Development of SSV Series Multilane Checkweighers

Atsushi Iida, Junichi Tamura, Kenta Yamada, Kohei Suzuki, Hironori Sato, Takamasa Ito, Hirotaka Anzai, Mark Bajo

[Summary] With the world's smallest belt pitch of 50 mm, Anritsu Infivis developed a multilane checkweigher which can simultaneously support up to 12 production lanes. A compact, force-balance type weighcell was designed as the checkweigher's main scale. The mass of the weighing platform conveyor was reduced, and the center of gravity was optimized to improve stiffness and reduce the influence of surrounding vibration. These measures in turn increased the checkweigher's accuracy. In addition, by lowering control-board's power consumption, integrating board parts, and minimizing wiring, the indicator installation area was reduced. As opposed to conventional checkweighers, an overall space-saving of 40% was achieved.

1 Introduction

Checkweighers are used mainly on food and pharmaceutical production lines to both weigh every product, and to reject under- and overweight ones using a downstream rejector unit. Reasons for introducing a checkweigher into a production line include removing products not meeting the target weight, using feedback control to minimize losses due to overfilling, collecting data to manage production quantity, and monitoring line faults, etc. These together make checkweighers a key part of every production line.

Along with the recent increasingly strict rules governing detection quality to prevent the risk of delivering faulty products to customers, there has been an urgency for production lines to introduce various inspection methods to their products. This increases the need for space-saving inspection equipment on ever-more-crowded lines. In addition, manufacturers are actively working on line automation - reducing personnel to improve yields by minimizing losses due to costly packaging and raw materials, and to deal with skilled labor shortage. In the checkweigher market, there is an increasing demand for precise weight inspection while cutting the equipment's line footprint, as well as raising the checkweigher's accuracy to minimize raw-material and rejection losses. When these matters are addressed, production efficiency rises.

The multilane checkweigher has several lanes for inspecting weight of products sealed with three or four edges, and filled goods such as ice cream on cups, yoghurt, etc.. Due to the recently increasing volume of easily openable product packaging, multilane filling lines are developed to having narrower pitches. Additionally, with the rapid spread of products such as instant coffee in newly industrialized countries in SE Asia, etc., and concurrently with the growing number of smaller nuclear families, the switch to smaller single-use packages is increasing dramatically. These circumstances demand an efficient and simultaneous use of production lines for individually packaged products to improve efficiency. Moreover, with the diversification of customer requirements, it is becoming a must for production lines to be able to handle varying products in each production lane.

To satisfy these market requirements, a multilane checkweigher featuring reduced production loss and smaller production line footprint - all while keeping the well-known key safety and accuracy features of the SSV series, has been developed (Figure 1). This article explains the adopted technical approach to developing this model.

Figure 1 External View of SSV Series Multilane Checkweigher

2 Basic Structure and Operation Principle of Multilane Checkweigher

2.1 Basic Checkweigher Structure

As shown in Figure 2, the latest model of the multilane checkweigher has more lanes - each of which is composed of an infeed conveyor, a weighing conveyor, and an integrated rejector conveyor. The weighing conveyor utilizes a newly developed force-balance weighcell.

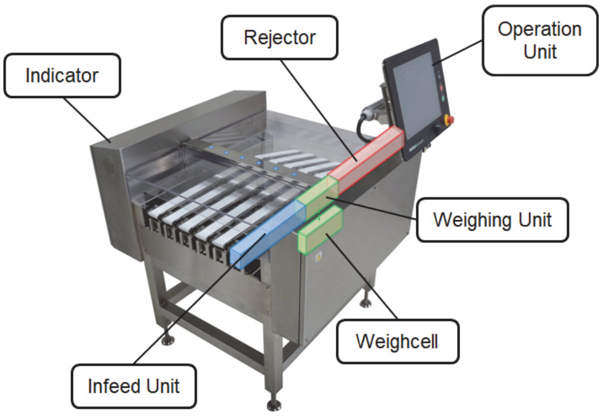

Figure 2 Structure of SSV Series Multilane Checkweigher with Integrated Rejector Unit

2.2 Weighcell Unit

In the weighing section, the weighcell unit is positioned under the weighing conveyor and quantifies the product's mass to a weight value. The development of this narrow force-balance type weighcell is also the basis of innovating a narrower multilane conveyor pitch.

