Benchmarking Paper Machines for Financial Performance

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Introduction

Benchmarking paper machines provides a valuable insight into their relative performance and can be used as a tool to indicate potential areas for improvement. It can pinpoint quality and performance deficiencies, quantify financial savings and justify strategic investment. The results from a benchmarking survey can also help ensure brand uniformity for products that are manufactured globally. A case study is reviewed in this paper to illustrate the analysis procedure and benefits available from the benchmarking process.

Looking at Performance

As a consequence of the high investment combined with operating costs of making paper, paper makers are acutely sensitive to the cost of their operations. Because paper and board products are price-sensitive, they are continuously challenged to drive down their costs and produce high quality products as efficiently as possible. Production costs represents a significant portion of the mills operations through materials consumption, energy utilisation and broke levels. Add to that is the efficiency of the process afforded by automation systems, process engineering and process integration. Finally there are product issues that range from quality to market share. While there are many financial aspects related to paper manufacture, automation plays a key part in controlling costs and improving efficiency.

In order to address demand and efficiency, there have been a number of new world-class paper machines recently introduced in Europe to replace less efficient operations. These new machines are supplied fully automated and commissioned process experts who are highly skilled at achieving the performance targets for acceptance by the customer. With the advent of this new capacity, mills recognise that minor efficiency changes of these production assets can have a significant effect on the profitability of their operations. The question is "how well must these assets perform and what is the basis for comparison?" In other words, what are the key performance indicators (KPI) and how do these translate into bottom line financial benefits for the mill?

With so few standards, mills often look to their competitors to see how their machines compare in terms of productivity and quality against their peers in the industry. In particular they recognise that their process systems are vital tools to help maintain their performance and profitability competitiveness. This includes their distributed control systems (DCS), quality controls (QCS), cross direction (CD), web inspection (WIS) and information systems. These assets are strategically important and in order to be successful, they must perform optimally throughout their lifecycle. So while all paper machines and their systems are created equal, the optimum performance of the mills automation systems experienced immediately following the commissioning cycle seldom lasts, promoting the erosion of profitability.

The Technology Timeline

The cost of process automation for a new mill can be up to 10% of the total investment of the project. Indeed many existing mills will have millions of dollars currently invested in their automation and information platforms. Because reliability, accuracy and robust controls are key to delivering productivity and quality, these automation solutions are essential assets to the company. Often they also represent considerable embedded intellectual knowledge from both the suppliers and the mills staff; so in order to be successful they must perform optimally. Yet despite this, the performance of these systems falls into decline called the Results Gap (*Fig 1*) that has a direct influence on both quality and productivity or quality.

