of the related section. In case the time increase to more than 1.6 hours a shift, the matter is considered important, and compressor tank fill up time is checked again to ensure proper functioning and health of the compressor.

In case both the compressors are operated in parallel-synchronized mode, minor leakages from the one section only cannot be traced out so easily. Furthermore, duration of compressor operation in a cycle will increase resulting in compressor heating up and energy loss due to the same, though of a negligible amount.

Improving Clutch Operation

It was observed that some operators frequently operate air clutch ON/OFF during machine/section startup. This type of practice is implemented in sectional paper machine drive type systems in order to minimize startup load on a particular system. The existing paper machine is a line shaft drive machine, and also the machine drive (AC drive) is suitably sized. To further eliminate the problem of jerk load during startup of a particular clutch, the drive software provides a facility of *di/dt* adjustment, and ramp up/ramp down adjustment. These values have been so adjusted that any jerk load is easily absorbed within the system.

It, therefore, becomes unnecessary to frequently switch the clutch On/Off during a machine/section startup. This can be easily done by training paper machine operators for switching on the clutch in a single stroke.

Arresting Leakages in the Pipelines

Though almost all major leaks are being attended as soon as possible with the present system, the mill must formulate a daily compressor operation check on the basis of operation of different sections/valves/clutches this would help in regularize the audit work, and also ensure leakages are being attended fast. Also, the mill should initiate frequent leakage checking-arresting program. Though it may appear unnecessary, but some more minor leakages would get detected in this way, and thus the air consumption can be brought down to much lesser value.

Comments on the Modified System & Available Benchmarks

Maximum losses in the compressor system are due to unaccounted losses as well as due to wastage. For the same the compressor system has been optimized for better efficiency in generation, distribution and consumption. In the attached sheets, as indicated the air utilization efficiency is to the tune of 10-12%(Ref. Annex. 1 & 2), which is much better than the practice in most mills. As per the available information, a figure for similar systems having 6% air utilization efficiency can be considered satisfactory.

In some paper mills, specific power consumption per ton of paper produced (kWH/T) is considered a benchmark. For waste paper based paper mills, a figure of 5-6 kWH/T is reported in some publications. While in the present system, it is as low as less than 1 kWH/T. Though there exists some more energy conservation possibilities, but, as obvious, they won't be very cost effective.

CONCLUSION

On the basis of the analysis above, we may conclude that now the compressed air system is working at much above satisfactory levels. Some opportunities for improvement of the compressed air system have been proposed above, which may be used to further improve the system.