Role of on-line gauging systems in providing insights into the Web Coating process

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Abstract

On-line gauging Systems provide timely and valuable insights into the Coating process with Process Analytical tools and Process Diagnostics Visualization tools. Though the On-line gauging systems' role in Coating Measurement and Control is well known, their crucial role in trouble-shooting the Coating Process is not well understood. This paper focuses on the application of the tools such as FFT, Contourview, Process variables trending etc. to pinpoint the coating process problems in a timely manner. The system monitors a multitude of process variables continuously and trends the data for process monitoring. Time-based trends of various temperatures, pressures and speeds can be displayed continuously, along with coating thickness to show cause and effect. The high degree of process visibility is of tremendous value to the Line Operators and Process Engineers to setup the equipment at start-up and product changes, as well as to monitor production continuously. System ensures full-width coating gauge uniformity through effective process controls in the cross and down web directions, while monitoring substrate variability. The resultant Process Optimization contributes significantly to improved product quality, increased productivity, scrap reduction and coating material yield. The impact on coating production economics is very significant.

Introduction

On-line gauging systems have been widely used in the Web Coating Industry for decades to measure and control coating thickness. Over the years, as PCs have become more powerful, on-line gauging systems employing PCs have exploited their processing power to expand their capabilities. These systems have become adept in data acquisition from various process monitoring devices used in Web Coating Lines. Continuous monitoring of a multitude of process variables coupled with powerful processing capability has enabled these systems to become premier real-time process diagnostics tools. The powerful HMI (Human Machine Interface) that is an inherent feature of many of the advanced on-line gauging systems, facilitate real-time and historical trending of the process variables in conjunction with the product attributes such as coating weight quality. The real-time window into the Web Coating process provides process insights, as well as enables the Web coating Line Operators and Process Engineers to troubleshoot the process at various stages of manufacturing.

The on-line gauging system's troubleshooting capability coupled with continuous coat weight measurement and control has resulted in significant economic benefits to the Web Coating manufacturer through raw material savings, scrap reduction and increased productivity derived from faster start-ups and product changeovers.

Various types of Web Coating Processes

The Web Coating Industry encompasses a variety of processes for coating substrates. The major types are Extrusion Coating and Roll Coating.

Extrusion coating is used for single-layer or multi-layer coatings on a substrate. Often co-extrusion is used to coat the substrate with different polymers to provide different properties. In the case of Aseptic packaging, multi-station extrusion coating is used in conjunction with lamination to impart barrier properties to the multi-layer packaging structure. Such a packaging structure may consist of a paperboard with an outside decorative layer, tie-layer between the paperboard and Aluminum foil and co-extruded inside layer to provide barrier properties to preserve the contents of the package for longer shelf-life.

Roll coating process has a variety of configurations.
Typical Roll Coating methods are:

- Direct Roll Coating
- Gravure Roll Coater
- Reverse Roll Coater
- Saturation Coating
- Hot Melt Coating
- Blade Coating
- Knife Coating
- Slot Die Coating
- Meyer Rod Coating
- Air Knife Coating

Common process problems in Web Coating and their Causes

In an Extrusion Coating process many factors influence the quality of the end product: Raw materials such as Resins and substrates; processing conditions such as temperatures and speeds. An alphabet soup of problems such as Adhesion, Applesauce, Draw resonance, Edge tear, Gauge bands, Gels, Heat sealability, Molten curtain breaks, Odor, Oxidation, Pinholes, Surging, Voids etc. are caused by poor quality and control of Resins, Substrates, Temperatures, Thermal degradation, Draw ratio and so on.

Continuous monitoring and control of the Extrusion Coating process parameters such as Melt temperature, Die Zone temperatures, Melt flow, Screw surge, Back pressure, draw speeds etc., enables the line operators to minimize, if not prevent, these problems during various stages of manufacturing such as start-up, high-speed production and product changeovers.