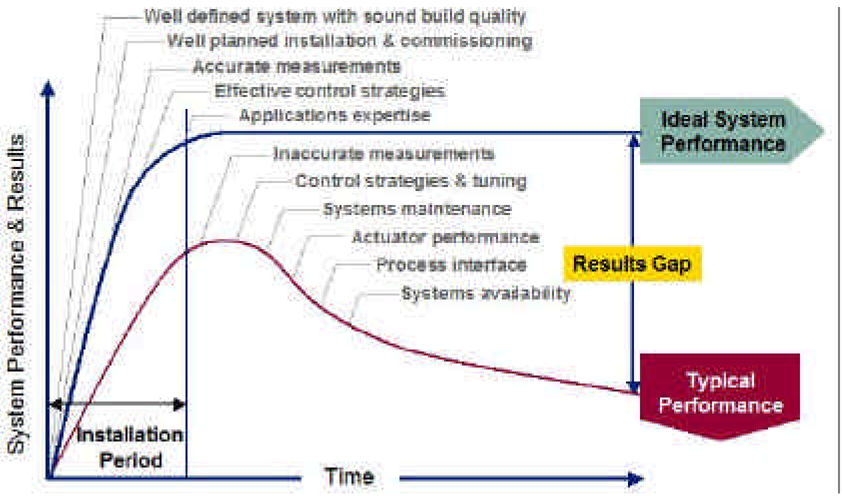

Figure 1: The Results Gap

The Results Gap can arise for a number of reasons, for example, poor measurement & control. When systems are commissioned there exists a certain set of machine conditions. These can be process-related such as machine speed or can be grade related, such as quality and paper structure. The systems are set up and optimised around a specific set of parameters such that any change may have a significant influence on their measurement and control effectiveness. Most frequently, machine speeds increase from 30% to 50% over a 10-15 year period, taking most controls out of their set-up range. So while the "green control light" is on, the systems ability to attenuate disturbances becomes constrained. The same holds true for measurements, where new additives and grades can limit their accuracy to a point where new calibration groups are created. This often leads to difficulties during grade changes, as the measurements do not transition smoothly to a new grade. The measurements may be seen to jump part way though a grade change, confusing the operators and prolonging the time taken to meet the new quality requirements.

Next is system obsolescence. While it is commonplace for our own PC's to be replaced every 3-5yrs due to technology enhancements, the average life of a process automation system is at least 10yrs. Indeed, there are still systems in operation that are over twenty years old. This creates problems of supportability, both in terms of expertise and spare parts. Suppliers may not have the engineering staff or spare parts to support legacy equipment. Some mills rely on key staff to maintain their legacy equipment, such that if they are unavailable, they risk the break down of their vital assets, resulting in production down time. Low system availability directly affects production as every 0.5% of equipment failure translates into almost two days downtime annually.

System complexity has grown almost exponentially over time, creating the need for expert service programs. Most are familiar with routine or continuous maintenance contracts that directly contribute toward high system availability. The most overlooked programs are those directed toward process optimisation. While most production and engineering staff may be content when the paper machine and its process automation are performing as new, little thought is directed as to how to improve the value of these assets in terms of productivity or quality. These new systems incorporate a greater ability to capture, analyse and simulate process conditions. Open systems technologies now permit information to be viewed on a single platform and analyse data from many platforms via an OPC link. The new domain of process optimisation services has proven highly valuable to many paper makers.

It is not uncommon to enter a control room on relatively new paper a machine that is crowded out with many consoles, printers and disparate systems. Every system may function as an independent island of operation has its unique set of training and support requirements. This makes it difficult to operate the machine, especially during transitions such as start-up, grade change and break recovery. For example, at one mill the machine tender may walk up to 10km a shift just to keep track of the various controls and pieces of information needed to run the machine. Despite the introduction of open systems technologies in 1991, few mills have successfully embraced this approach. Clearly, the mills automation strategy must take the path of open systems integration, not only to improve operator efficiency but also to help support process optimisation previously discussed.

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There has been an emergence of Advanced Process Controls that utilise multivariable control strategies to further optimise the process by combining together integrated automation platforms. For example, these may optimise the stock approach system more tightly with the machine via the DCS and QCS systems. Then there are the Embedded Solutions, designed to extract greater performance from head boxes, forming sections, presses, coaters and super calendars.

The Technology Timeline therefore demands that mills process automation strategy affords sufficient attention to its automation systems, the legacy position, service support, systems integration and the advanced technologies for effective process management. Unless these facets are observed, then the Results Gap will build and the competitiveness of the machine will suffer.

Benchmarking for Financial Performance

So, the questions remain. For example, are your automation assets making money? Should they be working harder to help your bottom line? Indeed, do they need to be upgraded, replaced or expanded? Are they being serviced properly? And how much are they contributing to your product quality?

One effective approach is to benchmark the paper machine (*Fig 2*) to see how it compares globally against its peers in terms of productivity and quality. ProfitMill is an independent consultancy whose proactive services are able to survey the process operations and evaluate its automation systems to see how they can contribute toward productivity, efficiency, costs and quality. The ProfitMill Performance database contains information from over 130 machines worldwide and can be used to pinpoint areas of process improvement and identify the actions necessary to place the machine in the upper quartile of performance.

