FOCUSING ON THE FUTURE OF CONTROLLING THE PROCESS

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SUPPLIERS OF PROCESS CONTROL AND DRIVE EQUIPMENT OFFER THEIR VIEWS OF WHAT A FASTER PAPER MACHINE WILL MEAN TO THE INDUSTRY

THIS IS THE THIRD PART OF THE *TAPPI JOURNAL* Technology Spotlight series dedicated to focusing on current topics of interest for the industry as a whole. This month we questioned several industry leaders on the question of machine speeds and if they were to double within the next five years to perhaps 10,000 ft/min (3300-4000 m/min) or more, what impact would that have on the process control and drives areas? How will forming fabric and dryer felts be effected by operating drives at higher speeds?

TAPPI JOURNAL posed the questions to a select group of roundtable participants from the 1997 TAPPI Process Control, Electrical and Information Conference. Responding were James A. Bourque, Marketing Director, Bailey Controls; Pete Werner, Principal Engineer, Rockwell Automation Drive Systems; Peter Worland, Technical Manager-Pulp and Paper Industry, Control Techniques Worldwide, a division of Emerson Electric Co.; Tom Lantz, Product Manager-Sensors, Honeywell-Measurex; and Tom Cissell, Director of Product Development, ABB Industrial Systems Inc.

Please see the January issue of *TAPPI JOURNAL* pages 31-34 and the February issue, pages 70-78, for the first two parts in this series.

TAPPI JOURNAL: Are current drives capable of running at 10,000 to 12,000 ft/min (3300-4000 m/min) on a paper machine?

Bourque, Bailey Controls: Drive systems are available to attain these speeds. Look to the TVG train of France and the bullet train in Japan.

Worland, Control Techniques Worldwide: Technically there is no reason why current technology should not be used. I am assuming that the increased speeds will be obtained by selection of the correct gear box ratio, hence there is no need for any significant change in motor speeds. Obviously motor torque's and hence horse power (HP) ratings will need to be increased, i.e. larger motors in ration to the speed increase. Possibly an increase in the ration of recommended drive capacity (RDC) to normal running load (NRL) service factors may increase in order to achieve higher mechanical forcing factors and also prevent overlong run up times when starting high inertia sections. The secret will be in obtaining control over motor speeds which reflect the required accuracies when translated into surface speeds on the machine. Drives are already attaining these accuracies for other applications typically servo-type drive solutions. We believe our drive technology is up to the mark, high performance drives with servo-type performance in the larger HP ranges are becoming more available and could be a critical component availability wise, gearless drives will allow considerable enhancement in performance.

Werner, Rockwell Automation Drive Systems: Paper machine (PM) winders have far more demanding performance requirements than a paper machine. This includes rapid acceleration and deceleration rates, very accurate tension control, and far more sophisticated torque distribution strategies. PM Winders are already operating at paper surface speeds approaching 10,000 ft/min. Motors, power units, or control strategies should not prevent paper machine speeds from reaching this speed.

TAPPI JOURNAL: Can current drives be controlled at those speeds to provide the proper tension to the sheet?

Bourque, Bailey Controls: The drive systems will have to evolve to meet these requirements as will the control system.

Worland, Control Techniques Worldwide: On a modern digitally controlled drive system, the resolution to which a section speed can be controlled depends upon the numerical values used by the drive speed control system to represent maximum speed. If a drive can only represent maximum speed with an internal number of say 1000 then at 5000 ft/min a single increment in the internal value would imply a speed change of 5 ft/min, this extreme example would obviously be totally unsatisfactory even at 1000 ft/min as draw changes on a paper machine would be far to coarse. Control Technologies currently uses a numerical value of 30,000 to represent the maximum speed of the machine in high performance applications such as this. I suggest that this degree of fineness would probably be suitable for the higher speeds envisioned here.

A similar problem also applies to the numerical value used to measure actual speed which is used as a feedback signal to the controller, if this signal does not conform to the level of accuracy used for the reference then we are clearly wasting our time. The conventional incremental encoder currently the industrial standard for speed feedback can only provide about 2000-3000 lines per revolution. By using all four quadrature signals the drive can be arranged to convert this to 4 times the encoder count i.e. 8000-12,000 counts per revolution. Encoders with higher line numbers are technically difficult to manufacture and will probably cause drive speed jitter due to inaccuracies in the spacing between successive lines within the encoder. This type of encoder could well prove to be the weak link at higher operating speeds. A new type of encoder the sine-cosine encoder overcomes these problems and is capable of providing the drive with a speed feedback signal with an accuracy equivalent to several thousand lines per revolution. Control Technologies has already experienced the gain in operating accuracy achievable with these encoders where they were used to overcome bearing problems on a very critical plastic film application where the jitter caused by a encoder was not acceptable.