In Roll Coating processes, factors such as coating material viscosity, roll pressure, roll gap, roll run-out, blade angle, blade/knife sharpness etc. influence the quality of the coated product.

Continuous monitoring and control of the Roll Coating process parameters such as Viscosity, Roll gap, Roll pressure, Applicator Roll Speed etc., enables the line operators to minimize, if not prevent, these problems during various stages of manufacturing such as start-up, high-speed production and product changeovers.

Additionally, continuous monitoring of the substrate being coated provides valuable information to the Web Coating Line Operators.

PC-based on-line gauging systems play a critical role in providing process insights during manufacturing. Historically, on-line gauging systems have excelled in continuous monitoring and control of web coating quality. The process diagnostics capability of these systems has not been fully exploited in the past.

Web Coating Process monitoring with PC-based on-line gauging systems

The on-line gauging systems used in Web Coating usually consist of multiple sensors on multiple scanning platforms, Operator Station, Process I/O modules coupled with powerful software process diagnostic and process control tools. The ability of the systems to interface with third party sensors, PLCs and other process equipment to provide ***a central location for visual graphical presentation*** for comprehensive process monitoring by the Line Operators is of primary importance in process troubleshooting.

PLCs for control of various temperatures are widely used in the Extrusion Coating Industry. The data can be brought over an OPC link into the On-line gauging system. The various temperature setpoints are programmed in the Product Recipe and downloaded to the PLCs at start-ups or Product changes. The temperature measurement data are sent over the link to the gauging system to be displayed. A typical temperature page displays setpoints and high/low limits for various Zones together with measured values in real-time. The Alarm features of the system highlight any out-of-spec condition in red for Line Operators. Digital outputs to trigger audio equipment for alarm conditions are also available. Additionally the temperatures are trended in **real-time** on a Trends Display. Similar data for pressures and speeds can be monitored and trended. These process data are continuously monitored and trended, whether the gauging system is in the web scanning mode or in the off-sheet position.

Further, the various process parameters can be trended on the same display page as the coat weight trends to show the cause and effect in **real-time**. This capability of the system lends itself to real-time diagnostics and effective process troubleshooting. The end result is faster start-ups and product changeovers with minimal scrap. The production economics in terms of reduced scrap and improved productivity is a boon to the Extrusion Coating manufacturer.

On-line Product Quality Monitoring

The on-line gauging systems provide continuous monitoring of coat weight quality. A software feature known as Process Variance Analyzer (PVA) provides a measure of coat weight distribution on the substrate in both the transverse and down-machine directions.

The total variation in coat weight can be expressed as,

$$\text{Total}3\sigma = \sqrt{(CD3\sigma)^2 + (LTMD3\sigma)^2 + (STMD3\sigma)^2}$$

where,

CD is cross direction (profile) variation causing Gauge bands; CD is controlled by the system through the Auto Profile Control of the Coating Die

LTMD is the Long Term Machine Direction variation caused by long term temperature drifts, melt viscosity variations etc.; LTMD is controlled by the system through Screw Speed or Line Speed control.

STMD is the Short Term Machine Direction variation. This is a high frequency variation caused by screw surge, out-of-round rolls in the processing equipment etc. The STMD is not controllable by the gauging equipment.

However, the on-line gauging system with a FFT feature can diagnose the STMD variations to display the magnitudes and the corresponding frequencies.
This process analytical tool easily identifies the equipment causing the variation, which then can be fixed during the maintenance cycle of the process equipment.

Typical process diagnostics displays of an on-line gauging system include:
Data Display & Alarm, Process variable real-time trends (seconds or minutes), Historical Trends (hours or days), FFT, Temperature Display Page etc.

