WEBFREX3ES Dedicated Coat Weight Measurement System for Battery Electrode Sheets

Takaaki Kishino [*1] *Yoshihiko Hagiwara* [*1] *Takeo Haraguchi* [*1]

Recent global environmental policies, such as the Sustainable Development Goals (SDGs), are accelerating the transition from conventional gasoline vehicles to electric vehicles. To meet the high-capacity and high-quality requirements for lithium-ion batteries in electric vehicles, quality control on battery electrode manufacturing has become increasingly strict in recent years.

The WEBFREX3ES is an online measurement and control system for the coat weight of battery electrode sheets. Using linear servo drive technology which enables high-speed scanning and high synchronization accuracy, with rollerless and beltless mechanisms to be used in a clean environment, the WEBFREX3ES is easier to maintain. It also has a wide range of sensors, including materials for positive and negative electrodes, and meets the demand for higher resolution in the cross-machine direction, thus improving uniformity of coating weight and quality control of battery performance according to customer requirements. This paper describes the features and functions of the WEBFREX3ES system including the lithium-ion battery market and industry trends.

INTRODUCTION

The rechargeable battery market has been growing recently and is forecasted to keep expanding. Especially, the market for lithium-ion batteries is expected to grow significantly larger than for other rechargeable batteries such as nickel-metal hydride (Ni-MH) and nickel-cadmium batteries. One reason why lithium-ion batteries are attracting so much attention is the massive shift from gasoline-powered vehicles to electric vehicles in line with global environmental protection efforts in recent years. Lithium-ion batteries have higher energy density than the conventional Ni-MH batteries, and have no memory effect, which is a gradual decrease of battery capacity with repeated recharging. Thus, lithium-ion batteries are suitable for a wide variety of applications including electric vehicles, household batteries, and mobile devices. Manufacturers of lithium-ion batteries are ramping up production capacity and relocating production plants to areas where demand is high. As a result, new lithium-ion battery plants are being built mainly in areas where electric vehicles are produced, such as Korea, China, Taiwan, the U.S., and Europe. The major battery manufacturers of Japan and East Asia are following this trend.

One serious problem with lithium-ion batteries is that they contain rare and precious raw materials. In addition, there is market demand for further improvements in battery capacity, quality, and safety. Accordingly, development is focusing on strictly controlling costs and quality, improving manufacturing technology and production line speed, and creating added value such as new coating materials and over- or anchor-coatings.

Under such circumstances, battery electrode manufacturers are increasingly demanding reductions in the cost of raw materials, faster measurement of electrode coat weight with higher precision for quality control, measurement functions adaptable to various coating patterns of end products, and fast feedback of values measured immediately after the coating process for controlling the coat weight.

In response to such demands, Yokogawa has developed various models of the WEBFREX3ES dedicated coat weight measurement system for battery electrode sheets, to be used in the lithium-ion battery industry. This paper describes the functions and features of the WEBFREX3ES.

*1 P & W Solution Department, Analyzer Center,
IA Products & Service Business Headquarters

