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THEORETICAL REVIEW OF THE ECONOMICS OF PAPER MACHINE OPERATION

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ABSTRACT

This paper reviews the variables affecting the production capacity of a paper machine. Paper grammage,machine deckle and operating speed of the machine are cited as major determinants, amongst others, in theevaluation of the machine production capacity. The daily production capacity of a paper machine in finishedmetric tonnage (FMT) can be calculated, using the formula P = $0.00006dvgc_1c_2c_3$ (tons/day). Variation ofthe production variables upward can translate to increase in machine output, though increments in thesevariables need to be carried out in a manner not to compromise product quality for a given paper grade.Optimum profitability of paper machine operation is enhanced by the production of mid-range grammagesof paper. While production loss can be reduced by promptly identifying and defining the various categoriesof faults affecting machine runnability, upholding scheduled maintenance plan for the machine system andensuring sustained capacity building for technical staff in paper machine operation are prerequisites forimproved paper machine efficiency. Globally, loss time analysis is used by mills to assess ways of reducingproduction loss and as a tool to assess the economics of paper machine operation, with a view to evaluatingthe efficiency or otherwise of the operating, maintenance and service departments in machine roomoperation.

Key words: Paper machine, production capacity, paper grammage, machine deckle, machine operating speed, lost time analysis, paper machine efficiency and machine runnability.

INTRODUCTION

Paper is an indispensable material to mankind. Today, there is hardly any home without paper in one usable form or the other. From time immemorial paper has served as a veritable source of preserving history as well as the medium for communicating the thoughts of the various peoples of the world (FA0, 1991). Paper is a packaging material for several articles of commerce, and practically, it has no rival as a base material for hygienic and sanitary conveniences. Paper and paper products are therefore an essential part of modern living, and it would be hard to imagine how our life styles would be without them (Noah, 2009 and Caltex, 1998).

Paper, a thin network of fibres and non-fibrous materials, is manufactured on a paper machine - an assembly of several equipment items spanning through a number of inter-related and inter-dependent operating sections. In paper machine design and operation, parameters that influence output from the machine are cardinal. These are the operating variables capable of affecting the economics of paper machine operation.

LITERATURE REVIEW

Calculating the Production Capacity of a Paper Machine

Three operating variables predominantly play influential roles when calculating the output from a paper machine.

- Grammage of the paper produced, g in g $/m^2$
- Machine deckle (trim width at reel), d in metres(m)
- Machine operating speed, v in $^{m}/min$

If the production capacity of the machine is represented by the letter P, then for every minute of running the machine, the theoretical output from the machine is governed by the relationship:

$P = dvg$ __________ (1)

Using the respective units of the variables in equation (1) to compute, then the unit for P is gotten via the expression.

$m \times {}^{m}/min \times g/m^2$

Hence, $P = dvg$ (g/min) _________ (2)

Converting the units in equation (2), i.e. gramme to kilogramme and minute to hour, the unit expressing the machine hourly production rate is arrived at:

P = *dvg* (0.06kg/hr)

Dividing both sides of the equation by 0.06

P = *0.06dvg* (kg/hr)

Thus, the hourly machine production is given by P = *0.06 dvg* (kg/hr) _________ (3)

Assuming the number of hours the machine can operate in a day is represented by c_1. In a day, the number of hours is 24. However, when projecting for the operability of a paper machine, the actual operating hours per day is considered to average from 22.5 to 23 (Fliate, 1988).

From equation (3), where the machine hourly production is given as

P = *0.06 dvg* (kg/hr), then in a day,

P = $0.06\ dvg\ c_1$, where c_1 = the number of hours the machine runs daily.

P = $0.06\ dvg\ c_1$ (kg/hr x hr/day)

P = $0.06\ dvg\ c_1$ (kg/day)

Therefore, the daily machine output (brutto) is given by:

P = $0.06\ dvg\ c_1$ (kg/day) ___________ (4)

Equation (4) holds sway if the machine runs without any break (stoppage) in the course of production, or there is no broke arising from paper slabs at reel-up, wastages from super-calendering or winder trimmings. In practice, this is not always the case. Therefore, to arrive at the daily finished output from the machine, two other coefficients c_2 and c_3 are usually factored into the calculating formula; c_2 stands for coefficient of idle running of the machine and c_3, the broke coefficient.

