What is good paper machine performance?

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ABSTRACT: By improving performance on our paper machines, we can avoid some of the problems experienced by other U.S. industries.

KEYWORDS: Bag papers, corrugating medium, efficiency, fine papers, liners, newsprint, paper machine, parameters, performance, performance evaluation.

Paper machine performance standards were first developed in the late 1970s and have been continuously updated. Operating information has been compiled on a broad spectrum of machines. Current performance standards for liner, corrugated medium, fine paper, newsprint, and bag are shown in **Tables I–V**. Good performance targets are typically halfway between the average and the top performing machines.

Paper machine efficiency

Paper machine efficiency is probably the best indicator of overall machine performance. However, since paper companies use several different definitions of efficiency, it is often difficult to make comparisons between mills.

In this paper, overall machine efficiency (OME) is calculated by multiplying percent uptime by percent salable product. This definition is similar to the formula used by the Canadian Pulp and Paper Association to rank newsprint machines.

Uptime is defined as:

Uptime = (annual hours sheet on reel/ annual available hours) x 100%

The annual available hours excludes scheduled outages of 24 hours or greater. This would include holidays and extensive periods of scheduled maintenance. Scheduled outages of less than 24 hours for field days and washups are counted as available hours. Unscheduled outages are counted as available hours no matter how long they last. Availability of pulp, steam, power, maintenance support, and other factors, in addition to machine performance, affect the calculation. This definition does not include a factor for machine speed. The highest reported uptime is 97% on a linerboard machine. The lowest uptimes are around 80%.

Percent salable product is defined as:

Percent salable product = (salable tonnage/ reel tonnage) x 100%

For a typical paper machine, salable tonnage is the net tonnage off the winder. For machines with off-line coaters or supercalenders, salable tonnage is net tonnage off the winder following the supercalender.

Losses between the reel and winder include trim, slab losses, and off-quality paper. Trim losses are high on some machines and have a negative effect on percent salable product. Some papermakers feel that trim losses should not be counted because they have no control over trim sold by the marketing department.

Slab losses between the reel and winder are significant on many machines. Some papermakers do not realize how high these losses can be. Installation of reel turn-up devices has reduced the amount of slab losses on many machines.

Some mills downgrade tonnage as "seconds" or "job lot." This paper is normally counted as salable tonnage with separate accounting to monitor downgrading. Downgraded tonnage should not exceed 5% of machine production.

The highest reported percent salable figures noted are 99% on newsprint and liner machines. Some fine-paper machines report values as low as 80%.

The highest reported overall machine efficiencies are shown in **Table VI**.

In many cases, overall machine efficiency can be improved without major capital expenditures. Lost-time and shrinkage losses should be broken down by category and then traced to the cause. Significant improvement can often be achieved by focusing on problem areas.

Some typical guidelines for paper machine lost time are shown in **Table VII**. These targets vary somewhat for different grades but are generally ap-

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plicable to a broad spectrum of paper machines.

Lost-time due to breaks varies widely from machine to machine. For example, low-speed liner machines producing heavyweight grades have fewer breaks than high-speed fine-paper machines with size presses.

Open draws have a significant effect on break frequency. The maximum speed with an open draw off the couch is around 2000 ft/min. Break frequency at the couch can be minimized on open-draw machines by optimizing couch transfer geometry. Guidelines for good sheet transfers have been reported in other articles (*1*). The maximum practical speed for an open draw after one press appears to be between 2000 ft/min and 2500 ft/min. Machines with no open draws until after the second press are achieving speeds as high as 3500 ft/min. Some high-speed machines with single-tier dryers have no open draws until the dry end of the machine.

Another factor that varies widely from machine to machine is average lost time per break. Obviously, it takes longer to thread a long, low-speed machine than it does a high-speed lightweight machine. However, lost time per break can vary by a factor of three on similar machines. Some mills organize their crews so everyone has specific jobs, and they get them done efficiently. In other mills, crew members stroll down to the wet end and leisurely attempt to get the sheet back on the reel.

Scheduled maintenance includes planned outages for major jobs such as roll changes and piping repairs. Many machines schedule one eight-hour maintenance outage per month. Efficient mills coordinate machine washups, clothing changes, and carrier rope installations with scheduled maintenance outages to minimize downtime.

Unscheduled maintenance is downtime caused by mechanical breakdowns. Good preventive maintenance programs combined with vibration and process monitoring systems have greatly reduced unscheduled maintenance in many mills. Monitoring of bearings along with appropriate maintenance has been especially beneficial.

Improving maintenance effectiveness has been emphasized in many mills in the last 10 years. These programs have led to improved paper machine uptime as well as reduced maintenance cost. There is a wide range of maintenance cost on paper machines. In some cases, maintenance cost per ton varies by a factor of two on similar-vintage machines.

Miscellaneous operating lost time includes washups, rope changes, clothing changes, and other operating problems that are not done on scheduled maintenance outages. Good management is required to keep miscellaneous operating lost time below 1%.