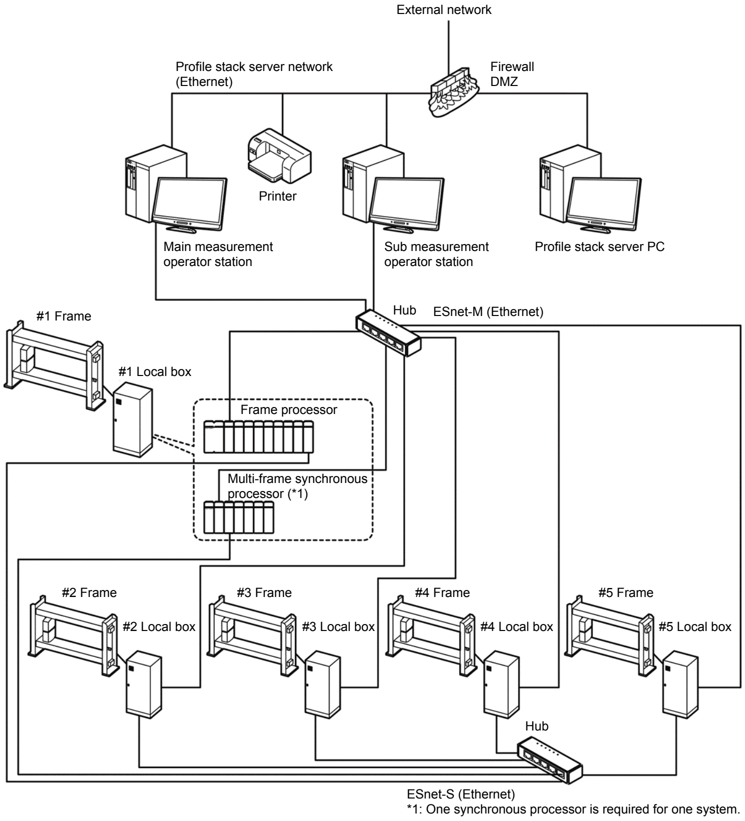


Figure 1 System configuration of the WEBFREX3ES

COAT WEIGHT MEASUREMENT TECHNOLOGY

The WEBFREX3ES is a dedicated system for measuring coat weight on battery electrode sheets from the difference in sheet thickness between before and after the coating process. This system has computation and display functions adaptable to various coat patterns of battery electrodes, and enables high-speed, high-precision measurement based on Yokogawa's proprietary drive mechanism.

Outline of the WEBFREX3ES System

Figure 1 shows the system configuration of the WEBFREX3ES, which consists of frames and local boxes (up to five pairs), sensors (β-ray or X-ray) mounted on frames, measurement operator stations, and an optional profile stack server. An outline of each part is described below.

(1) Frames and local boxes

High rigidity and durability are required for frames to minimize the aging deterioration caused by changes in ambient environment and temperature.

This unit consists of two separate parts, a frame and a local box (Figure 2). In the frame, a pair of non-contact sensors, one placed above and the other beneath the plane of sheet travel, scans from end to end of the sheet across the width. The local box contains a frame processor, a synchronization control unit, and a motor driver. The maximum measurement width can be selected from 800 mm or 1,500 mm depending on the measured object, enabling the system to meet the requirements of battery electrode coat lines.

The frame has a remarkably compact design to fit into the limited space of battery electrode production lines that are designed to minimize space. In addition, electric peripheral devices are easily mounted in a dedicated local box that can be placed separately outside the production line.

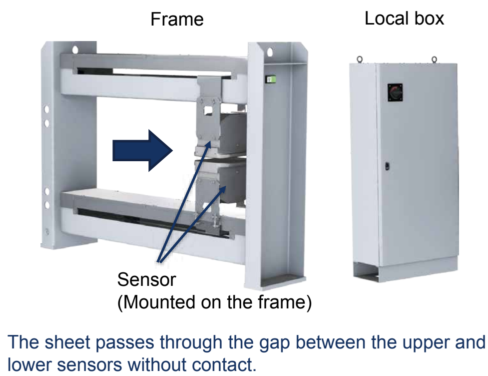


Figure 2 Frame, local box, and sensor

Features of the frames and local boxes are described below.

(a) Yokogawa's proprietary drive mechanism

The WEBFREX3ES uses a linear servomotor drive method that enables high-speed, high-precision scans, while competitors use AC motors and timing belts for the drive mechanism.

The new drive mechanism helps achieve highly-precise synchronous scanning at the same point at all frames, which is vital for calculating the coating weight from differences in measurements.

- Linear servomotor drive

This mechanism can drive the sensor head at up to 30 m/min (500 mm/s), which enables the sheet width to be scanned in 3.0 s in the fastest case (Figure 3). The minimum time required for a turnaround is 0.1 s. Thanks to the fast, stable acceleration/deceleration and travel motion by this drive mechanism, measured values can be fed back quickly to operators. As a result, the coat weight is quickly controlled at the target value, which helps reduce the cost for raw materials and improve productivity.

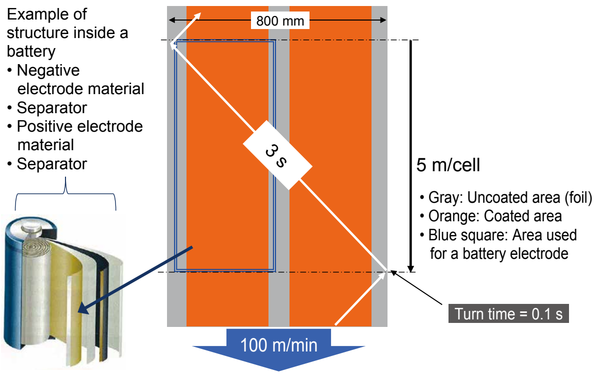


Figure 3 Image of high-speed measurement of battery electrode with 3-s scan

- Beltless, rollerless mechanism

The linear servomotor drive method eliminates the need for belts and rollers. As a result, the number of spare parts and dust generation points is reduced, which helps lower maintenance costs and achieve a cleaner environment with less risk of contamination. In addition, the mechanism is designed to be suitable for the environment of battery electrode production lines that aim not to use copper or zinc.