2.3 Conveyors

The standard checkweigher has three conveyors - the weighing conveyor running above the weighcell unit, the infeed conveyor, and the integrated rejector conveyor. The infeed conveyor is positioned a wide gap away from the weighing conveyor in order to rigorously transport only one product to the weighing conveyor at any given time. Both conveyors run on equal speed.

Conveyors are designed for products of various sizes and for diverse environments. Stable conveyance of measured products is assured by fitting anti-spill and alignment guides.

2.4 Operation Unit

The indicator is used for displaying weight measurements, for evaluating results and statistical data, as well as for setting operating parameters. Machine operation is performed with a 15-inch high-visibility, color TFT LCD touch panel. In addition, the detachability of LCD display from the indicator unit enables remote operation of the checkweigher.

2.5 Integrated Rejector

The integrated rejector unit separates products that pass the customer's set standards (PASS), from those which have not (NG/off-weight). It uses the dropout method where off-weight products drop vertically from the conveyor. Machine rejection can be executed in either two or three directions (optional). Moreover, a built-in rejection confirmation sensor is also utilized to prevent passage of off-weight products due to rejection error.

2.6 Basic Operation Principle

Figure 3 shows the basic operation principle of the multilane checkweigher.

Optoelectronic sensors positioned at the gap between the infeed conveyor and weighing conveyor detect products which are about to be weighed. They also control measurement at a fixed interval until the measured weight stabilizes. That result is evaluated against user-specified limits to judge whether the measured product passes or fails, and as mentioned earlier, off-weight products are removed from the lane by the integrated rejector.

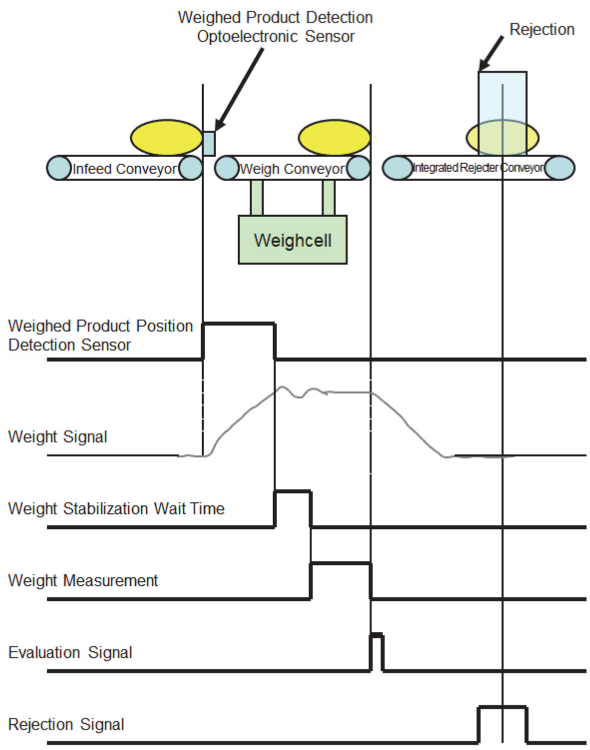

Figure 3 Basic Operation Principle

3 Development Concept

The development of the multilane checkweigher aims to address the following key issues to meet market requirements.

