Optimizing Paper Picking Capability: Light Weight & High Speed

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This paper discusses development work Check Technology Corporation undertook to optimize the paper feeding capability of their unique high performance, large format cut sheet printer–the Imaggia. This printer employs multiple input tray dynamic collation technology, coupled with ion beam imaging, dry toner-based non-impact printing technology. The goal was to extend the throughput performance by 30% from commercial versions already in production, and simultaneously drive the printing capability down to even lighter weight sheets - in the 14lb or less, true basis weight range. This requirement is necessary to handle specific challenges in security printing, specifically USA consumer check printing applications which commonly use very lightweight duplicate, or carbonless, counterfoils for the consumer to keep an automatic, detailed record of his checkbook transactions.

Reliably feeding and handling large cut sheets, including short grain in process direction, up to 18in wide and 20in or more in length, at speeds of 130 feet per minute, faced us with new challenges to manage the mechanical instability of such sheets subject to significant aerodynamic and impact forces at these rates. We will discuss solutions we pursued to dampening paper ripple effects to ensure reliable feed behavior and the development of innovative dynamic electro-mechanical feed motion profiles we developed to be capable of agiley adjusting their characteristics according to the stock weight/characteristics being fed. With these methods, we were able to randomly dynamically feed sheets ranging from 14 lb. to 110 lb. basis weight within single jobs forming part of complex on-demand, secure personalized documents.

Introduction

The Imaggia Digital Print System is the World's highest production cut-sheet digital printer. Check Technology Corporation has invested considerable resources developing the Imaggia Digital Print System to be capable of operating with a high degree of operational reliability while running a wide variety of stock sizes, types, and weights. This has been important to achieving successful operation with the diverse print applications encountered worldwide.

This system employs our "Dynamic-Collation" capability that allows users to run <u>any</u> arbitrary sequence of sheets from multiple, large capacity feed bins (typically eight bins) at full rated throughput. The Imaggia System is used in very high production applications, where any deficiencies in reliability are quickly evident.

Development Challenges

One of the greatest challenges to operational reliability has been creating a sheet feeding mechanism that operates at the necessarily high speeds with few failures. These failures can be miss feeds, double feeds, sheet jams, sheet skews and others. A substantial development project was implemented to address this challenge.

Many high speed presses utilize a sheet rear edge feed device with a shingled feed output. This type of feeder advances the sheet relatively little distance prior to subsequent feed initiation, which allows for appreciable inter-sheet pick time allocated for sheet capture and feed. The Imaggia System's dynamic collation requires a different approach, but has demonstrated the capability to reliably feed sheets without shingling. The basic layout of the sheet feeder deploys lead-edge lifting vacuum feed using multiple suction feet. This layout allows for a practical multi-bin tower design that is quick and easy to load. Although vacuum suction-cup based sheet feeding has been widely used for decades, this development was required to handle the wide range of sheet variables and some extreme stock types, and support a marketing requiremnt for a rapid changeover in stock sizes or weights. The rapid changeover time limits the possible operator interventions to reconfigure and re-optimize the mechanism especially with multiple bins.

An example sheet length of twelve inches must be fed and fully advanced by the drive rollers in less than 500 milliseconds in order to clear the sheet and allow the subsequent sheet feed from the same bin. Only about half of this period is available for the sheet feeding action, to allow the drive rollers to clear the preceding sheet, and yet run at reasonably low speeds necessary for light weight sheet handling stability. Longer sheets also allow about the same available time to capture and feed the sheet. Reliably feeding extreme sheets types and sizes in this time period is much more challenging than with less extreme sheets, or where more time is available. The Imaggia system runs in a sheet velocity print range of 22 – 30 inches per second with a minimal inter-page gap, typically one inch, which substantially constrains the available time for sheet feeding.