(b) Frame processor

The processing speed of the frame processor had to be improved because of the increased number of measurement data compared with conventional thickness gauges for films and sheets, due to the multiple frame configuration (max. two frames in conventional systems) and the faster scan speed. The use of Yokogawa's FA-M3 Leading Edge Controller for the frame processor enables real-time, high-speed computation and generation of profiles (thickness data across the width) with up to 1,500 measurement points, during a minimum scan time of 3.0 s.

(c) Multi-frame synchronous processor

It is crucial to measure precisely the same points before and after coating, because the coat weight is calculated from the difference in sheet thickness before and after coating. Thus, highly precise synchronization is the key to improving quality. The WEBFREX3ES achieves extremely small positional misalignments, thanks to the high resolution in measurement position attained by the linear servomotor drive and to the high-speed synchronization control by a dedicated processor (Figure 4).

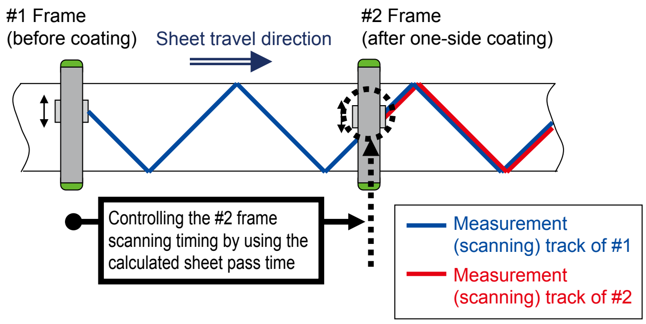


Figure 4 Synchronization control

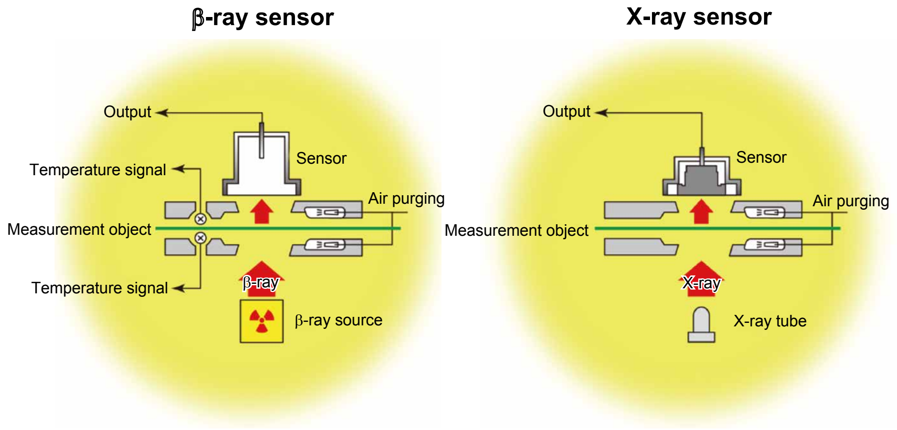
(2) Sensors

Optimum sensors must be selected for measuring the coat weight of battery electrodes depending on the base material of positive and negative electrodes, and on the coating material. The WEBFREX3ES uses β-ray or X-ray transmission sensors to enable high-precision, high-stability measurement of coat weight. The influence of external disturbances is suppressed to a very low level by Yokogawa's original countermeasures such as temperature compensation and air purging, based on long field experience[1]. In addition, being contactless, these sensors can be used for continuous measurement in production lines without damaging the measured objects. Table 1 shows the sensor specifications.