I. Linerboard performance indices

Parameter	Observed performance range	Good performance
Overall machine efficiency, %	73–95	90
Uptime, %	80–97	93
Salable product, %	85–99	97
Primary headbox consistency, %	0.46–0.75	0.4–0.6
Secondary headbox consistency, %	0.37–0.71	0.4–0.6
Steam box steam consumption, lb steam/lb paper	0.15–0.49	0.15–0.25
Flatbox vacuum, ft^3/min/in. fabric	17–80	40–50
Couch vacuum, $ft^3/min/in.^2$	4.3–8.2	6–7
Consistency off couch, %	20–29	27
Consistency after last press, %	36–52	42/48
Consistency entering breaker stack, %	47–59	50–53
Steam consumption, lb steam/lb water evaporated	1.2–1.9	1.3
TAPPI drying rate, lb water/h/ft^2	4.5–6	5.7 (at 140 psig)
Conditioned weight profile total variation, %	0.6–10.3	4/1.5
Moisture weight profile peak to peak, %	0.7–7.6	2 (at 7% avg.)
Water consumption, 1000 gal/ton	4–10+	3

II. Corrugating medium performance indices

Parameter	*Observed performance range*	*Good performance*
Overall machine efficiency, %	76–95	90
Uptime, %	80–96	93
Salable product, %	85–99	97
Headbox consistency, %	0.8–1.7	1.0–1.2
Steam box consumption, lb steam/lb paper	0.15–0.49	0.15–0.25
Flatbox vacuum, ft^3/min/in. fabric	10–40	18
Couch vacuum, $ft^3/min/in.^2$	4.3–8.2	6–7
Consistency off couch, %	19–29	27
Consistency after last press, %	36–48	40/47
Steam consumption, lb steam/lb water evaporated	1.2–1.9	1.3
TAPPI drying rate, lb water/h/ft^2	4–5.5	5 (at 140 psig)
Conditioned weight profile total variation, %	1.2–10.3	3/1
Moisture weight profile peak to peak, %	1.8–7.6	4/2 (at 7% avg.)
Water consumption, 1000 gal/ton	0.7–10+	3

III. Fine paper performance indices

Parameter	Observed performance range	Good performance
Overall machine efficiency, %	67–93	84–88
Uptime, %	75–94	92
Salable product, %	80–96	94
Headbox consistency, %	0.2–0.8	0.4–0.6
Flatbox vacuum, ft³/min/in. fabric	2–12	5
Couch vacuum, ft³/min/in.²	1.9–8.2	6–7
Consistency off couch, %	8–22	20
Consistency after last press, %	25–46	40–42
Moisture entering size press, %	1.0?–4.2	3
Steam consumption, lb steam/lb water evaporated	1.2–1.6	1.3
TAPPI drying rate, lb water/h/ft²	3–5.5	4.7 (at 60 psig)
Bone-dry weight profile total variation, %	0.8–10.3	3/1
Moisture profile peak to peak, %	0.7–4.0	1% (at 5% avg.)
Water consumption, 1000 gal/ton	4–40	3

IV. Newsprint performance indices

Parameter	Observed performance range	Good performance
Overall machine efficiency, %	74–94	89
Uptime, %	80–95	93
Salable product, %	85–99	96
Headbox consistency, %	0.5–1.6	0.5–.7
Flatbox vacuum, ft³/min/in. fabric	2–12	5
Couch vacuum, ft³/min/in.²	1.9–8.2	6–7
Consistency off couch, %	14–22	20
Consistency after last press, %	35–44	40–43
Steam consumption, lb steam/lb water evaporated	1.2–1.6	1.3
TAPPI drying rate, lb water/h/ft²	2.8–4.2	3.8 (at 40 psig)
Bone-dry weight profile, %	0.8–10.3	3/1
Moisture profile peak to peak, %	0.7–4.0	1% (at 8% avg.)
Water consumption, 1000 gal/ton	0.4–10+	3

Grade-change time varies widely depending on grade mix and furnish change requirements. Some mills minimize lost time on grade changes by adding dyes and other additives at various points in the wet-end system instead of shutting down, dropping water, and washing up. Some mills add bleach to the wet-end system while running to eliminate the need to shut down and wash up on color changes.

Headbox consistency

Headbox consistency should generally be as low as possible for optimum formation and sheet tests. One exception is corrugating medium. Most corrugating medium papermakers feel they get the best tests by running in the range of 1% to 1.2%. Headbox consistency guidelines for major grades are shown in Tables I–V. Equipment limitations or poor retention can require higher headbox consistencies.

Steam shower steam consumption

Steam showers in the forming and press sections are effective ways to increase machine speed potential. However, some steam shower designs are very inefficient and contribute to moisture profile problems. Steam consumption should be checked to ensure that usage is not excessive. Thermographic scanning systems can be used to check temperature profiles after steam showers.

Vacuum application

Low vacuum application at the flatboxes and couch results in a wet sheet off the couch and can cause sheet runnability problems and crushing in the press section. Vacuum pump and blower performance should be checked regularly to see if they are performing near their design levels. Inefficient vacuum sources should be upgraded. Several older machines have realized significant improvement in performance with upgrades to their vacuum systems (*2*).