Various Examples are shown below:

Figure-1: Temperature Overview Display integrated into the on-line Web gauging system HMI

Figure-2: Barrel & Die Zones Temperature Control Display integrated into the on-line Web gauging system

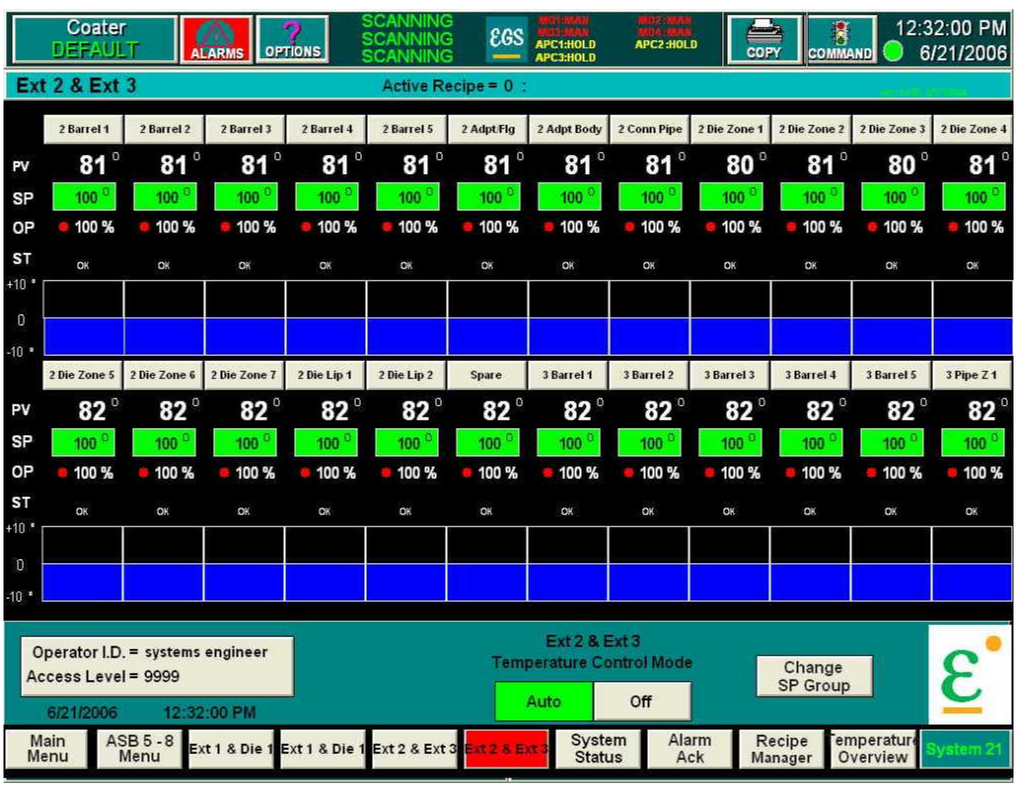
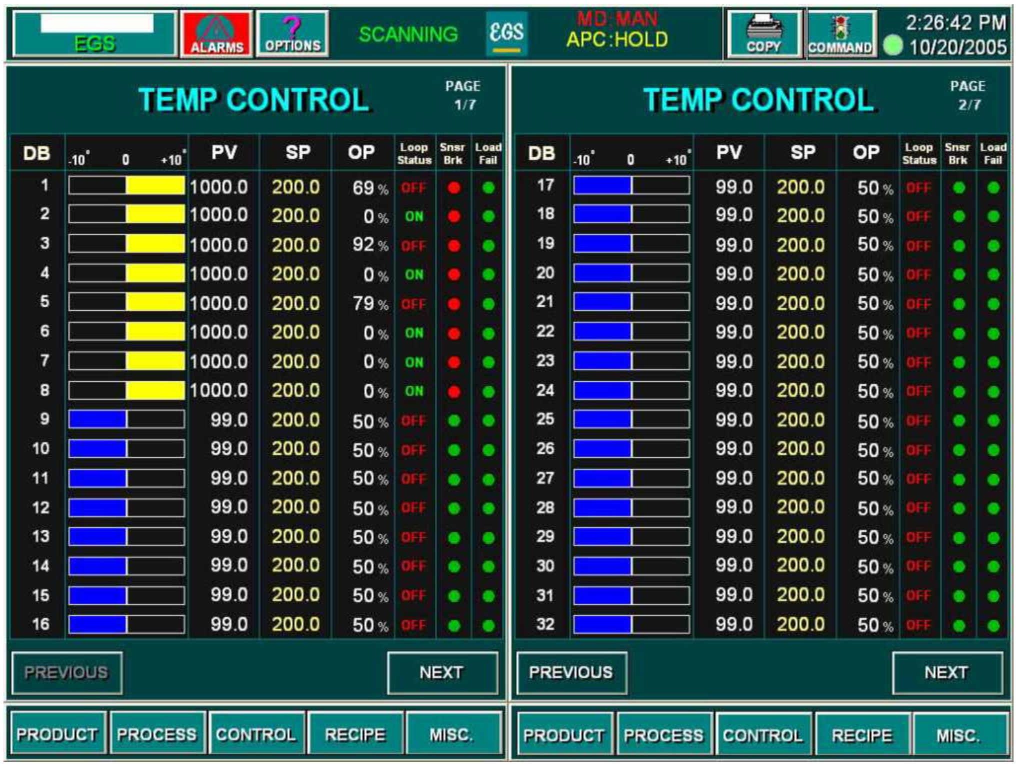