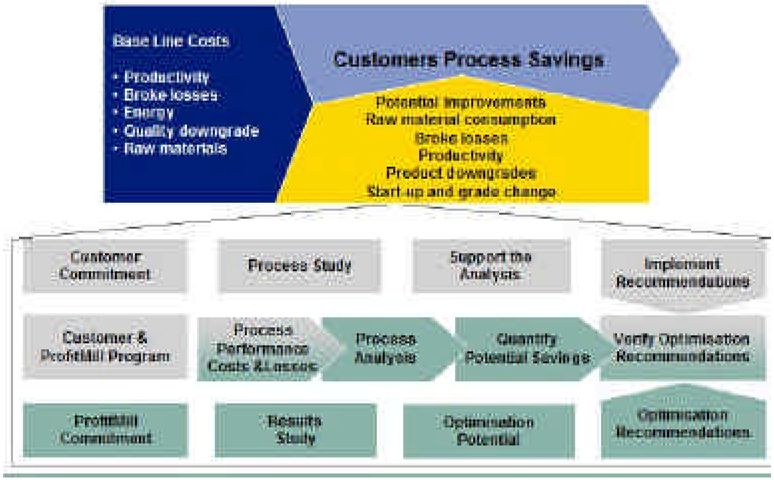

Figure 2: The Benchmarking Process

The benchmarking system uses key performance indicators (KPI) captured globally from a wide range of graphic and packaging machines that enable comparisons to be made between peer machines. The data is de-identified and kept strictly confidential. During the benchmarking process, data is collected and validated involving commitment from the entire mill including management, finance, production, quality assurance and automation. This exercise is not restricted to a statistical study. Instead the exercise involves spending a great deal of time on the paper machine with the operators, often conducting trials on the paper machine and its automation equipment to establish its effectiveness. In addition, raw material consumption, energy utilisation, broke records; transitions (start-up, grade change and breaks) data are collected for the benchmarking analysis.

The data is then integrated into the ProfitMill Performance database and each machine is ranked for performance in a number of key areas. At this point it becomes clear how well a machine is performing and the outstanding financial potential that achievable through further improvement. These improvements are translated into expected savings that can be assigned to a broad spectrum of automation and process improvements. The benchmarking case study that follows illustrates some of the typical benefits that can be expected annually in the range $150k to over $500k through equipment and process performance improvements.

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Benchmarking Case Study

This case study examines the performance of a world-class newsprint machine and is presented here in a summary version. The machine has a gap-forming head box with an extended nip press section (ENP) operating at around 1700m/min. The machine is just over ten years old and was considered to be operating satisfactorily by the mill. The machine is equipped with DCS, QCS, WIS and information systems plus profile controls for weight, moisture and caliper. Taking a detached perspective, this machine should have been performing in the upper benchmarking quartiles compared to its peers and on the surface gave the appearance of a well-run process. The machine was benchmarked against thirty-two newsprint machines from Europe (EU), North America (NA), Japan (JAP) and Brazil, Russia, India, China, South Africa (BRICS). A number of these machines may be classified as world-class, implying they are wide and fast, while others represent the better-performing conventional machines in certain geographies. ProfitMill's Performance database is not restricted to the information presented in this technical paper; instead it is intended to provide a graphic account of this machines performance and its potential quality and performance improvements as a result of the benchmarking process.

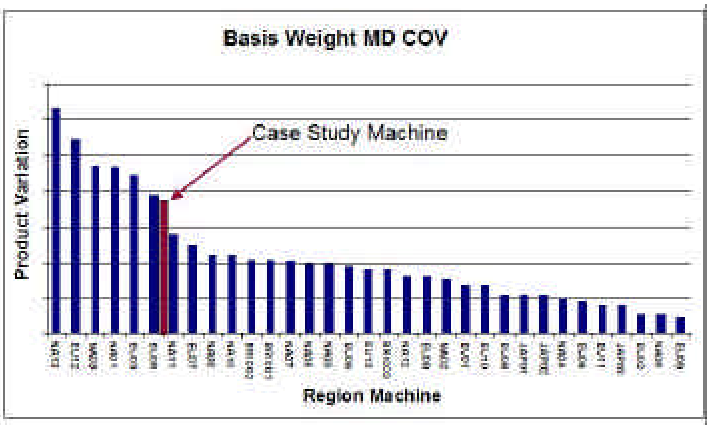

Fig 3: Basis Weight MD Coefficient of Variation

Basis Weight Machine Direction Variation

The machine direction (MD) variability (*Fig 3*) represented as a coefficient or variation (one sigma percent) displayed very poor performance when benchmarked against 33 other newsprint machines, placing it in the lower benchmarking quartile. This situation was not improved even after the original QCS supplier retuned the controls.