(1) Narrow-pitch space-saving design, supporting up to 12 lanes
- Achieving maximum rejection performance of 1200 pcs/minute for 12 lanes, 1.5 times better than conventional checkweigher models
- Design of the world's smallest 50-mm belt pitch, notably used for production of narrow stick-shaped products
- Reducing equipment footprint by using a more compact indicator unit

(2) High accuracy and minimized production losses
- Achieving an all-time rejector accuracy of ±0.01 g (1.5 times better than conventional models)
- Lessening vibration impact on nearby equipment, such as machine fillers
- Increasing yield using the double-product error reduction function, Smart Measurement Function (SMF)

(3) The ability to support a wide array of products

(4) Improved operation and monitoring
- Up to a maximum of 12 lanes can simultaneously be monitored on a single screen.
- A free layout of the indicator unit translates to improved usage clarity.
- Maintaining the unit is now made easier. Tool-free cleaning can now be implemented.

4 Development Points and Implementation

4.1 Narrow-Pitch, High-Accuracy, Force-Balance Weighcell

4.1.1 Basic Mechanism of Force-Balance Weighcell

Figure 4 shows the structure of a force-balance type weighcell. The main balance uses mechanical displacement to measure load using a position sensor and electromagnetic force. The Roberval mechanism coupled to the weighcell pan mechanically "amplifies" the positional displacement, which is detected by the position detection sensor. The sensor's output is used to generate an opposing current in the force coil so as to maintain scale equilibrium similar to a no-load state. This generated current is interpreted as the measured weight value of the product.

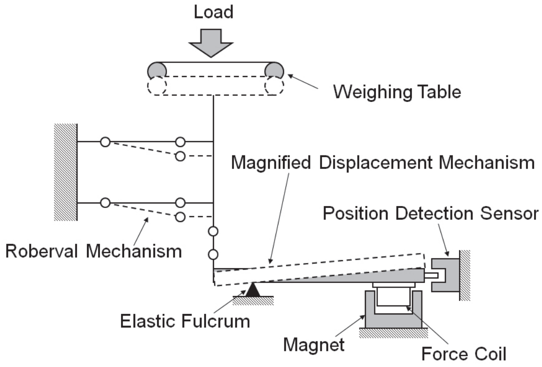

Figure 4 Force Balance Weighing Mechanism

4.1.2 Relation Between the Weighcell's Roberval Structure Side Rigidity and Measurement Accuracy

As opposed to using a static balance, with an automatic checkweigher, products are weighed in a span of just a few hundred microseconds as they pass along a production line. As this happens, the balance must stabilize quickly while under the influence of the product's mass and external vibration. Moreover, precise measurement demands improved balance responsiveness.

If balance structure is modeled as a simple mechanism composed of three elements - a spring, a mass, and a damper, assuming vibration has one degree of freedom, the three dynamic characteristics, namely positional displacement x, fixed angular frequency ω, and attenuation coefficient ζ, can be expressed by Equations (1) through (3).

$$x = \sqrt{Mg/K} \quad \cdots\cdots\cdots\cdots (1)$$

$$\omega = \sqrt{K/(m+M)} \quad \cdots\cdots\cdots\cdots (2)$$

$$\zeta = C/(2(m+M)K) \quad \cdots\cdots\cdots\cdots (3)$$

where M is the mass of the weighed object, g is acceleration due to gravity, K is the system spring constant, m is the conveyor mass, and C is the damper attenuation coefficient.

Assuming an ideal step response, the time to stabilize, t, is also expressed by Eq (4). Here, ε is the permissible error.

$$t = \frac{1}{\zeta\omega} log \frac{1}{\varepsilon\sqrt{1-\zeta^2}} \quad \cdots\cdots\cdots\cdots (4)$$

To increase the balance responsiveness, it is necessary to shorten t in Eq. (4), which can be achieved by increasing ω (fixed angular frequency). In other words, this requires an increase in the vertical and horizontal spring constants and a reduction of the conveyor's mass m.

