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Investigation on Energy Efficiency and Saving Opportunities of Industrial Compressed Air system in Process Industry

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Abstract**: In textile manufacturing compressed air systems constitute the bulk of energy cost besides motor, lighting, fans, pumps and boiler systems. Reducing energy cost through energy efficiency and conservation measures is the clear option for textile industry to reduce overall energy use in order make profits and remain competitive.In this research paper energy efficiency and energy saving opportunities for industrial compressed air system in process industry is presented. Energy investigation was done to determine power consumption, power factor, power ratings, operation time and other important details of the air compressor for the case study industry. Air leak test was also conducted to determine the extent of percentage air losses by air compressor.The study found potential savings in electric energy to be approximately 157,164 kWh/yearwith simple payback period of 0.3 years. Based on results obtained enormous energy savings could be achieved through implementations of low cost investments such as fixing air leakages and regular maintainance.**

Keywords**: Energy efficiency, saving opportunities, Air compressor, Process industry, Textile, Kenya.**

I. INTRODUCTION

Compressed air system is one of the leading energy consuming equipment in textile industry. It is estimated that compressed air represents approximately 10% of industrial energy consumption [1].The total cost of compressed air over a ten-year period can be estimated as 75% energy, 15% capital and 10% maintenance. It shows clearly that energy efficient system is highly cost effective measure to reduce energy consumption [2].Inefficiencies in compressed air systems can therefore be significant. Energy savings from system improvements can range from 20 to 50 percent or more of electricity consumption [3]. A properly managed compressed air system can save energy, reduce maintenance, decrease downtime, increase production and improve product quality. Only 10-30% of energy reaches the point of end-use, and balance 70-90% of energy of the power of the prime mover being converted to unusable heat energy and to a lesser extent lost in form of friction, misuse and noise[3, 4].

Air leaks are the single greatest source of energy loss in manufacturing facilities with compressed air systems. While leakage can come from any part of the system, the most common problem areas are couplings, hoses, tubes, and fittings, pressure regulators, open condensate traps and shut-off valves Pipe joints, disconnects and thread sealants[5]. The percentage loss to leakages should be less than 10% in a well maintained system. Leaks can waste 20–50% of a compressor's output.

The cost of compressed-air leaks is the cost of the energy required to compress the volume of lost air, from atmospheric pressure to the compressor's operating pressure. The cost of compressed air leaks increases as the diameter of the leak increases. The energy wasted in compressed-air systems because of poor installation and maintenance can account for up to 50% of the energy consumed by the compressor, and it is believed that about half of this amount can be saved by practicing energy conservation measures [6].

A typical plant that has not been well maintained will likely have a leak rate equal to 20% of total compressed air production capacity. Leak detection and repair can reduce leaks to less than 10% of compressor output.

Studies show 20% potential reduction in annual energy consumption by fixing air compressor leaks.In addition to being a source of wasted energy, leaks can also contribute to other operating losses. Leaks cause a drop in system pressure, which can make air tools function less efficiently, adversely affecting production, shorten life of system equipment, increased maintainance requirement, increased unscheduled downtime and unnecessary compressor capacity [1].The aim of this paper was to investigate the energyperformance of compressed air system used in textile industry and identify energy saving opportunities to reduce energy consumption.

II. METHODOLOGY

The industry owns a rotary screw air compressor GA-808 by Atlas Copco used to operate pneumatic machines in the textile plant. The air compressor serves spinning, weaving and wet processing departments for 16 hour a day. The design specifications for GA-808 air compressor are given in table 1.

Table 1: Air compressor nameplate parameters

PRODUCT TYPE	GA 808
SERIAL NUMBER	ARP856460
MAXIMUM PRESSURE	8 BAR
ABSOLUTE INTAKE PRESSURE[1]	1.017 BAR
FREE AIR DELIVERY	183 L/s
MOTOR POWER	75 KW
MAXIMUM SPEED	1,500 r/min

[1]Atmosperic pressure

The power consumption of air compressor was measured with power and energy logger. The setup of the experiment inside the compressor control panel is shown in the figure I. The measured parameters include; voltage, current,Hz, PF, kW, kVA and kVAR.