Figure-3: Bolt Temperature Control Display



Figures 4: Time-based Trends showing cause & effect

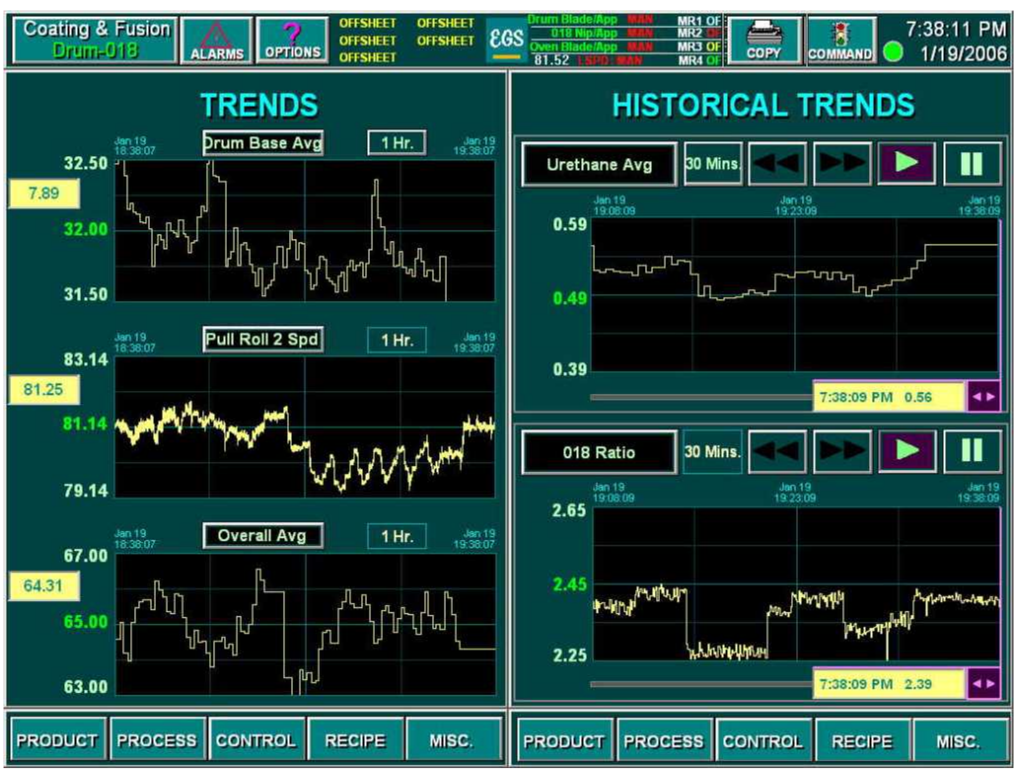