When load is placed, the vertical displacement can quickly be controlled using the coil's electromagnetic force. There is, however, no method yet for controlling horizontal displacement. There is also a tendency for the responsiveness to worsen as the scale's stiffness drops from the narrowing of the Roberval mechanism (Figure 5a). In addition, responsiveness is also affected by stiffness drops resulting from changes in balance pan size and center of gravity (Figure 5b).

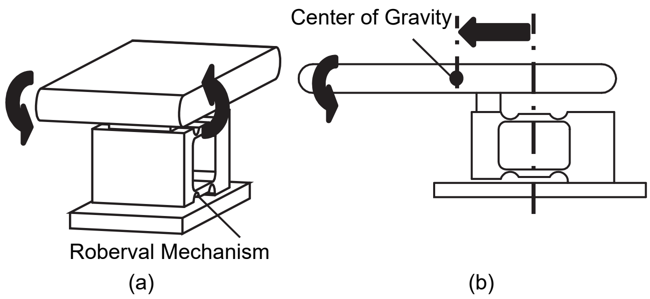

Figure 5 Weighcell Roberval Structure Side Rigidity

4.1.3 Optimum Weighcell Design for Lane Pitch

Since the multilane belt pitch varies with different product dimensions, the weighing section must be able to support belt pitches ranging from 140 mm to a minimum of 50 mm. However, as previously stated, fabricating a weighcell for a narrower 50 mm pitch also causes a degraded response function due to the narrower width of the Roberval balance. As a measure, the developers implemented the optimal design for the balance based on the required specifications listed in Table 1.

Table 1 Required Multilane Checkweigher Specifications

Belt Pitch	Narrow 50 mm	80 to 140 mm
Target Products	Wrapped stick	Sealed on 3 or 4 sides Non-packaged foods such as cup ice cream
Target Mass	50 g max.	300 g max.
Product Width (mm)	10 to 20	40 mm to
Conveyor Belt Width (mm)	25	40/70/100
Protection Class	Corrosion resistant, drip-proof	Corrosion resistant, IP65 waterproof SUS

(1) 80 to 140-mm Belt Pitch Support

In comparison to the 50-mm pitch, dimensions for the 80 to 140-mm pitch are much larger, and the conveyor mass becomes heavier due to its waterproof construction. The 80-mm pitch was implemented by arranging the balances alternately as with conventional 140-mm pitch checkweighers, shown in Figure 6. However, this sequence lead to poor accuracy due to the reduced stiffness from bias displacement inconsistencies on the weighing conveyor's center of gravity. To reduce the effects of this bias displacement, a narrower balance whose dimensions enable it to be arranged in parallel is developed. By doing so, stiffness of the balance Roberval mechanism is assured and optimized for the dimensions of the built-in conveyor.

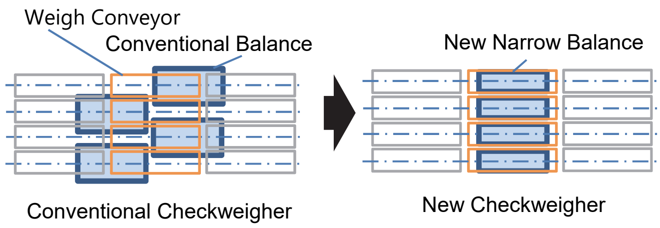

Figure 6 Weighcell Arrangement (80-mm Belt Pitch)

(2) 50-mm Belt Pitch Support

Since the range of inspected product weight is limited, the weighing conveyor's size and mass can be reduced. Bearing in mind the need to assure consistent stiffness, a compatible arrangement for the narrow balances was used (Figure 7a). Aluminum alloys are also employed to reduce weighing conveyor mass by about 65%. Furthermore, the conveyor's motor is relocated near the center of gravity to help reduce bias displacement error.