Werner, Rockwell Automation Drive Systems: Again, more accurate control of tension than is required for paper making is already being achieved at the PM winder, and this is under more demanding operating criteria such as acceleration, deceleration, and transitions from and to zero speed.

In all likelihood, physical limitations of dancers (or float rolls) will preclude their use for tension control at high speeds as their variable dynamics will be more problematic at these speeds. Therefore, reliance on already developed sound, closed-loop tension control strategies employing tension transducers will be a must at the dry-end of the machine. Open-loop draw control will still be the requirement at the wet-end of the machine. Implementation of outer surface-speed control loops will likely be required for sections with fabrics.

TAPPI JOURNAL: What control strategies or innovations will be needed to upgrade current drives to highspeed standards?

Bourque, Bailey Controls: This will depend on the final configuration of the paper machine itself. The control systems available today are capable of handling speeds much higher than those of today's paper machines. The coordination and synchronization will be the largest challenges.

Worland, Control Techniques Worldwide: Due to their inherently higher switching rates and subsequently improved bandwidth, AC drives are the way to go now and in the future

Werner, Rockwell Automation Drive Systems: Actually there are potential benefits to increasing paper machine surface speeds relative to drive systems. In a paper machine, the driven rolls that process and transport the sheet are relatively large in diameter. Therefore, higher surface speeds will reduce the degree of, and in many cases eliminate the need for, speed reduction components in the drive train.

This situation will reduce the difficulties associated with drive train power losses as well as the variable dynamics associated with multiple shafts and couplings. In other words, simpler, more straight forward in-drive systems are a major advantage for drive-system performance as line speed increases.

TAPPI JOURNAL: Can current process control systems control a machine running at twice the speed?

Lantz, Honeywell-Measurex: One of the limiting factors of conventional process control is the time delay between the measurement point and the control actuator; typically ranging from several seconds on a tissue machine to 10 minutes on a heavy multilayer board machine. In speeding up the machine by a factor of two, the time delay is reduced by a factor of two in terms of time, but in terms of tons of paper, losses due to the distance between the measurement and the control actuator (be it a cross direction actuator or a thick stock or steam valve) remains the same. That is, there is a fixed distance between the reel scanner and the thick stock valve, but in running at twice the speed, the paper will cover this distance in half the time. So, despite doubling machine speed, the same percentage of paper is lost during startups, upsets, etc. that is lost now.

The opportunity here is to eliminate the time delay via such products where measurement across the sheet is simultaneous. Another opportunity is to obtain a good enough understanding of the process that a good predictive model of the process can be created for each quality variable. Then, measuring the quantity and qual-

ity of raw materials and process variables enables prediction of final product quality. Both of these solutions will reduce the percentage of lost production, regardless of process speed.

Cissell, ABB Industrial Systems Inc.: While current process control systems can technically control machine's that run at twice today's speed, the demand for increased quality has always kept pace with the demand for increased productivity. This means most current process control systems will not be acceptable forpapermakers use on machines running at twice the speed. If the paper machines run at twice the speed, so will the converters and printing presses, thereby requiring a more uniform, flatter sheet. Also, it will take half the time to produce the same amount of paper, leading to shorter runs and more frequent grade changes on fine paper and specialty grade machines. Therefore, faster machines will require full sheet imaging systems, which measures 100% of the sheet, to provide sufficient data for product quality control and diagnostics.

Bourque, Bailey Controls: Yes.

Worland, Control Techniques Worldwide: Current control systems can give the necessary levels of control. From a drives perspective the need for improved speed accuracies at higher operating speeds on this type of paper machine lends itself well to distributed control systems. Distributed control systems allow individual drives on specific sections of the paper machine to make decisions locally and send the information to other pertinent drive sections very quickly. This type of deterministic control scheme provides a means of truly distributing the control down to the individual drive sections so that the responsiveness of the drive system is maximized at higher operating speeds.

TAPPI JOURNAL: Will new control standards be needed if paper machine speeds double or can current systems be upgraded?

Lantz, Honeywell-Measurex: Controlling a slow machine is generally regarded as being a more difficult task than controlling a fast machine. However, as discussed above, using a new standard for measurement and control that has the ability to positively impact the percentage of paper that is lost in startups, grade changes and upsets for a given machine.

Cissell, ABB Industrial Systems Inc.: Next generation two-dimensional control strategies will be needed to build a uniform sheet, minimize waste and reduce grade change time. Since downtime will generate twice the amount of production losses, improved diagnostics that leverage full sheet imaging will be required to diagnose and eliminate causes of waste and breaks.