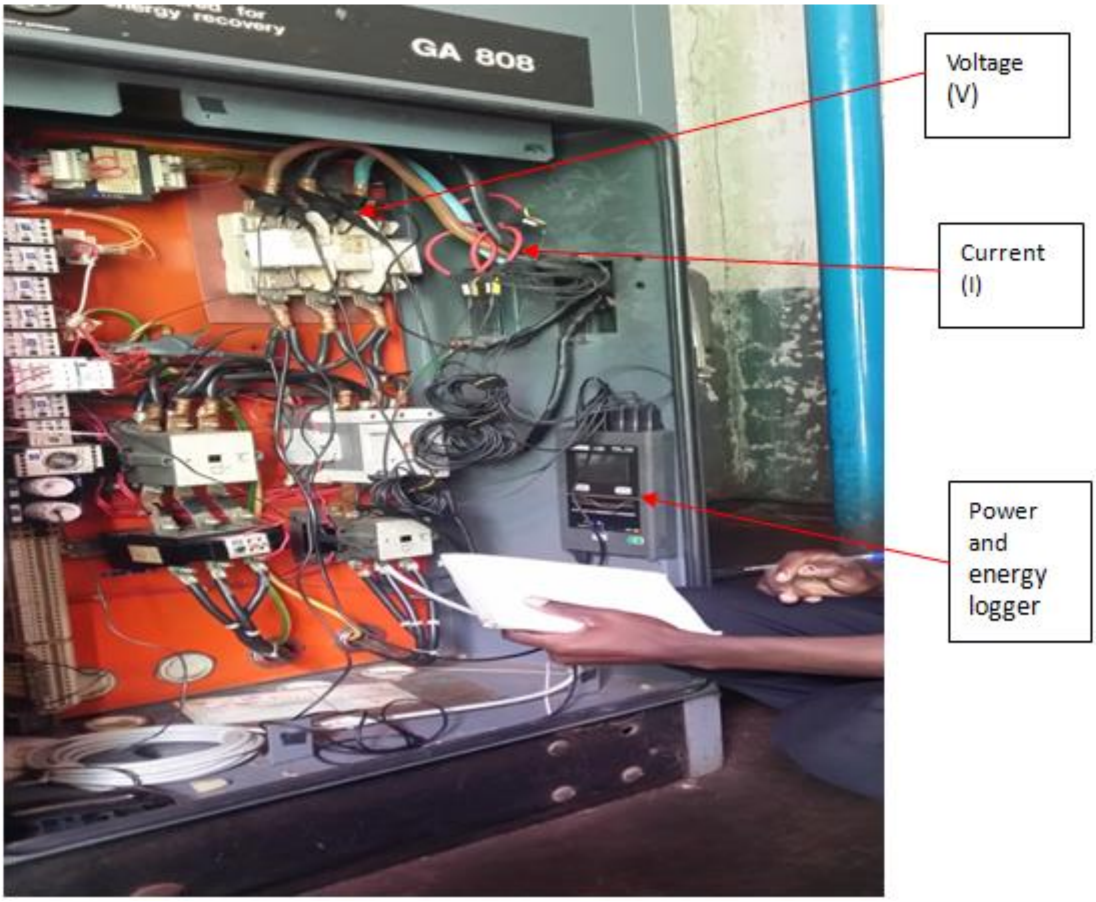

Figure I: Power and energy logger set up for Air compressor energy consumption trends recording

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Air leak test during shut down was performed to determine the extent of percentage air losses by air compressor. The method used involved starting the air compressor when all air operated end-use equipment (pneumatic machines) was turned off. A number of measurements were taken to determine the average time it takes to load and unload the compressor. The compressor load and unloads because the air leaks causes air compressor to cycle on and off as the pressure drops from air escaping through leaks. Total leaks were calculated as follows [2];

$$\text{Leakage (\%)} = [(T \times 100)/ (T+t)] \quad (1)$$

Where:

T = on-load time

t = off-load time

$$\text{System leakage (L/s)} = Q \times T / (T + t) \quad (2)$$

Where:

Q = compressed air capacity

$$\text{Energy loss (kWh)} = H \times P\, [(T / (T+t)] \quad (3)$$

H = Annual working time for the factory in hours

P = Compressor rating (kW)