Incorporating c_2 and c_3 into equation (4), the daily finished output (netto) is arrived at:

P = $0.06\ dvg\ c_1\ c_2\ c_3$ (kg/day) _________ (5)

Since commercial production is usually expressed in metric tonnage, the daily finished metric tonnage of the machine is governed by the equation:

$$P = \frac{0.06\ dvg}{1000} c_1\ c_2\ c_3 \text{ (tons/day)}$$

Hence, P = $0.00006\ dvg\ c_1\ c_2\ c_3$ (tons/day) ---- (6)

From the forgoing, the daily capacity of the machine expressed in finished metric tonnes (FMT) can be calculated using the formula:

P = $0.00006\ dvg\ c_1\ c_2\ c_3$ (tons/day) -----(6)

Where, P = daily production capacity of machine in finished metric tonnes (FMT/day)

0.00006 – conversion factor

d = paper machine deckle (trim width of paper at reel), m

v = operating speed of machine, $^{m}/min$

g = grammage of paper produced, g/m^2

c_1 = number of operating hours per day (actual running or working hours of the machine in a day)

c_2 = coefficient of idle running of the machine (machine running without paper reeling). Such time lapse is for removal of paper breaks, change or repair of machine clothing or carrier ropes. It corresponds to 2-5% of the machine running time, usually taken as 0.98-0.95

c_3 = broke coefficient, taking into account paper wastage from paper slabs after turn-up (removal of full parent roll of paper) or paper wastage at winder, super-calender. It is considered to be 2-12% of daily machine output, and usually taken as 0.98 – 0.88 (Noah, 2009 and Fliate, 1988).

Lost Production Time

The paper machine is supposed to run until shut down. Thus, time available to it is supposed to be translated into productive time to meet planned production targets. In practice, the machine is sometimes caused to shut down or be shutdown due to operational hitches or maintenance exigencies. In either case, there is attendant loss of production.

The concept of lost production or loss time analysis is to assist the operating crew and by extension, mill management to identify and define the possible causes of non-productive time of the machine. This is with a view to taking appropriate remedial or proactive measures to improve operating discipline of the production and maintenance crew for enhanced paper machine efficiency (Smook, 1992).

Categories of fault likely to be responsible for lost production from the paper machine are operations, maintenance, utilities and others.

Operations - faults arising from operators' inefficiency or the inability of the production crew to tend and exploit the paper machine for targeted paper grades. Basic operating sources of downtime are start-up procedure (needful), paper breaks occasioned by slack or tight draws, calendering, reeling or turning-up hitches, grade changes in between production, machine clothing repairs or change on the fourdrinier, press and dryer sections, splicing or replacement of carrier ropes at machine dry end.

Maintenance - loss time due to mechanical, electrical and instrument repairs on the paper machine system.

Utilities - loss of services such as power, steam and compressed (mill and instrument) air supply to the machine room.

Others - production of off-grade paper, slab-offs at reel-up and broke, generally.

Each category of downtime is usually calculated as a percentage of the total down time. Graphs (bar or pie charts) are produced to show at a glance downtime distribution according to category. Relevant information on the time the machine is down and the time it comes up together with explanatory notes of the possible causes of downtime is carefully and meaningfully entered by the machine operating crew in the lost time form or data log format, according to the needs of individual mills.

The concept of lost time analysis varies from mill to mill, depending on the needs of individual mills. If in a typical paper machine room operation, categories of faults in the mill responsible for machine downtime and lost productive time are designated as follows:

Mechanical – A

Electrical – B

Instrument – C

Operations – D

Scheduled shutdown – E

Power – F

Steam – G

Mill miscellaneous – H

Non-mill – I

Then,

1. Hours available to mill= *24 – (E+I)*
2. Hours available to machine = *item 1 – (F+G+H)*
3. Productive time = *item 2 – (A+B+C+D)*
4. Machine hourly rate = *0.06dvg*(kg/hr)
5. Realised machine tonnage = *item 3*× *item 4*, expressed in BDMT/day
6. Theoretical tonnage, $P_{theoretical}$ = *0.00006dvg* × *item 1*
7. Tonnage off winder is the cumulative weighed output slitted out from the winder
8. Efficiency:

(a) Machine efficiency based on output = $\frac{\text{item 5}}{\text{item 6}} \times 100\%$

(b) Machine efficiency based on productive time = $\frac{\text{item 3}}{\text{Item 2}} \times 100\%$

(c) Winder efficiency = $\frac{\text{item 7}}{\text{Item 5}} \times 100\%$

(d) Mill efficiency = $\frac{\text{item 3}}{\text{Item 1}} \times 100\%$

On the whole, although paper machine efficiency serves as a useful yardstick to assess the performance in the machine room, winder efficiency remains the ultimate index of assessing the overall efficiency of paper machine room operations. After all, at the end of the day, it is the accepted and marketable tonnage of finished products going to the customers that eventually determine the effective work done by the machine (Noah, 2009).