The reasons for this may have been the slow scan rate of the QCS system combined with the lack of control modelling of the process by the system. Slow scanning restricts the effectiveness of the control as it extends its noise cut-off frequency and hence the ability to attenuate disturbances. The poor MD control limited the potential performance of the other MD controls, as most are cross-coupled to the basis weight loop. Poor MD control also leads to a deterioration in cross direction profile control performance for weight, moisture and caliper, resulting in serious losses due to quality and reel structure.

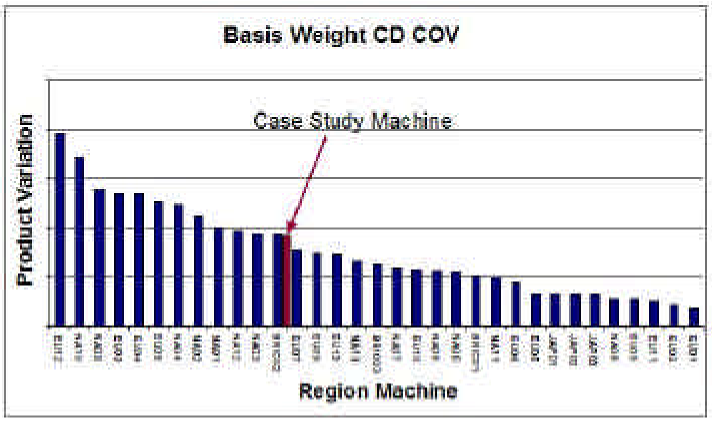

Fig 4: Basis Weight CD Coefficient of Variation

Basis Weight Cross Direction Variation

A similar situation was found for cross direction basis weight variability. While the benchmarking plot shows (*Fig 4*) this machine in the middle quartile, a number of machines in the lower quartiles did not have weight profile control, leaving this machine behaving as if it was operating without basis weight profile control.

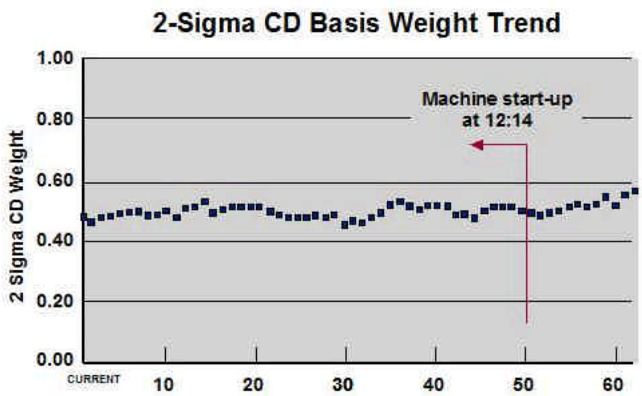

Fig 5 Basis Weight 2-Sigma Trend

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Of great concern was the performance of this loop following a paper break. The cross direction spread value showed no measurable control response following the recovery period after a paper break (*Fig 5*). The reason for this could have been either a non-functioning link to a 3rd party actuator, mapping errors or the bending limit clamps being exceeded for the control software.

Basis weight profiles are strongly coupled to the moisture and caliper profiles. By improving the performance of this control, it will assist the other profiles and greatly contribute toward reducing level-related profile broke.