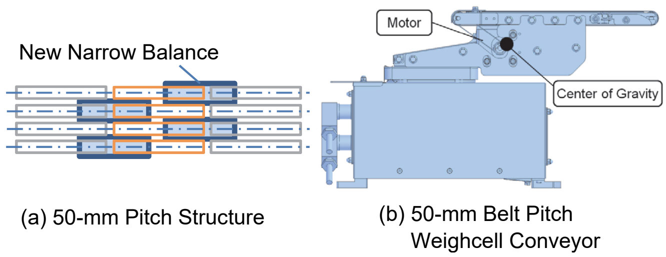

Figure 7 50-mm Belt Pitch Support

4.1.4 Narrower Pitch, Higher Accuracy

(1) Effects of a Narrower Pitch

Implementing the world's narrowest 50-mm belt pitch eliminates the need for a wide, spreading conveyor in a filling line. Doing so not only saves space but it also cuts line equipment costs. In addition, it helps in solving yield problems due to poor product conveyance on wide conveyors; and, it also helps in mitigating off-weight product losses (Figure 8).

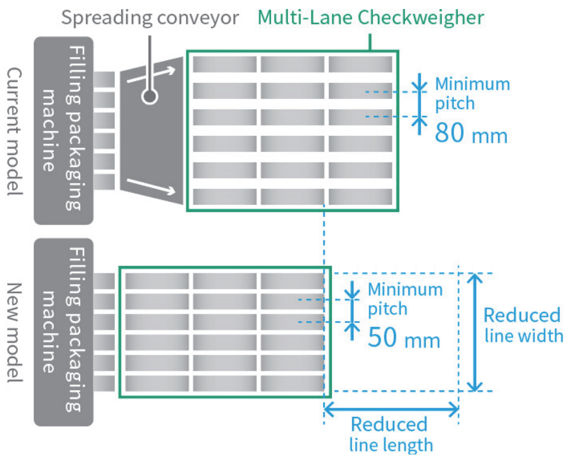

Figure 8 Space Saving by Reducing Belt Pitch

(2) Improved Vibration Damping, Higher Accuracy

The optimized balance design achieved a maximum rejector accuracy 3σ of ±0.01 g. Moreover, the impact of vibration from nearby equipment and floor vibration was halved as opposed to a conventional checkweigher. Reducing the impact of environmental vibration made it possible to locate the filler closer to the checkweigher - shortening the production line while still maintaining high accuracy. Figure 9 shows the measured weight 3σ randomness for both conventional and new checkweighers when subjected to external vibration using a shaker machine.

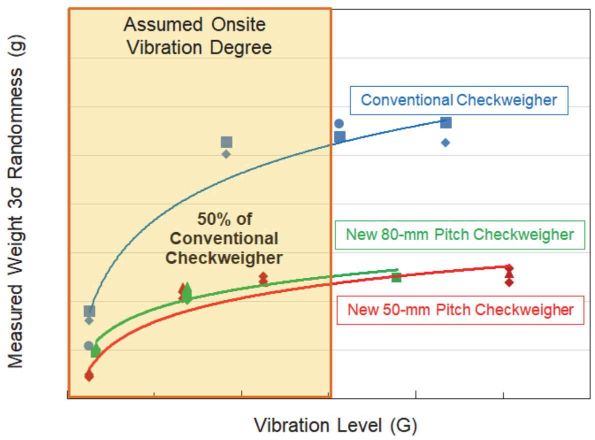

Figure 9 Improved Vibration Damping

4.2 Compact Indicator Unit

Due to processing performance issues of the measuring and rejector control units, conventional checkweighers have their multilane units built separately from their respective indicators. This results in requiring a larger indicator unit - consequently increasing the equipment's footprint.

In developing this checkweigher model, the developers aimed to redesign the indicator's layout to make it more compact.

First, the controller is fitted with multitask processing capabilities to accommodate multiple lane control even from a single board. Moreover, internal wiring lengths were reduced by using high-speed network communications. Compared to conventional checkweighers, the area of units built into the indicator is reduced by 75%.