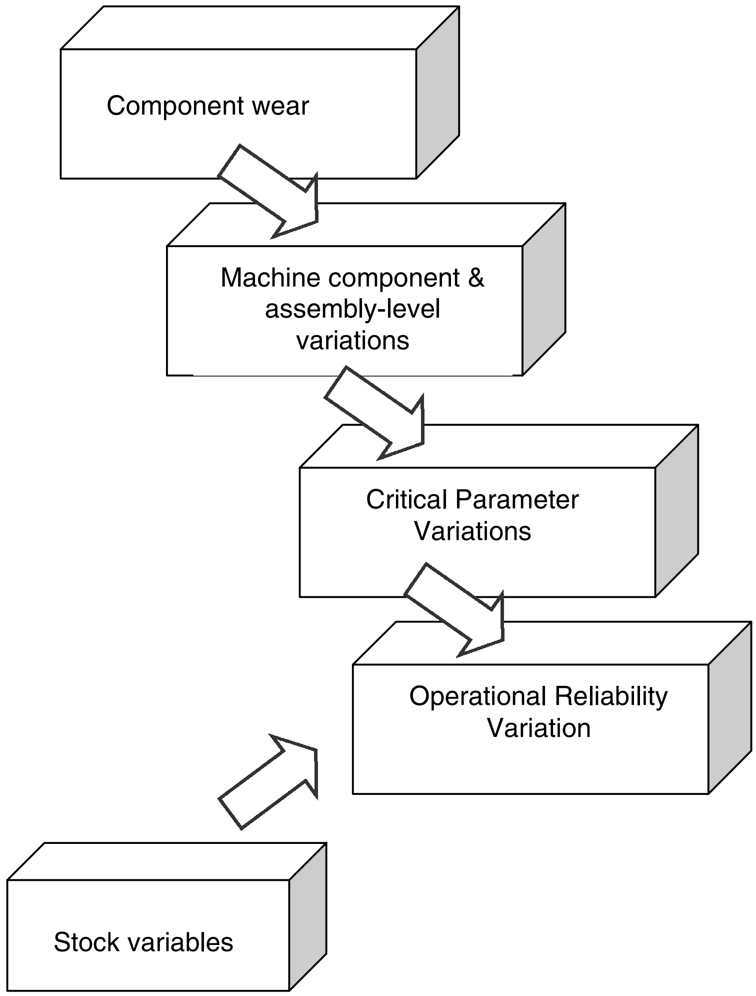

Figure 1.

The various stocks tested have demonstrated a number of important stock parameters that affect sheet feed reliability.

These Include:

Size – width/length
Weight
Stiffness
Grain direction
Surface gloss and finish coatings
Curl, which can be directionally complex
Moisture content
Static
Edge effects including any inter-sheet mechanical bonding

One of the most challenging are lightweight stocks of low stiffness, particularly when the sheet grain is perpendicular to sheet feed direction. Sheet corners are a special challenge on light sheets, especially at full width, which can generate many feed failures. The behavior of sheets varies considerably with changes in stock sizes, weights, conditioning and types. Sheet sizes of ~1-3 square feet and weights of ~65-300 gms/sq. m. were tested. The sheet feeder design had to demonstrate a high degree of feed reliability with all stocks, with the intent that many stock types would be run in the same job and even from the same bin, if pre-collated. The optimal feed design for a heavy, stiff or large sheet is very different from that of lightweight, limp and small sheet. Experience demonstrated that it would have been much easier to develop a feeder around a smaller sheet weight range and handle all the required sizes, or develop a feeder around a smaller sheet size range and handle all of the required sheet weights.

Development Approach

A substantial amount of development of any high reliability machinery involves testing to determine the critical control parameters, the effects of variation of critical control parameters on process success and consequent operational reliability, and determination of the effects of machine tolerances on critical parameters. Finally, the effects of machine wear on operational reliability are evaluated. Development of this feeder has followed this framework.

Development of this sheet feeder has concentrated on hardware configuration and control of critical parameters in the feed process. Testing has identified approximately fifty machine parameters that influence feed reliability, and several critical parameters. Sheet feed reliability has improved as much as 300% in some applications throughout the development period.

A substantial amount of field testing was conducted. This allowed for a very large amount of data to be quickly generated. Often field testing was conducted with less instrumentation than used in the lab, so types of available data was restricted, but overall reliability of sheet feeding was measurable. Field testing introduces further variables simply since the system is operated by individuals of varying experience and who have not been privy to lab experience, where knowledge of the effects of set-up variables is known and thus often accommodated for best results.

