Direct Drive Modular Mounter "GXH-3" Contributing to High Productivity and High Density Placement

Hideaki Fukushima
Yoshinao Usui
Ikuo Takemura
Shigeo Katsuta

OVERVIEW: The latest generation of mobile electronic appliance are requiring increasing functionality and performance in less space with lower weight, and this is driving further miniaturization of electronic components and higher chip ratios. These factors plus shorter product life cycles and increased production are fueling a demand for electronic parts mounting machine that support greater productivity and higher density mounting. Hitachi High-Tech Instruments Co., Ltd.'s new modular direct drive mounter "GXH-3" provides even better performance than the GXH-1S that it replaces. The "GXH-3" not only provides the highest throughput of any placement machine in the industry of 95,000 chips per hour, it also delivers increased high-density mounting reliability thanks to new soft mounting nozzles and PCB height measurement feedback function. To extract the full potential performance from the system, the GXH-3 also features optimization software and multi-product line balance software enabling clients to create optimum production data tailored to their production lines.

INTRODUCTION

PLACEMENT equipment and modular mounters have evolved very rapidly in response to growing demand and increasing ratio of chip-based components for mobile electronic devices — cellphones, MP3 [MPEG (Moving Picture Experts Group) Audio Layer-3] players, digital cameras —, laptop computers, flat-screen TVs (televisions), and increasing digital components and systems in vehicles.

Modes of production are also changing with the transition to smaller production lots to accommodate greater diversification of products and life cycle. High-volume production has been largely superceded by adaptable production for large or small volume to achieve high-mix low-volume production, and further shrinkage of production lead times to meet the needs

Fig. 1—Photos of Modular Direct Drive Mounters GXH-3 and GXH-3J. Hitachi's latest modular direct drive mounters are fast, accurate, provide excellent placement accuracy, achieve a throughput about 20% better than previous placement equipment, and are now commercially available. GXH-3 on the left has a throughput of 95,000 chips per hour, and GXH-3J on the right has a throughput of 47,500 chips per hour.

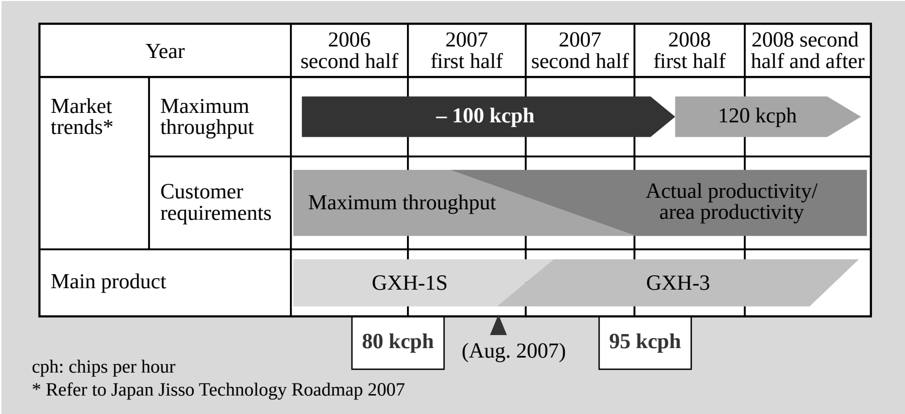

Fig. 2—Modular Mounter Market Trends.
Market trends reveal maximum throughputs up to 100,000 chips per hour, but actual productivity and area productivity are more important for meeting customers requirements.

of inventoryless production systems has led to the demand for even better productivity.

Increasing functionality of ever smaller wireless products in particular is driving the evolution to thinner PCBs (printed circuit boards) and parts, use of smaller electrical parts in greater number, and narrow and adjacent mounting technologies. The smallest components used extensively in products for today's mobile electronic sector are 0201 (0603 metric, 0.6 mm × 0.3 mm), but 01005 (0402 metric, 0.4 mm × 0.2 mm) parts are already beginning to appear in higher frequency modules. It will be some time before 01005 parts become pervasive, but demand is already emerging for faster and more reliable mounting equipment that can support these high-density mounting demands of smaller components. This paper provides an overview of the GXH-3, a modular direct drive mounter developed by Hitachi High-Tech Instruments Co., Ltd. that meets the production and high-density mounting requirements of current and next-generation devices (see Fig. 1).

BETTER PRODUCTION AND HIGHER DENSITY MOUNTING

Better Productivity

When considering the performance of module mounters, people tend to look first at the maximum throughput of the equipment, but as illustrated in Fig. 2, actual productivity and area productivity tend to be more important in terms of meeting customers' needs. Boosting the productivity of placement equipment can be done by either speeding up the operation of the equipment or by reducing dead time. The key to faster speed is to accelerate the heads that pick up and place the components. However, this is easier said than done, for simply speeding up the motion of the heads could cause vibration, a loss of pick and place accuracy, diminished life for some parts of the equipment, and other adverse effects. Considering these possible negative impacts, we kept the speed of the GXH-3 equipment itself the same as that of the previous GXH-1S mounter. Rather, the GXH-3 saves motion time through enhancements to the up and down motion of the nozzles, the rotation of the heads, and by overlapping the motion of the X and Y axes beams. The X axis beam supporting the heads also had to be made lighter and more rigid, and we accomplished this by rethinking the head motion and structure. To reduce dead time, we cut the stop time to zero by implementing nonstop on-the-fly recognition of 12 components simultaneously and other capabilities.