Second, indicator size is further reduced by moving lane-control motor drivers away from the indicator unit and into the weighing unit. Heat was, however, generated from a limited shared space accommodating the motor drivers. Upgrading the motor control method solved the issue by cutting switching losses at 10% per unit.

Overall, the above measures enabled reduction of the indicator unit size - cutting the required installation space by more than 40%.

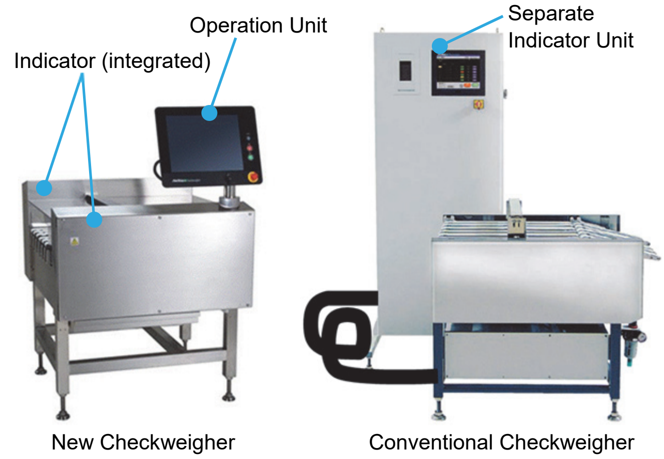

Figure 10 External Views of New and Conventional Checkweighers

4.3 Improved Yield using SMF Double-Product Error Reduction Function

In conventional checkweighers, double-product errors occur when two or more products are simultaneously boarded on a conveyor. As individual measurements cannot be taken, the rejector is prompted to make an off-weight reading and discard said products, unfortunately reducing production yield. To reduce the occurrence of double-product measurement, the checkweigher belt speed is increased to further distance two products; but, conveyance randomness and higher conveyance speeds also lead to lower measurement accuracy.

The new Anritsu-patented Smart Measurement Function (SMF) is a unique function designed to improve yield by measuring individual product weights even when double-product errors occur.

Figure 11 shows the SMF measurement principle. When a product boards the weighing conveyor, its weight is measured from when the weight signal starts to go down until it stabilizes.

Under good conveyance conditions, weight measurement is completed within this time interval; but when a double-product error occurs, the weight of the second product adds to the weight of the product being measured, and as a result both products are rejected. However, with SMF, measurement of the first product is interrupted and completed just before double-product error even occurs – giving way for the detection of a second product. Measurement of the second product starts at the instant the first product exits the weighing conveyor and moves on to the next stage.

When using SMF, since it is not necessary to separate products by increasing belt speed, product conveyance is stable and measurement accuracy is guaranteed. On a high-speed line with a production rate of 200 pcs per minute, an improved 0.4-g measurement accuracy is observed, and the double-product rejection loss is cut from 0.15% to 0.03%.

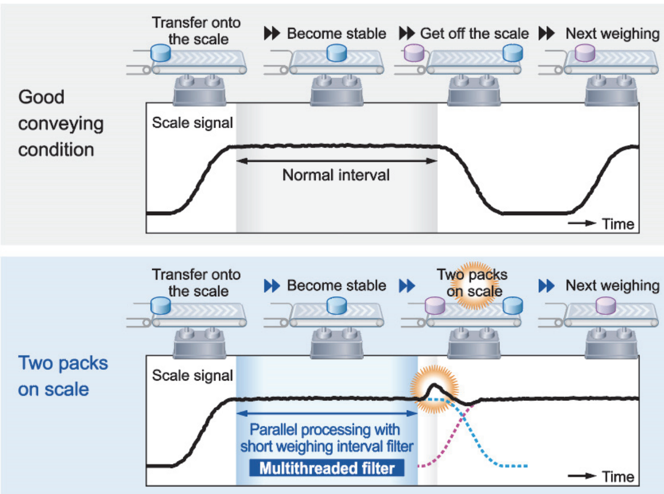

Figure 11 SMF Measurement Principle

4.4 Assorted Production Support

To support production of products with varying contents and volume per lane, different standard values and upper and lower limits can be set for each lane (Table 2). Product inspection conditions can also be set as either unique for each lane, or identical to all. Inspection of multiple product types with one checkweigher helps increase the customer's productivity.