Feeder Design

The motion generation of the Imaggia sheet feeder is based on a four-bar mechanism, which is driven by a step motor. **Figure 2** shows a side view of the general form of this mechanism. The geometry of the mechanism creates a very specific sheet lift and advance motion. The vacuum suction cups are moved outward and downward to approach the sheet stack. A short dwell allows a positive capture of the sheet. Then the sheet is lifted and advanced into the drive roller nip, which subsequently advance the sheet into sheet conveyance tracks supporting both translation and turning through one or two 90 degree turns, plus convergence to a common print engine input feed track. Sheets are lightly lofted in the stack with pressurized air to assist sheet separation, and thus avoid multiple sheet feeds.

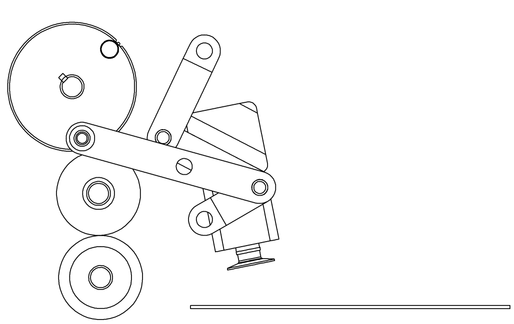

Figure 2.

The step motor is an economical choice, which also provides a suitably fine motion resolution on which to base a speed profile. Rather than employing a simple constant speed, a fairly sophisticated profile has been developed that provides the best match of speeds, accelerations and dwell intervals for various segments of the sheet feed cycle to optimize feed reliability. This proved to be a key asset in relation to managing the complete pick and feed cycle. The programmability of the step motor cycle through use of specifically developed pick profiles allows for both a tailored profile per bin and even dynamic profile adjustment in between picks where bins contains pre-collated stocks of differing weights or characteristics.

The motion has been studied and tested in detail and the motion is defined to a resolution finer than 1 millisecond increments. Additionally, multiple profiles have been developed for matching to lighter and heavier sheet types and sheet sizes. **Figure 3** describes an example motor speed profile. Vacuum and pressurized air levels and timing were generated in concert with speed profile development. Small changes in the timing of all three along with adjustments to geometry were discovered to frequently have profound impacts on feed reliability. The measurements of reliability often required the running of thousands of sheets to demonstrate differences, but at times differences were immediately detectable when failures were obvious and repeating.

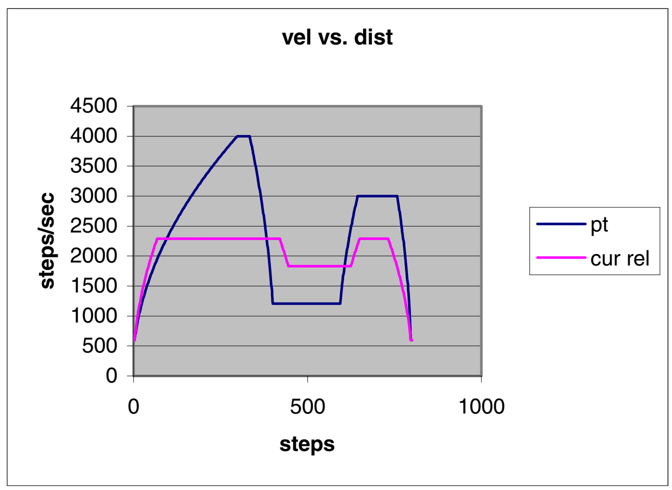

Figure 3

Additional important control parameters are sheet stack height, and sheet restraints within the stack.

Many of the design requirements were dictated by need to handle very lightweight stocks, with their tendency to behave with low mechanical stability in multiple modes during very rapid feed capture, lift and advance. These motions, and controlling them, were exhaustively studied using high-speed photography to reach optimal feed stability and reliability with these more extreme stocks.