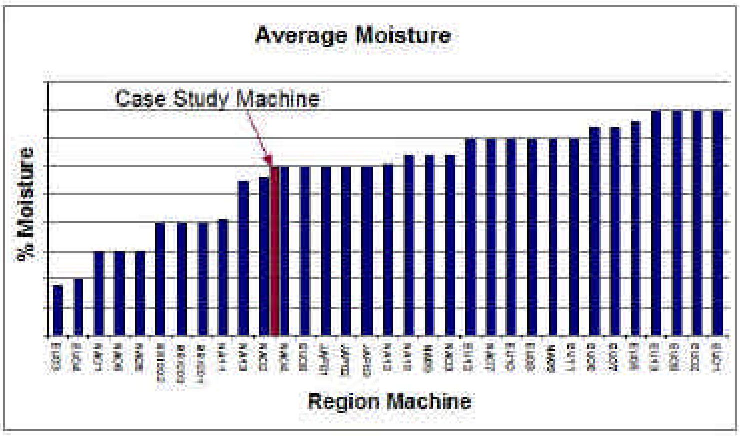

Fig 6: Reel Average Moisture

Average Moisture Content

Due to the basis weight instability on this machine, it was prevented from running a competitive moisture average. In fact this machine ran at between 1-2% below that of its peers (*Fig 6*).

As this machine is capable of producing some 350kt/yr of newsprint there are consequentially substantial lost economics associated with low moisture targeting. Obviously selling water makes good sense, especially for a large machine such as this one. However, there were other constraints at play that helped drive the average to a lower value that this machines peers.

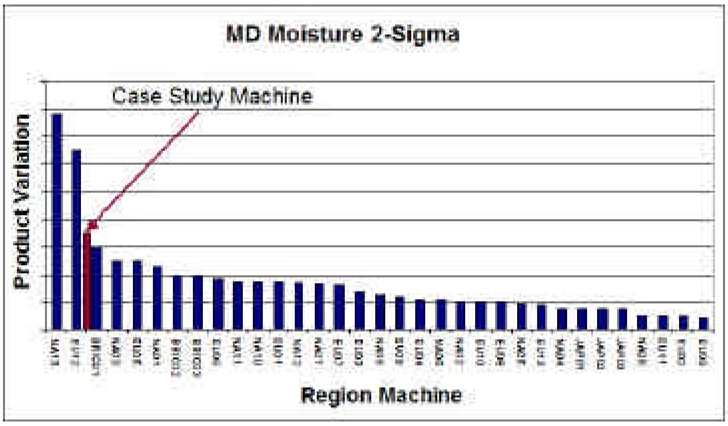

Fig 7: Machine Direction Moisture Variation

Machine Direction Moisture Variation

Of all the benchmarking parameters, machine direction moisture variation was among the worst (*Fig 7*). Here, the MD moisture control supervised the final steam section in the dryers based on feed back from the reel scanner signal.

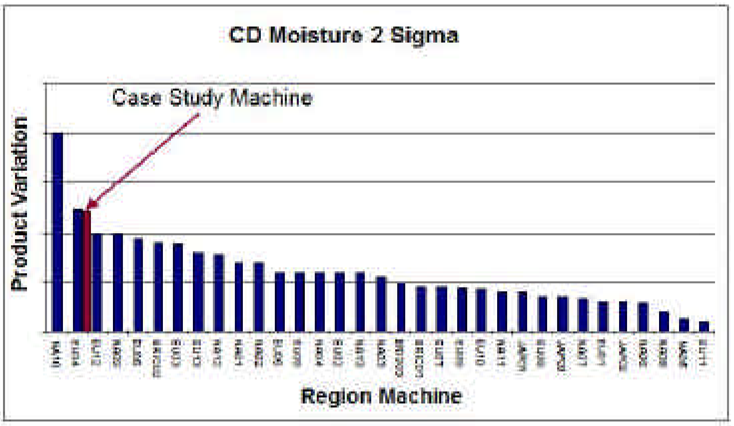

Fig 8: Cross Direction Moisture Variation

There are a number of reasons for this poor performance. First is that steam sections cannot respond to fast changes in weight or moisture. Hence, basis weight disturbances will take moisture along with it. Second, there was instability in ash content arriving at the machine from the de-inking plant. Again, ash fluctuations translate into moisture variations. It is highly probable that the supervisory control software was unable to decouple the effect of these in its multivariable matrix. In addition, the controls were hindered by the slow scan time of the measurement head, that served to extend the noise cut-off frequency of the controller, limiting it to cycles of 20-30 minutes or more in terms or disturbance attenuation. Finally, like basis weight, the controls did not accurately model the process, resulting in poor response and an inability to hold