Table 2 Settings using Assorted Production Function

Lines	Standard Value (g)	Upper Limit (g)	Lower Limit (g)
1	120	+1.2	−1.2
2	120	+1.0	−1.5
3	100	+1.0	−1.0
4	90	+1.0	−1.0

4.5 Improved Operation Efficiency

4.5.1 Easy-to-Operate Display

A 15-inch, high-visibility touch panel display makes it easy for the operator to monitor the checkweigher's operating conditions, production status, and any alarms and errors with a glance. Some typical operation screens are introduced below:

(1) Filler Adjustment Screen

On a filler line, measured weights and weight variations of products are fed-back automatically to the filler to serve as reference data for filler setting correction. On the contrary, if the filler has no filling adjustment function, adjustment can be performed manually while observing the checkweigher's integrated rejector operation screen. At manual operation, the operator standing in front of the filler operation panel is able to make adjustments from the checkweigher's display panel without needing to operate the whole checkweigher unit. Additionally, one screen can simultaneously display all production lanes in colored bars, offering an intuitive grasp of the fill shortage from the set standard as relative values (Figure 12).

Figure 12 Fill Adjustment Screen

(2) Statistics Screen

Figure 13 shows the screen displaying various statistical data and histograms for all measured products, passing and off-weight. In addition, this display screen can be switched to simultaneously monitor all lanes, or even specific ones, helping manage production by indicating lane trends and abnormalities.

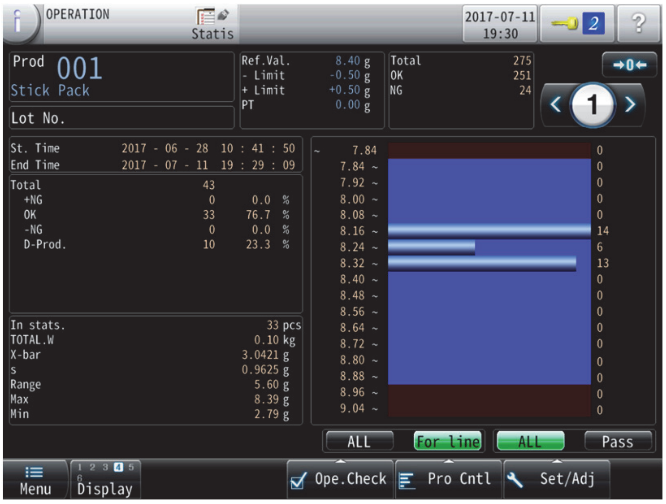

Figure 13 Statistics Screen

4.5.2 Easy Cleaning with Tool-free Assembly/Disassembly

The new checkweigher product line includes models with an IP65-class protection for weighing pre-packaged and liquid-filled products, such as cup ice cream. When used in a waterproof environment however, daily cleaning is required to sanitize leaks from damaged products as well as residues from unpackaged ones. Additionally, the new checkweigher is designed for easy tool-free assembly and disassembly with flat springs securing conveyors with direct contact to products, as shown in Figure 14.