Table 1 Sensor specifications

	β-ray sensor	X-ray sensor	
Measurement range	0 to 1,200 g/m^2 (PET standard sample)	0 to 600 g/m^2 (Aluminum standard sample)	
		0 to 300 g/m^2	301 to 600 g/m^2
Repeatability of indication value	Within ±0.1 g/m^2 or ±0.1%, whichever is larger	Within ±0.1 g/m^2 or ±0.1%, whichever is larger	Within ±0.15%
Repeatability of profile average value	Within ±0.1 g/m^2 or ±0.1%, whichever is larger	Within ±0.1 g/m^2 or ±0.1%, whichever is larger	Within ±0.2%

Selecting the optimum sensor, β-ray or X-ray, depending on the material and thickness (maximum measurement range) of the measured object enables higher-precision measurements and improves quality. For example, users may select an X-ray sensor for positive electrodes and a β-ray sensor for negative electrodes, based on the material properties of the electrodes and the characteristics of both rays, to improve the absorption sensitivity of coating materials and enable higher-precision measurement of coat weight (Figure 5).



	Positive electrode Cobalt #27 Atomic Aluminum #13 Atomic	Negative electrode Carbon #6 Atomic Copper #29 Atomic
Base + Coat	$LiCoO_2$ (Coat) Aluminum foil (Base) $LiCoO_2$ (Coat)	Carbon (Coat) Copper foil (Base) Carbon (Coat)
β-ray absorption Good for both electrodes	Base and Coat show nearly the same degree of absorption. ○	Base and Coat show nearly the same degree of absorption. ○
X-ray absorption Good for positive electrodes	High absorption by Coat (coating material is seen clearly). ◎	High absorption by Base (coating material is not seen clearly). △

Figure 5 Image of sensor sensitivity and materials

(3) Measurement operator station

The measurement operator station is a general-purpose PC with dedicated software installed. It displays measurement data such as base material thickness and coat weight profile, and is used to set and maintain parameters for frames and sensors, and monitor alarms. Information necessary for operation can be optionally assigned to the operation screen and monitored on this station. An optional sub measurement operator station is also available for remote operation and monitoring, and hence more flexible operation.

(4) Profile stack server (option)

The profile stack server has functions to maintain measured profile data, and to display and analyze measured profiles. The features of these functions are described below.

(a) Function to maintain measured profile data

Multiple sets of profile data (thickness distribution data across the width), obtained from the differences among the data from multiple frames, are saved for quality control.

(b) Diverse functions to display and analyze measured profiles

I. Real-time 3D profile display

This is a display and analysis function to help visualize product quality by displaying in 3D the profile data stored in the profile stack server. This function features auto-output and restoration of CSV data for displaying the data in 3D. Saved profile data of the past can be redisplayed and reanalyzed. In addition, the function can predict the changes in operation and quality that could occur in the next production, based on the previous production data (Figure 6).

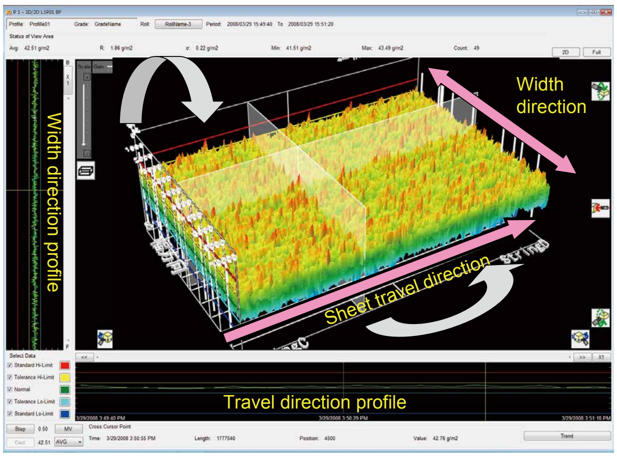


Figure 6 3D profile display function

II. Profile display adaptable to diverse coating patterns

There are several coating patterns depending on the forms of the end product. The WEBFREX3ES offers software that can be adapted to various coating patterns, based on the experience and know-how Yokogawa has accumulated in delivering many battery electrode coat weight measurement systems for over 20 years (Figure 7).

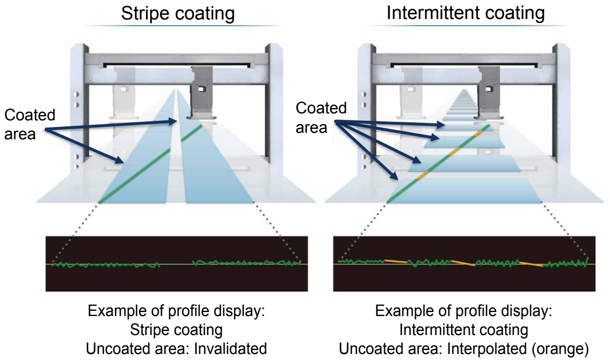


Figure 7 Image of coat patterns

- Stripe coat pattern calculation function
  The average value of the coat weight across the width is automatically calculated for each coat zone, and the trend in the average value is displayed.
- Intermittent coat pattern calculation function
  The system automatically judges coated or uncoated areas based on a threshold value, interpolates or invalidates the data for uncoated areas, and displays the coating profile in an appropriate way for the coating pattern.