Productivity was also improved by optimizing the software to minimize the setup time, and optimize the production sequence and multi-product line balance to significantly reduce the PCB finish time.

Higher Density Mounting

We are beginning to see the use of 01005 parts in modules, but as one can see in Fig. 3, this form factor

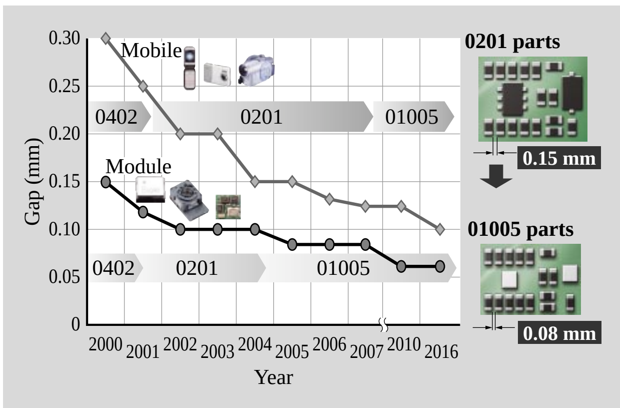

Fig. 3—Very Small Electrical Part Gap Requirements.
The required gap for 0201 parts is 0.13 mm, and the required gap for 01005 components is 0.08 mm, and the gap continues to shrink.

requires a gap of 0.08 mm and a placement accuracy of less than 0.03 mm at 3 σ. To achieve such high-density mounting, it is essential to stabilize pick position accuracy and also to reduce any factors that might have a disturbing affect on placement accuracy. The GXH-3 provides improved pick positional accuracy by implementing two new capabilities: auto feeder axis adjustment and pickup height control. The head motion positioning accuracy was enhanced by applying full-closed linear motor drive to the XY axes. Particularly in the case of the Y axis with its 2 axes parallel motion, better accuracy is ensured by adopting dual linear drives that monitor the positions of the two linear motors with respect to each other.

Once a component has been picked, precision placement of the part on a board requires accurate recognition of the part and mounting at the proper placement level. To determine if the mounting level is right, a line sensor is used to make sure the bottom surface of the picked component reflects the actually measured placement height. The GXH-3 also features a board warpage measurement and feedback function.

MODULAR DIRECT DRIVE MOUNTER GXH-3

Configuration and Features

A key advantage of the GXH-3 modular mounter is that it is essentially implemented as a single platform, but supports a wide range of optional configurations. It not only handles a wide range of different parts, it also can be optimized to practically any production mode from high-volume production to high-mix low-volume production. Fig. 4 shows a schematic overview of the GXH-3, and its main features are summarized as follows.

(1) Heads driven by Hitachi’s unique direct drive motors achieve remarkable speed coupled with very high placement accuracy.

(2) Exceptional placement reliability using Hitachi’s well-proven intelligent line sensor mounted on each head verifies the presence of parts, the status of picks, and measures the thickness of parts.

(3) Highly accurate placement thanks to linear motor drives mounted on XY axes beams

(4) High speed and high recognition accuracy achieved using nonstop gang fly imaging of 12 components, individual component recognition, and on-the-fly position correction system

(5) Application of a servo-motor drive to the tape feeder made the tape feeder faster and more accurate and better able to handle very small electrical parts.

(6) Productivity is improved and losses in coordinated motion between fore and following beams are reduced using Hitachi’s original adjustable Y axis position on PCB that works on any size board.

(7) New optimization software has been developed based on a high accuracy simulator engine and multiple optimum algorithm that equalizes the time between stages in the equipment and equalizes the motion time of the various beams to minimize the fab time.

Faster Throughput of 95,000 Chips per Hour

Fast accurate direct drive head

The direct drive heads shown in Fig. 5 adopt a rotary head configuration driven by an AC servo-motor and

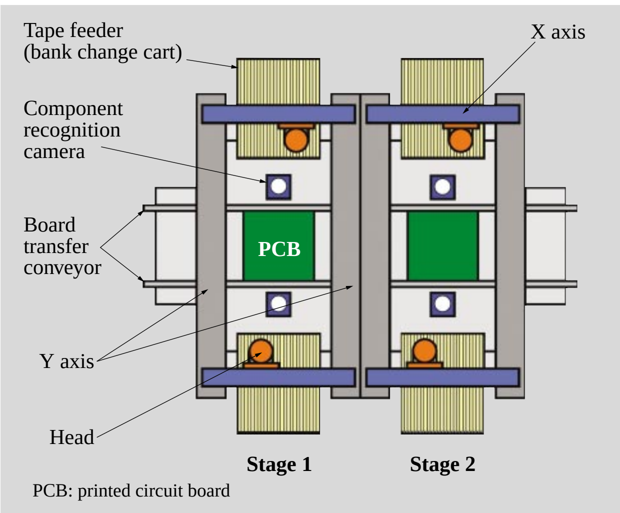

Fig. 4—GXH-3 Configuration.
Equipped with two stages, four beams, and four heads, the GXH-3 mounts parts on two boards simultaneously.