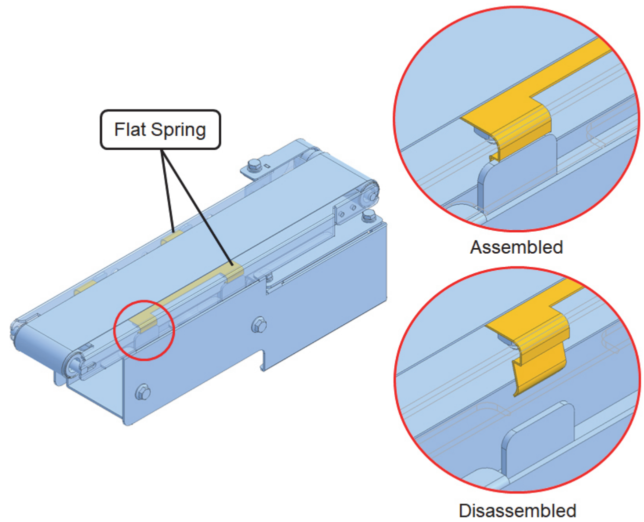

Figure 14 Tool-free Assembly/Disassembly

5 Main Specifications

Table 3 lists the main specifications for the new multilane checkweigher model in the SSV series. Table 4 lists complementary conveyors which cater to the customers' specific needs.

Table 3 Multilane Checkweigher Specifications

Model		KWS6031FP12
No. of Lanes		12
Weighing Range		0.4 to 100 g
Display Scale		0.002 g
Max. Integrated Rejector Rate		100 pcs/minute (per lane)
Max. Integrated Rejector Accuracy (3σ)		±0.010 g
Display		15-inch color TFT LCD
Operation Method		Touch panel (Direct keys for Run/Stop/Home buttons)
Max. Displayed Mass		100.9 g
Supported Product Variety		50 max
Integrated Rejector Stages		2 (3 as an option)
Supported Product Dimensions	Width	10 to 40 mm
	Length	46 to 230 mm
	Height	5 to 25 mm
Belt Speed		15 to 30 m/min
Power Supply and Consumption		100 to 120 Vac +10%, −15% or 200 to 240 Vac +10%, −15%, single phase, 50/60 Hz, 550 VA, surge current 30 A (typ.) (130 ms max.)
Compressed Air Supply (with dedicated rejector fitted)		0.4 to 0.9 MPa, 0.2 liters (ANR) (Max. per single rejection operation per lane)
Mass		190 kg
Operating Environment		0° to 40°C (within 5°C/h temperature change for optimum integrated rejector accuracy) 30% to 80% relative humidity without dewing
Protection Class		IP30
External Finish		SUS304
Data output		USB2.0, 10BASE-T, 100BASE-TX

Table 4 Supported Conveyors

Type	Belt Pitch	Belt Width (mm)	Balance Conveyor Length (mm)
Narrow pitch	50 mm to	25	270
			345
General Purpose (Not Waterproof)	80 mm to	40	270
			345
	110 mm to	70	270
			345
	140 mm to	100	270
			345
General Purpose (Waterproof)	80 mm to	40	270
			345
	110 mm to	70	270
			345
	140 mm to	100	270
			345

6 Conclusion

Anritsu Infivis developed a multilane checkweigher model utilizing force-balance measuring. It supports high-accuracy measurements to a minimum belt pitch of 50 mm. This new model helps improve quality assurance and product yield on both food and pharmaceutical production lines.

Now and in the future, Anritsu Infivis aims to provide customer safety and satisfaction with its continuous research in developing unique technologies to improve production lines.

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Authors

Atsushi Iida
Common Technology Development Dept.
Development Division
Anritsu Infivis Co., Ltd.

Junichi Tamura
1st Development Dept.
Development Division
Anritsu Infivis Co., Ltd.

Kenta Yamada
1st Development Dept.
Development Division
Anritsu Infivis Co., Ltd.

Kohei Suzuki
1st Development Dept.
Development Division
Anritsu Infivis Co., Ltd.

Hironori Sato
Common Technology Development Dept.
Development Division
Anritsu Infivis Co., Ltd.

Takamasa Ito
Common Technology Development Dept.
Development Division
Anritsu Infivis Co., Ltd.

Hirotaka Anzai
1st Development Dept.
Development Division
Anritsu Infivis Co., Ltd.

Mark Bajo
1st Development Dept.
Development Division
Anritsu Infivis Co., Ltd.