Figure-5: Time-based Historical Trends

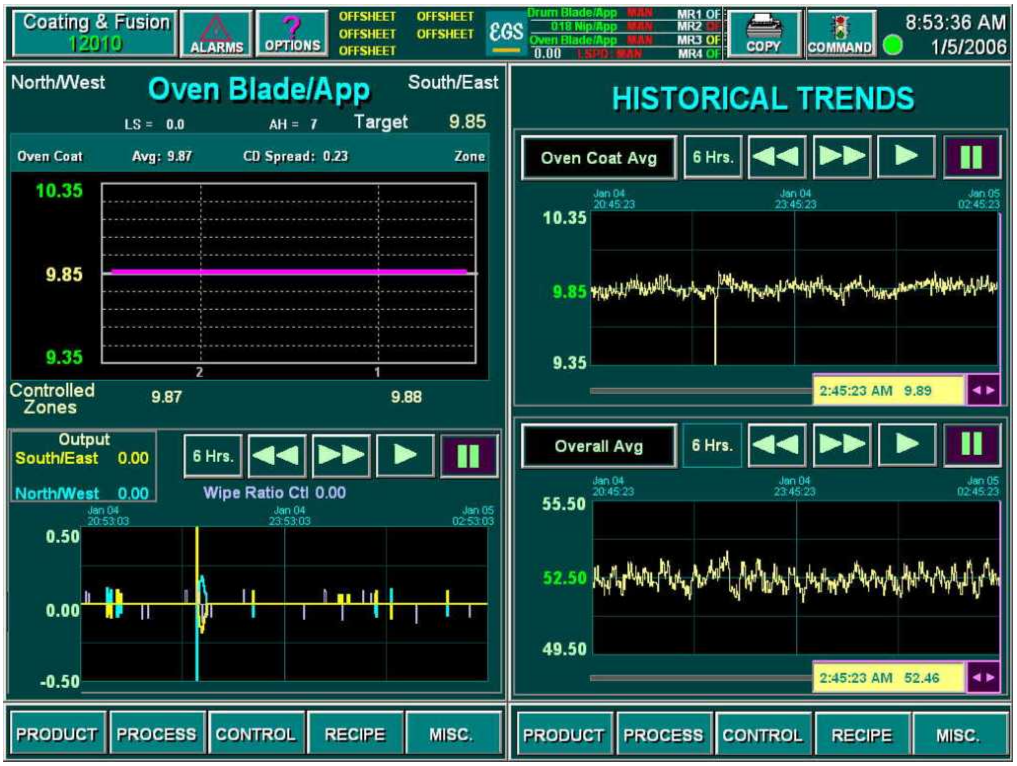
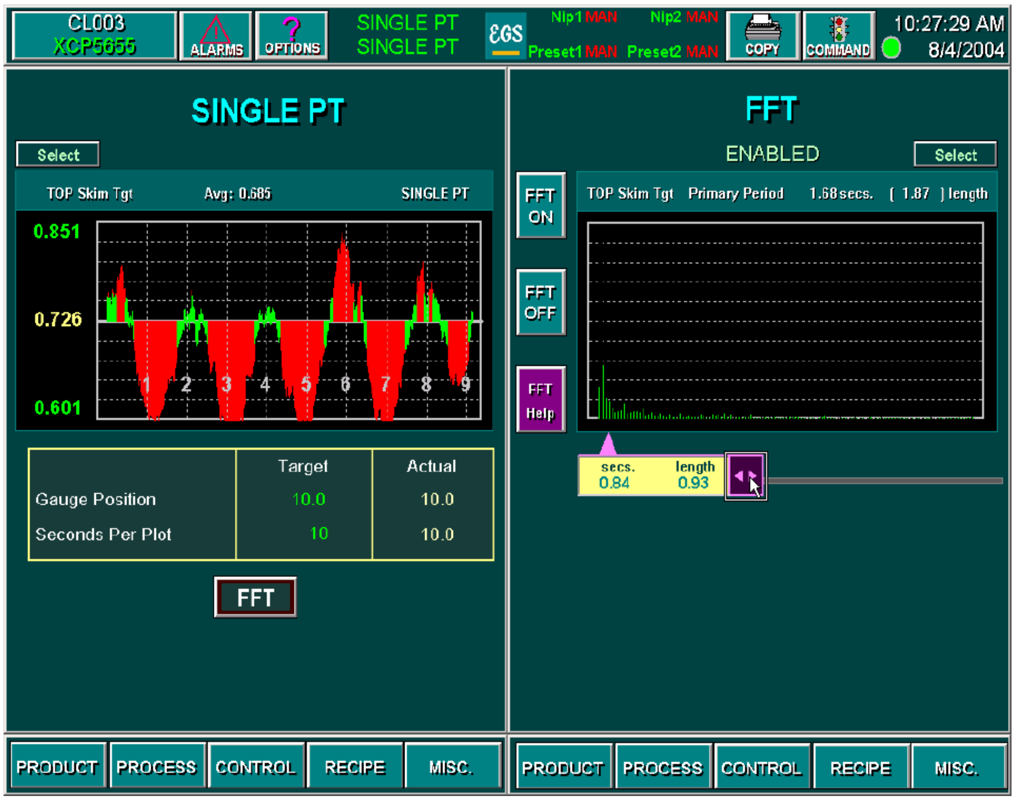