Bourque, Bailey Controls: Perhaps, as we ramp up the speeds of the paper machines we will discover new problems and issues. Setting standards before you attain the goals may be self-limiting.

Worland, Control Techniques Worldwide: Possibly.

Werner, Rockwell Automation Drive Systems: Standards are always evolving relative to new technologies, and significantly higher speeds will likely effect changes in control standards. Normally, upgrading a system is associated with a maximum 25% performance improvement. Upgrading isn't probable to achieve a doubling of performance.

Increases in speed certainly will require increases in connected sectional drive power. AC drives will be more attractive at higher speeds, and in-drive mechanical components will require significant improvement.

TAPPI JOURNAL: Are current sensors adequate for much higher speeds? Will cross direction (CD)/machine directiom (MD) equipment still be functional with appropriate software upgrades or will significant upgrades be necessary?

Lantz, Honeywell-Measurex: Current sensor technologies are probably adequate for future machines, given the limitations imposed by the time delay of existing paper machine technology. That is to say that the response of current sensors is adequate to provide a repeatable enough measurement to enable control at the cutoff frequency imposed by the process time delay. This applies to both machine direction and CD control. Signal processing (in the computer) is, for all intents and purposes, instantaneous, and today's state-of-the-art profile actuators are easily fast enough to control machines running at 4000 m/min.

While current technologies are adequate for feedback control, today's sensors do not provide the speed of response necessary for 100% visibility that is necessary not to provide feedback control, but to completely characterize paper quality for customer certification and increased understanding of the process. Nonscanning measurement is required to achieve this for most qualities, and this capability is now available for such qualities as flaws and basis (or dry) weight, but much more work is required in this area.

Cissell, ABB Industrial Systems Inc.: Traditional mechanical scanning sensors sample less than 1% of the sheet. As machine speeds increase, less sampling will be realized since twice as much paper will pass before the next measurement. Higher machine speeds will require Fullsheet Imaging Systems which measure and control 100% of the sheet through camera-based technology.

The current CD actuators on the market will still function on machines running at twice today's speed, but some of them do not have the necessary speed of response to keep up with the increased demand for uniformity that will accompany higher machine speeds. Also, those actuators with a wear characteristic that were deigned for a ten year life on current machines may wear out or fail, in half the time or less, if their duty cycle doubles.

Two-dimensional control algorithms will use CD actuators and MD actuators together to reduce total variability. The trend will be towards faster actuators and the current trend of higher CD actuator resolution will continue.

Bourque, Bailey Controls: Are current sensors adequate for much higher speeds? NO! Newer technology will lead the way.

The current control strategies will suffer with the current flow of information from today's scanning quality control systems (QCS). Newer technology will lead the way, but I think a far more cost effective technique involves predictive on-line analyzers (POA). These soft sensors will have the capability to handle much higher speeds and much more complex control strategies.

TAPPI JOURNAL: If the desired control is 1 ft/min accuracy between drives, that is 1/10,000 accuracy. Is that feasible for current drives as we know them?

Bourque, Bailey Controls: I don't think so. Perhaps a drives manufacturer could better answer the question. The control system is capable.

Worland, Control Techniques Worldwide: We normally use a value of 30,000 to represent machine top speed in our transmission network. So on a 3000 ft/min machine we can send speed increments of 0.1ft/min. A 12,000 ft/min paper machine could be controlled with speed increments of 0.4ft/min using existing technology. More Research & Development (R&D) is being done all the time on high accuracy feedback devices so this resolution will most likely improve in the future. Local drive based processors then use floating point routines convert these values to motor revolutions per minute(RPM). The drive is able to accept these RPM setpoint values to a resolution 0.01rpm.

Werner, Rockwell Automation Drive Systems: This statement or question is a common misunderstanding. The actual draw parameter in a moving sheet, which effects tension, is actually a ratio or percentage phenomenon and not an absolute difference phenomenon.

The reason for the confusion is that paper makers, who normally relate to a specific machine, operating within a relatively narrow window of surface speeds, use absolute ft/min differences in speed for their judgment as to appropriate section-to-section draws. As well, drive system suppliers, in order to satisfy this method of judgment for a particular application, provide speed / draw indicating systems that display draw in absolute ft/min difference. Both contribute to the misunderstanding.

Properly configured draw control systems actually control speed ratios that are more correctly dimensioned in ratios and/or percentages. As such, the ability to effect the control of required percentage draw accuracy as paper machine speeds increase should not be a problem. Displaying them effectively for the paper maker, in formats they are accustomed to, may be.

TAPPI JOURNAL: Will increased speed mean going to AC or DC drives?