Variation of the stack degrades feed reliability, and introduces sheet position variations such as sheet skew. These sheet position variations often affect downstream sheet handling reliability. Any variation will tend to reduce some contributing measurement of overall system reliability.

Error Detection

Also, considerable development was undertaken to create the Imaggia System's ability to detect errors in sheet feeding such as miss feeds and double feeds. Some error detections are redundant, creating a higher degree of overall detection reliability. A pneumatic sensor is employed to detect double sheet feeds. This sensor both senses and assists the separation of sheets for detection. The Imaggia System automatically reacts to a detected double feed by temporarily interrupting sheet collation, rejects any double sheets and any subsequently fed sheets, and then restarts the feed/collation process from the correct sequence position. This is necessary as the extended track geometry necessary to accommodate as many as 8 large capacity bins requires relatively long conveying track lengths such that a sheet emanating from a remote bin may actually be picked before a sheet at a closer bin even though the former is ahead in print sequence relative to the latter.

Both the detection and recovery process work very well in practice with a high level of reliability that is necessary to gain the confidence of users dynamically collating and personalizing printing complex, multi stock documents. Repeated errors will generate a system stop and error annunciation to signal required operator attention. Misfeeds and sheet jams are detected by optical sensors. These measure the presence and timing of sheets and inter sheet spaces. Sheet skew is detected by special optical sensors, that are part of the sheet registration system. The Imaggia System attempts to automatically handle all sheet feed errors without operator intervention. This includes use of an advanced dynamic sheet measurement and active de-skewing/spacing re-positioning system specially developed to accomplish this goal. This has proven to be an effective strategy to maximize system productivity.

Step Motor Control

The optimal motor speeds and accelerations are often dictated by the sheet motions, and the relation of the feed mechanism to the sheet. However, use of step motors requires that reasonable speed, acceleration and torque be observed to avoid step motor decoupling or loss of steps. This additional constraint required the study of motor torque margins.

Operational optimization during the early development phase was largely determined by intensive trial and error. More sophisticated methods have been deployed to more deterministically arrive at optimum profiles. As torque must be measured indirectly in a step motor system, These plots were experimentally generated by measuring rotor position versus field position utilizing an optical encoder for accurate measurement.

Studies of theoretical torque requirements and experimental measurement of torque margins were both conducted to ensure sufficient motor margin.

Figure 4 shows a typical pick head speed profile throughout a single, aggressive pick cycle and the measured real time instantaneous torque margin available at each instant of the cycle. It is arguably the most critical part of the Imaggia print system. At all times the margin remains sufficiently positive, to avoid entering a region where risk of step motor de-coupling occurs. The short positive excursions on the slow speed ends of the graph are resonance phenomena. The goal is to operate the motor at or near the peak torque point during the most critical acceleration and high speed portions of the cycle. The speeds for other parts of the profile were determined by other factors not related to the motor capabilities.

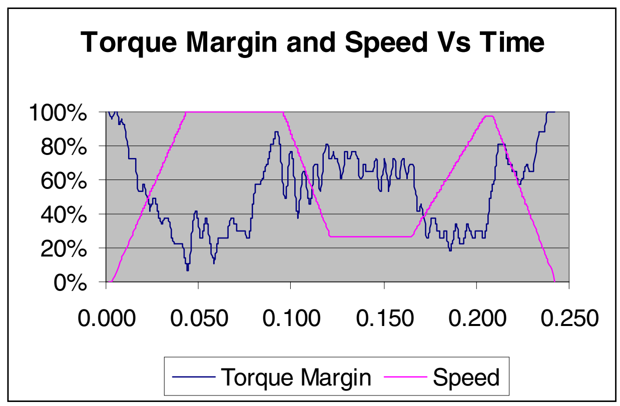

Figure 4.

Biography

Peter J. Wood holds a B.S. in Physics and is a chartered engineer (MIEE). He has specialized in the development and application of electronic color pre-press and digital printing product technologies for the professional printing, publishing and corporate in-house markets. He also has been involved in the innovation and management of electronic page make-up systems, electronic screening, RIP subsystems, various automated RGB to YMCK color reproduction production systems and the world's first digital CMYK color scanners.