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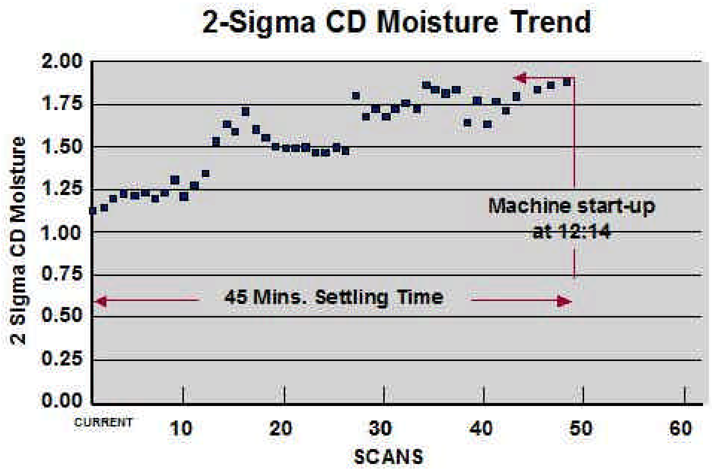
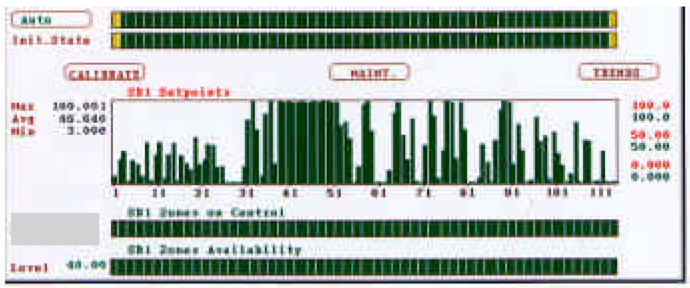
to target. Therefore the only alternative is to set the moisture target on the low side to reduce the risk of excessive broke.

Cross Direction Moisture Variation

The cross-machine moisture profile on this machine is controlled via a press section steam box. Currently, many European newsprint machines employ a combination of steam boxes and re-moisturisers in order to produce flat moisture profiles at the reel. The supervisory control strategy is able to decouple the longer cycle profile disturbances for the steam box, while the fine, short-term streaks are controlled using a re-moisturising actuator located about one third the way down the dryer section. Again, this machine was in the lowest quartile performance (*Fig 8*) when compared against its peers and is supported with some interesting further observations.





Figures 9 & 10: Moisture CD 2 Sigma Trend and Steam Box Actuator Control Display

Notice the exceptionally long settling time for the moisture profile following a paper break. According to the trend plot (*Fig 9*), the moisture profile spread is still 1.1% 2-sigma one hour after the break. This is probably linked to the basis weight control effectiveness. There are two other factors for consideration regarding the performance of this control. First is that the steam box actuator was installed when the machine was first commissioned and since that time its machine speed has been increased by almost 30%, making the steaming capacity of the actuator inadequate for the machines current production rate. The steam box and its supply need to be increased in terms of their steam delivery volume. Note the output array for this box (*Fig 10)* is fully ranged, suggesting either a delivery problem or a mapping problem or both. Finally it was later discovered that a number of the steam valves in the actuator were inoperative, further adding to the moisture profile control effectiveness.

Cross Direction Caliper Variation

This machine was equipped with a basic cold air shower actuator system on a two-roll calender stack, which for a machine of this production capacity was inadequate. Most of its peers either have induction actuators, zone control rolls or hot/cold air showers to control their caliper profiles prior to the reel. Figure 11 clearly shows this