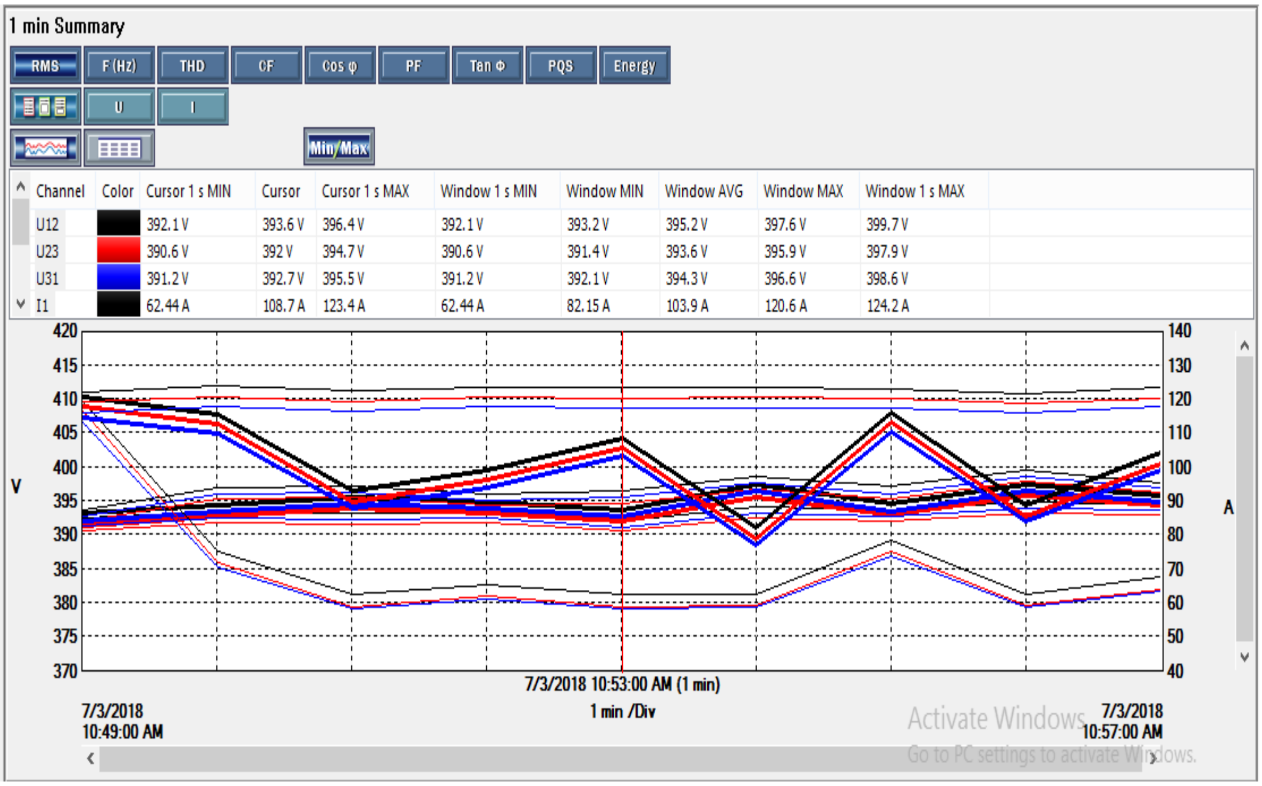
$$\text{Total cost for energy loss} = \text{energy loss (kWh)} \times \text{KES/kWh} \quad (4)$$

III. RESULTS AND DISCUSSION

Energy consumption pattern

The power consumption pattern for air compressor GA-808 is given in figure II.

Sample Recording: Loading trend of Rotary screw air compressor GA-808 (AC current/voltage logger, sample interval is 1min)



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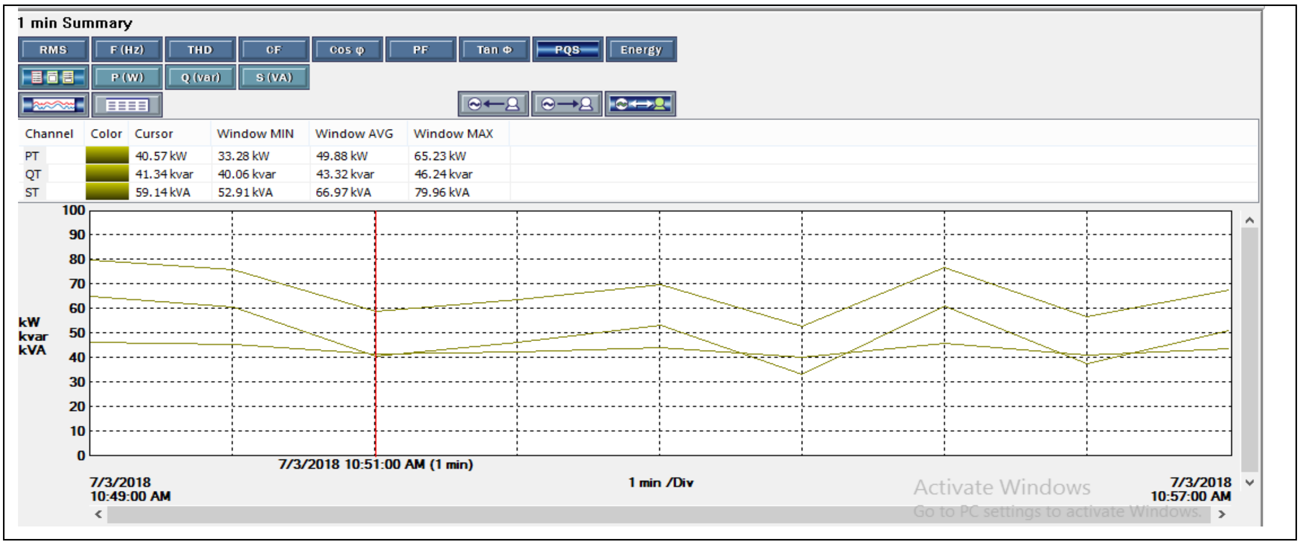