Bourque, Bailey Controls: Perhaps

Worland, Control Techniques Worldwide: Normal 6 pulse thyristor converters as used for the majority of Paper Machine DC drive solutions have a restriction on the transient response attainable by the current loop. This limitation is determined by the mains frequency at which the power converter is supplied. Changes in current output and hence motor torque can only be made 6 times in each supply frequency cycle period, the speed controller having detected an error cannot adjust the output current until the next possible conduction period occurs.

AC drives are not synchronized to the mains, their power stages are designed to operate at much higher modulation frequencies. The delay between the speed controller detecting an error and the related adjustment of the output current is therefore much shorter than with the DC version. The payback from this is a more stable drive capable of faster response to transient load changes.

As explained above AC out performs DC. Power levels on most sections are beyond the range of present servo motors. Servo drives may provide a solution for Silent Drive installations where motor HP could be reduced by the use of higher numbers of in drives.

Werner, Rockwell Automation Drive Systems: Certainly, AC drives will be much more attractive if significant increases in paper machine surface speeds are realized. The reasons are:

- AC motors, due to their mechanically reliable rotors, are more compatible with higher motor speeds, which will be required for the rolls in the machine with smaller diameters.
- Higher surface speed machines will likely result in wider operating speed ranges. This situation will make the unity power factor characteristic of the AC drive very attractive.
- Achievable torque and subsequent speed control loop bandwidths are significantly higher for pulse-width-modulated variable-frequency AC drives compared to DC drives. This will be a major consideration as surface speeds increase significantly.

TAPPI JOURNAL: Will limitations on the drives be mechanical or technological?

Bourque, Bailey Controls: Mechanical

Worland, Control Techniques Worldwide: As with all new developments there will be several unforeseen difficulties. I was trying to sound a warning, I am sure there will be factors which I have not covered here and currently cannot foresee. Most limitations will probably be mechanical.

Werner, Rockwell Automation Drive Systems: The more difficult hurdles will be mechanical. Drive motors are already operating at motor speeds far below existing limits or are having their speed significantly reduced mechanically.

The greatest problems will be dynamic issues (such as natural frequencies, mechanical dead- bands, and compliance in the drive-train) relative to shafts, couplings, and process and transport rolls.

TAPPI JOURNAL: What will be the affect on the forming fabric and dryer felts of operating drives at higher speeds?

Lantz, Honeywell-Measurex: The lives of forming fabrics, felts and dryer fabrics can be expected to remain approximately the same in terms of tons produced unless the process changes significantly. For example, if maximum dryer temperatures are increased from 300° F to, say 500° F, dryer fabric life could be expected to be shortened considerably. The same could be expected if press felt pressures are increased to increase machine speed, or as increased vacuum is applied to forming fabrics to double the dewatering rate in the forming section. At twice the operating speed, the number of running days for felts and fabrics will be halved versus current life.

Bourque, Bailey Controls: What will be the affect on the forming fabric and dryer felts of operating drives at higher speeds? The additional wear from speed and friction should be substantial. As the press and drying technology change, the need for paper machine clothing may change as well.

Werner, Rockwell Automation Drive Systems: Relative to the fabrics, this question is probably best answered by a paper machine fabric expert. Relative to the drive and its responsibility to control the sheet speed, as well as the driven equipment speed, the most obvious potential problem at significantly higher surface speeds, would be roll-surface-to-fabric-surface slippage, causing poor sheet-speed regulation.

Relative to this issue, and questions number 2 & 3, to achieve good sheet-speed control, outer surface speed control loops may have to be incorporated, utilizing new surface speed transducer technologies such as lasers.

TAPPI JOURNAL: How will maintenance of drives be affected at higher operational speeds?

Bourque, Bailey Controls: Higher demands on the drive system will require higher levels of maintenance. Race cars need more maintenance going shorter distances than the family sedan.

Worland, Control Techniques Worldwide: I suggest that most of the maintenance problems will emanate from the mechanical parts of the system, remembering as mentioned earlier that speed increases will be obtained by gearing and not by increasing motor operating speeds. Electrical maintenance procedures will probably not change much from current practice. More attention may be required in the encoder area. Alignment correctness etc. Power transmission devices on the gear box output side will be running at greater speeds and will no doubt need more attention.

Werner, Rockwell Automation Drive Systems: There is reason to believe that drive maintenance may be reduced due to the above-referenced expected reduction in complexity of the in-drive components.

Over the past decade, manufacturers of drive products and systems have positioned themselves well by incorporating high-speed diagnostics into drive and system products for analysis of both the drive products and the driven processes.

Significant increases in paper machine speeds, which as stated above is principally an increase in process speed and not necessarily an increase in drive motor speeds, will begin to rely more on the driven equipment, process diagnostics, and maintenance support features of the drives and drive systems.

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