The TAPPI Papermakers Committee has updated Technical Information Sheet 0502-01 on "Paper Machine Vacuum Selection Factors." The guidelines for suction boxes develop recommended cubic feet per minute from fabric width, vacuum factor (ft³/min/in.²), and number of boxes. The new couch vacuum recommendations are adjusted for machine speed.

Consistency after last press

Sheet consistency targets vary from grade to grade, as shown in Tables I–V. Two good performance values are shown for liner and corrugating medium. The first number is for roll presses, and the second number is for shoe-type presses. Sheet consistency can vary significantly due to furnish composition and sheet temperature. The trend toward greater use of recycled fiber is resulting in higher sheet consistencies out of the press section.

A generally accepted rule of thumb has been that each 1% increase in sheet consistency after the last press permits a 4–5% machine speed increase on drying-limited grades or a comparable reduction in steam consumption. A recent survey of linerboard machines indicated that drying rates go down as sheet consistency increases out of the press section (3). The study concluded that each 1% increase in sheet consistency out of the presses produced a 3–3.5% production increase potential. Similar relationships likely apply to other grades.

V. Bag paper machine performance indices

Parameter	Observed performance range	Good performance
Overall machine efficiency, %	74–94	89
Uptime, %	80–95	93
Salable product, %	85–99	96
Headbox consistency, %	0.2–0.6	0.3
Flatbox vacuum, $ft^3/min/in.$ fabric	15–50	30
Couch vacuum, $ft^3/min/in.^2$	1.9–12	7
Consistency off couch, %	18–28	26
Consistency after last press, %	35–43	40–42
Steam consumption, lb steam/lb water evaporated	1.2–1.6	1.3
TAPPI drying rate, lb water/h/ft^2	4–5.8	5.4 (at 90 psig)
Bone-dry weight profile total variation, %	0.8–10.3	3/1
Moisture profile peak to peak, %	0.7–4.0	1% (at 7% avg.)
Water consumption, 1000 gal/ton	3–10+	3

VI. Highest overall machine efficiencies

Grade	% OME
Liner	95
Corrugated medium	95
Newsprint	94
Bag	94
Fine paper	93

VII. Paper machine lost time targets

	Percent of available time
Breaks	3.0
Scheduled maintenance	1.5
Unscheduled maintenance	1.5
Miscellaneous operating	1.0
Grade changes	0–4

Breaker stack

Guidelines for sheet consistency into the breaker stack are included in the liner performance indices. Installation of large-diameter roll and shoe-type presses has required moving the breaker stack closer to the press section.

TAPPI drying rate

Drying rate is defined as the amount of water evaporated per area of dryer surface. Drying rates increase with higher average steam pressures, as demonstrated by the TAPPI Drying Rate Curves for various grades (TIS 0404-08, 0404-09, 0404-12, 0404-14, 0404-15, and 0404-16). Drying rates vary significantly from machine to machine. Some of the items that can improve drying rates include graduating wet-end steam pressures, reducing pocket humidities, improving dryer drainage, installing dryer bars, increasing dryer fabric tension, maintaining all dryers in service, and increasing exiting moisture contents.

Dryer section steam consumption

Steam consumption in the dryer section varies widely, as can be seen in the observed performance column in Tables I–V. Some machines still have very inefficient steam and condensate systems. Several mills do not have accurate monitoring of steam consumption. Steam consumption can be determined by measuring condensate in separator tanks according to TAPPI TIS 0404-02. Pounds of steam per pound of water evaporated is a good index since it eliminates the effect of sheet consistency.

Basis weight and moisture profiles

Basis weight profiles have improved significantly with widespread application of automatic cross-direction (CD) slice control systems. Several machines are achieving profiles with less than 1% variation. Two numbers are shown on the good performance column for weight profile variation in Tables I–V. The first number is for manual control and the second number is for automatic control. Moisture profiles also are improving with better basis weight profiles and good CD actuators for moisture control.

Water consumption

Water consumption is generally very high on machines in the United States. Most mills have abundant water supplies and have fairly open white-water systems. Typical water consumption is 4000–5000 gal/ton of paper. Some mills are doing much better. One newsprint mill reported 400 gal/ton, and a corrugating medium machine is running 700 gal/ton. Low water consumption reduces effluent treatment requirements and steam required to heat white water to desired operating temperatures. Keys to reducing water consumption are greater use of clarified white water for showers and recirculation of vacuum pump seal water.

Conclusion

There are opportunities to improve performance on most paper machines without major capital expenditures. Evaluation of machine performance using the parameters discussed is a good way to identify performance potential and determine requirements to improve operation.

By improving performance on our paper machines, we can avoid some of the major problems experienced by other industries in the United States. Optimized paper machine performance and wise expenditure of available capital funds, combined with advantages in raw material availability, can put the U.S. paper industry in a strong competitive position.

The performance targets included in this paper are based on my experience along with input from many different sources. Any comments on the targets and suggestions for improvement would be appreciated. TJ

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