Figure-6: Data display and Alarm history

Figure-7: FFT (Fast Fourier Transform) showing out-of-round rolls effect on product (STMD) In Calender Coating



Roll Quality Diagnostics

Inspection systems are often used to monitor and alarm on defects such as gels, streaks etc. The data from these inspection systems can be integrated into the on-line gauging systems for Displays, alarms and archiving.

The fast processing speeds of the on-line gauging system I/O processors permit these systems to poll data continuously at high speeds from various sensors that monitor temperatures, pressures, visual defects, product quality etc. on the Extrusion Coating Line to display and trend at a central location (Operator Console). This real-time on-line diagnostic and alarming capability enables the Line Operators to troubleshoot the process easily during various stages of manufacturing.

The on-line gauging systems also archive quality data and out-of-specification conditions with a roll length stamp, which is very useful for downstream processing of the finished rolls such as slitting. They also act as in-coming substrate roll inspection tools.

Customer Results

The real-time diagnostics for process troubleshooting and quality improvements derived from coating process control result in significant economic benefits to the Extrusion Coating manufacturer.

Customer results achieved on Multiframe/Multisensor for measurements of multilayer, multi-station coatings, in conjunction with Auto Profile Control of automatic thermal- bolt Dies, in Extrusion Coating applications are summarized below:

Multiple Case studies:

A) Reduction in CD variations

Typically in the range of 50-80%

B) Faster product change-overs

Product change-over times reduced from about 45 minutes to 15 minutes, a 67 % reduction. This is directly attributable to the real-time diagnostics capability described in this paper.

C) Scrap reduction

Scrap reduction at the Laminator in the range of 50 % was achieved, which included start-up scrap, edge scrap and sampling scrap.
Additional scrap reduction at downstream slitting operations resulted as well.

Conclusions

The on-line gauging systems, in addition to their primary function of providing continuous measurement and control of coat weight distribution, play a critical role in troubleshooting of the Extrusion Coating process during various stages of manufacturing. Uniform coat weight distribution ensures adhesion, barrier and other properties critical to the end product. The added value to the processor ensue from the consistent production of full-width high quality rolls at improved manufacturing efficiency due to faster start-ups/ change-overs, reduced edge-scrap, reduction in customer returns and increased customer satisfaction.

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