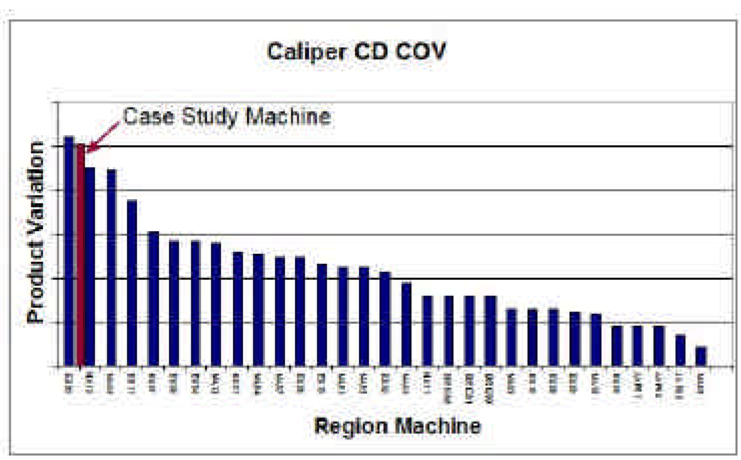


Figure 11: Caliper CD Coefficient of Variation

machine in the lower quartile of performance, equivalent to those machines without a caliper profile optimisation system. Retuning this control by the QCS supplier's engineers did not significantly improve its performance.

It is also interesting to note the recovery rate following a paper break as has been done with the other profile controls. Again, the recovery time is excessive (*Fig 12*) at around 45 minutes, indicating that the actuator is clearly out of range and needs replacing. Considering this actuator is a vital component for successful reel building, it is rather surprising that it had not received earlier attention and been replaced.

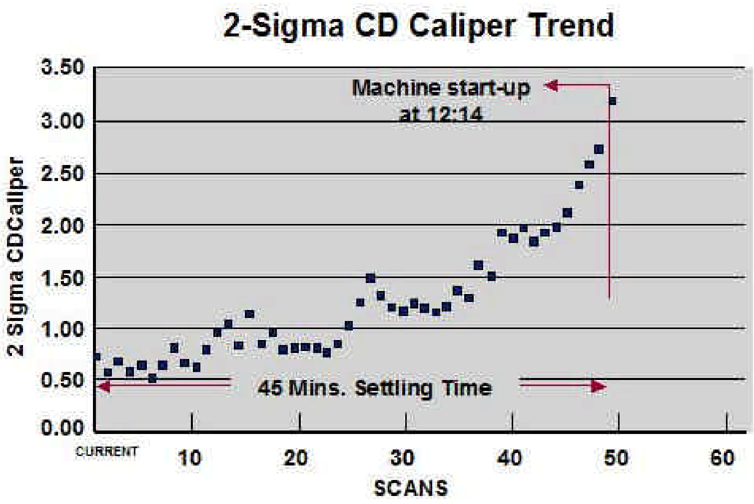


Figure12: Caliper CD 2 Sigma Trend

Summary

With the aid of the benchmarking data, the performance difference between a machine and its peers can be translated into potential financial benefits, assuming the machine has the ability to operate in the mid to upper performance quartiles. The savings can be expressed at three levels of confidence. Conservative indicates there may be an unidentified process constraint that will limit the performance of the machine even after the changes are made. Expected, as suggested, summarises results that are achievable through relevant process expertise knowledge. Target indicates a level of performance on the high side in the event that the machine performs exceptionally well following the changes that are made. Table 1 summarises the potential benefits available through benchmarking this machine in terms of materials, energy, broke and productivity. As expected, for a machine this size, the potential savings were considerable (though not untypical).

Item	**Conservative**	**Expected**	**Target**
Raw Material Savings	$149,000	$187,900	$225,400
Energy Savings	$27,000	$49,800	$72,500
Reduced Broke	$199,100	$295,300	$39,1500
Increased Production	$237,500	$310,200	$375,400
Total Estimate	**$612,600**	**$843,200**	**$1,064,800**

Table 1: Benchmarking Summary of Potential Benefits

The benchmarking approach can reveal a wide range of performance and quality deficiencies. It is a tool that represents a starting point for further investigation on the machine itself. It provides a quantitative approach to establishing the magnitude of the results gap and produces the basis for developing ago-forward automation strategy for the mill. The case study machine illustrates this point very clearly by having a potential bottom line of over $800k/year in improvements available with a return on investment in new equipment of less than one year.

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