Ways of Increasing Output from the Paper Machine

The production capacity of a paper machine is not only a function of the fundamental operating variables (paper grammage, speed and deckle of machine), but to some extent, also depends on the technical integrity of the machine, the qualifications and experience of the production crew tending and exploiting the machine as well as on the technical expertise of the maintenance staff to ensure enhanced safety culture (Filiate, 1988).

Basically, the output from the paper machine can be increased by

- increasing the operating speed of the machine
- increasing the grammage of the paper produced
- increasing the trim width of the paper at reel (Noah, 2009 and Kertulla, 1996).

However, attempts to increase these parameters should be done in a manner that the increment falls within the range that will allow for maximum output without compromising product quality. To complement these measures, upgrading the knowledge of operating staff in modern and innovative techniques in pulp and paper processing also enhances machine performance. Periodic but regular seminars or workshops are essential in-house training fora for capacity building to ensure improved operational efficiency. This facilitation makes room for proper and better understanding of the know-how to tend and safely exploit the machine, thereby reducing the period of machine idle running, quantity of broke arising from frequent paper breaks and by extension the overall process waste. (Noah, 2009 and Fliate, 1988).

According to Meinander (2005), stable machine runnability can be fundamentally enhanced by;

- having a more compact and simple designed process system
- reducing stock imbalance in composition through timely utilization of prepared stock
- eliminating air from the process system through centrifugal degassing
- maintaining a closed hydraulic system to reduce material imbalance and the attendant control problems.
- keeping a small system dimension for stability and fast process flow.

DISCUSSION

Although operating variables such as paper grammage, machine deckle and operating speed of machine are major determinants for increased output from the paper machine, high machine productivity should, however, be based on matching quantity of product with its quality. Paper grammage has influential impact on paper machine production capacity as higher grammage can directly bear on the production rate of the machine. However, attempt to increase output through basis weight increment should be done in a manner that will permit an allowable maximum output whose quality will not fall out of standard for a given paper grade. For instance, increase in output through basis weight increment should only produce an allowable maximum of $62g/m^2$ for a 60gsm paper, if the paper is not to fall out of standard for the said grade. Production of fine grade light weight paper induces better selling prices per ton while optimum profitability is achieved within the mid-range of grammages. Factors like machine speed, dryer capacity and machine runnability at wet end can also restrict direct translation of increased grammage to higher production rate. The effect of machine speed on machine productivity is obvious. If all other factors are unchanged, speed is proportional to the production of the machine (Smook, 1992). To derive maximum benefits from increase in machine speed, the drive status of the machine must be of high integrity and the bearings upon which the rolls of the wet and dry ends of the machine leverage must also be less prone to failure. Increase in machine deckle can vary the paper trim width at reel upward, but variation in machine deckle has its attendant problems. Cases of trims following sheet during paper making are common process constraints associated with increasing paper deckle (Noah, 2009).

Downtime in paper machine room operation cannot be eliminated but it can be controlled and reduced to the barest minimum. Hence, upholding scheduled maintenance plan will reduce percentage of maintenance done on break down basis, where considerable time is usually wasted in assembling and coordinating the maintenance crew. The key to a successful preventive maintenance system comes down to detail. The people involved in maintenance prevention and condition monitoring must be trained to become detectives of possible failures, not just observers that casually pass by the equipment (Idhammar, 1999). On the whole, maintenance is crucial to the smooth running of a mill. And the best way to maintain a paper machine or pulp line is having the equipment and machinery suppliers increasingly getting involved in the day-to-day maintenance activities of their customers (Toland, 2003).

CONCLUSION

Paper grammage, machine deckle and machine operating speed are major determinants when calculating the paper machine production capacity. Increment in these parameters should however be carried out within permissible range to allow for increased output from the machine without compromising product quality for each paper grade. Optimum profitability of paper machine operation is enhanced by the production of mid-range grammages of paper.

Identifying and defining promptly the various sources of faults on the machine system form the basis for ensuring sustained stable machine runnability for improved paper machine efficiency, while planned or scheduled maintenance is the panacea for higher overall maintenance cost and lost productive time on the machine. Globally, lost time analysis is used by mills to assess ways of reducing production loss in order to improve the efficiency of the paper machines.

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