Application Example

Figure 8 shows an example of a simultaneous coating system. A sheet is unwound from the unwinder roll, goes through the one-side coating section, the first dryer part, the other-side coating section, and the second dryer part, and is wound around the winder roll. The coat weight profile is measured before the sheet goes into the dryer for quick feedback and control. Thus, the time loss caused by waiting for the sheet to transit the dryer part is eliminated.

The WEBFREX3ES can control synchronization of up to five frames, thus enabling measurement and control of both surfaces of the base material (foil) and the coating in both wet and dry conditions in such simultaneous coating systems.

CONCLUSION

The WEBFREX3ES not only measures coating thickness and weight, but also helps increase added value, improve the quality of the sheets, and reduce material costs and labor for the process, based on the measured profile data. In addition, production efficiency can be improved by adding to the system such packages as the profile stack server for quality control.

Yokogawa offers extensive support for WEBFREX3ES users with a solid backup system such as a checkup and maintenance service by nearly 1,500 engineers located at 107 offices nationwide. Not only in Japan, Yokogawa also offers various types of support to overseas customers, such as a global response center that is available 24/7.

Yokogawa will keep proposing solutions for improving productivity and business efficiency, besides the traditional process improvements, aiming to achieve a sustainable society, and will develop the WEBFREX3ES further as a component of such proposals.

REFERENCES

(1) Akihiko Tsuchiya, Ikuo Sugaya, Takashi Sasaki, "Measurement and Control Technology in Film and Sheet Manufacturing," Yokogawa Technical Report, Vol. 50, No. 1, 2006, pp. 31-34 (in Japanese)

* WEBFREX is a registered trademark of Yokogawa Electric Corporation.
* All other company names, group names, product names, and logos that appear in this paper are either trademarks or registered trademarks of Yokogawa Electric Corporation or their respective holders.

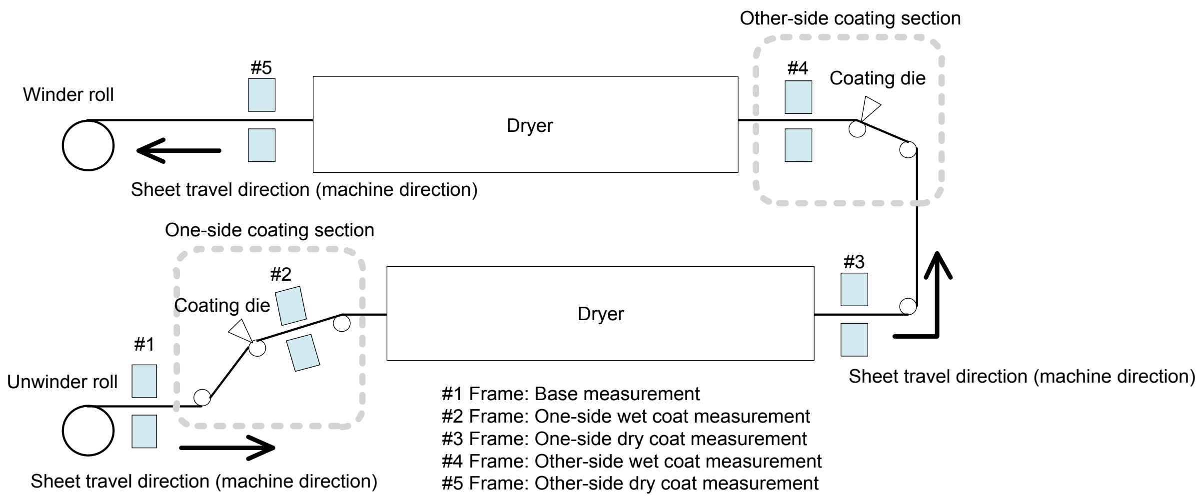


Figure 8 An example of a simultaneous coating system