Figure II: Power consumption trends for air compressor GA-808

The power consumption measured was observed to be varying between 40.57kW to 65.23 kW with an average consumption of 49.88kW. The rated power of the motor is 75 kW and from the above measurement the motor is operating at 66.5% of the rated power based on average power consumption. The power factor was found to be 0.724.

Isothermal efficiency

Isothermal Efficiency = Isothermal power / Input power

Isothermal power is the least power required to compress the air assuming isothermal conditions[4].

$$Isothermal power(kW) = \frac{[illegible]}{[illegible]} \qquad (5)$$

P_1 = Absolute intake pressure kg/ cm^2

P_2 = Absolute delivery pressure kg/ cm^2

Q_f= Free air delivered m^3/hr.

r = Pressure ratio P_2/P_1

$$Isothermal power(kW) = \frac{[illegible]}{[illegible]} = \mathbf{37.65\ KW}$$

$$Isothermal efficiency = \frac{37.65}{[illegible]} \times 100 = \mathbf{57.7\%}$$

$$FAD = \frac{[illegible]}{[illegible]} \times Q$$

$$= \frac{65.23}{[illegible]} \times 183 = \mathbf{159.2\ L/s}$$

Estimating amount of leakage

The air compressor in the industry uses start and stop controls which makes it easy to estimate the leakage in the system. The results of the experiment showing load and unload times are given in table II.

% Air leakage = T × 100 / (T + t) = 49.7 × 100 / (49.7 + 49.3) = **50.20%**

System leakage (L/s) = Q × T / (T + t) = 183 × 49.7 / (49.7 + 49.3) = **91.87 L/s**

Leakage per day, (L/day) = 91.87 ×3600× 16 = 5,291,712 L/day

Table II: Leak test results of Air compressor

	Load pressure(bar)	Load time (T) sec	Unload pressure(bar)	Unload time (t) sec
Cycle 1	6	50	8	49
Cycle 2	6	49	8	50
Cycle 3	6	50	8	49
Average		49.7		49.3

Source: Researcher's experiment, 2018

Specific power for compressed air generation = 65.23/ (183×3600) = 0.000099 kWh/L

Energy lost due to leakage per day = 0.000099 × 5,291,712= **523.88 kWh**

Cost of energy lost per year = 523.88 ×25 days ×12 months ×Ksh 20= Ksh 3,143,280

Energy saving opportunity for Air Compressor

1. The major opportunity to save energy is in the prevention of leaks in the air compressor system. Leaks were observed as the major cause of wasted energy in the industrial compressed air system. Apart from wasted energy, leaks reduce the efficiency of air operated tools due to pressure drop along pressure lines affecting overall production. Leaks also leads to addition of unnecessary compressor capacity and increase of maintainance cost. Regular maintainance is necessary so as to reduce leakages along the air compressor piping's to less than 10% of compressor output. Leakages and wastages of compressed air in the industry occur mainly at the joints, connections and hoses.

2. Regular maintainance program adopted to identify leakage points and repair.

3. All pneumatic operated equipment should be lubricated to reduce friction thus preventing energy wastage due to excessive air consumption.

IV. CONCLUSION

The aim of this paper was to investigate energy performance and conservation measures for industrial compressed air system utilized in textile manufacturing industry in order to minimize energy cost.The results displayed poor performance for the compressed air system used in the industry.Air leakage was found to be 50.2% which is significant compared to 10% or less for well maintained system. The study found potential savings in electric energy to be approximately 157,164 kWh with simple payback period of 0.3 years.Energy assessment conducted in the industry presented enormous energy saving potential to reduce energy consumption through implementations of low cost investments such as fixing air leakages and regular maintenance.Though the research focused on energy investigation and conservation measures for compressed air system in textile manufacturing industry, investigation could be conducted on other energy intensive utility systems to reduce energy cost.

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