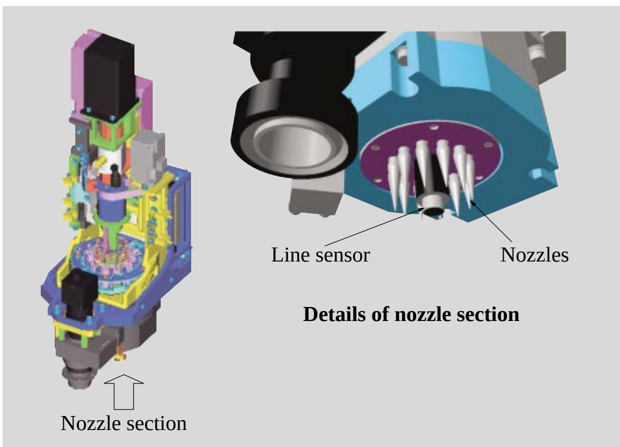

Fig. 5—Direct Drive Head.
Based on a unique Hitachi design, the direct drive head is fast and extremely accurate. Currently, work is continuing to improve the functionality, performance, and quality of the head. The revolution correction resolution is 0.0027°.

are equipped with 12 nozzles. Parts are rotated to their correct positions by the rotary heads, and accurately placed with little lost motion using this extremely simple configuration without timing belts or other transfer mechanisms.

To wring the maximum potential performance from the system, a near-real-time control system has been adopted for the motion and input/output control, and software-based synchronous control on the order of 1/1,000 of a second has been achieved. Considering the significant impact of the up and down motion of nozzles and rotating motion of the direct drive motor on the pick and place cycle, we did everything possible to make the motions overlap and reduce the time.

Vacuum value control during pick and place is exceedingly important to achieve precision handling of components at faster speeds. The GXH-3 supports optimum timing control over the pick and place cycle for all kinds of components with the vacuum valve moved closer to the nozzles in the rotor of the direct drive motor, and achieves very reliable placement of parts.

Rigid low vibration frame

The GXH-3 places 95,000 chips per hour, for one of the best throughputs in the industry. More than anything else, it is the GXH-3's frame structure that enables the mounter to reach its full potential speed performance.

As a leader in analysis-driven design, Hitachi conducted extensive CAE (computer-aided engineering) stress and vibration analysis as illustrated in Fig. 6 when designing the GXH-3 equipment frame. Note that if the frame is made too rigid, then stress is concentrated on certain elements — especially the linear guides — and this could actually reduce the life of the system. This led us to adopt a unique high-strength design approach that succeeds in distributing strain that would otherwise be concentrated in certain regions. Also, based on the results of our frame vibration analysis, we devised a scheme that feeds back information to a filtering mechanism for controlling the natural frequency of the equipment, and this greatly reduces the vibration of the mounter.

Dual linear drives on Y-axis beam

Dual linear drives were adopted to drive the Y-axis on the X-axis beam to distribute stress from the X-axis beam to the frame and also to promote better stabilization. The Y-axis linear motor delivers very fast movement of 2 m/s, and markedly reduces dead time not contributing to pick and place. A resist structure that does not need an escape mechanism was adopted to immobilize the beam, and the inter-axis correction control by both-side linear motors shown in Fig. 7 was incorporated to improve synchronization between the two Y axes. This works very well, as one can see in Fig. 8. The maximum deviation between the axes when operating at the maximum speed of 2 m/s is less than 0.03 mm.

Non-stop Gang Fly Recognition

Images are captured by strobe illumination from an xenon lamp without stopping the heads, thus enabling gang fly recognition of 12 components

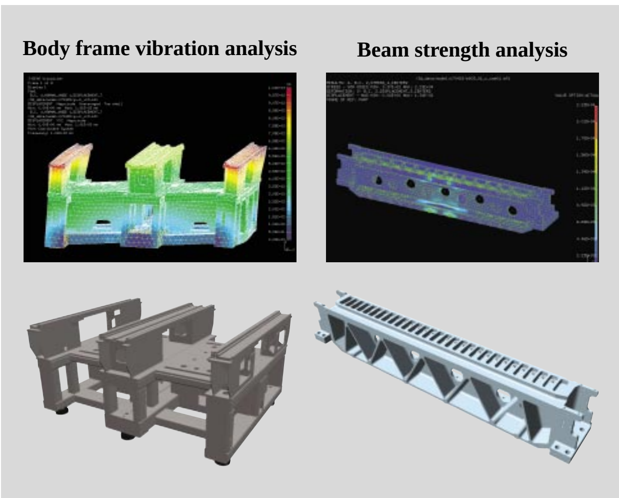

Fig. 6—Examples of CAE Analysis Results.
Optimized design of characteristic values and strength is achieved through CAE (computer-aided engineering) analysis.

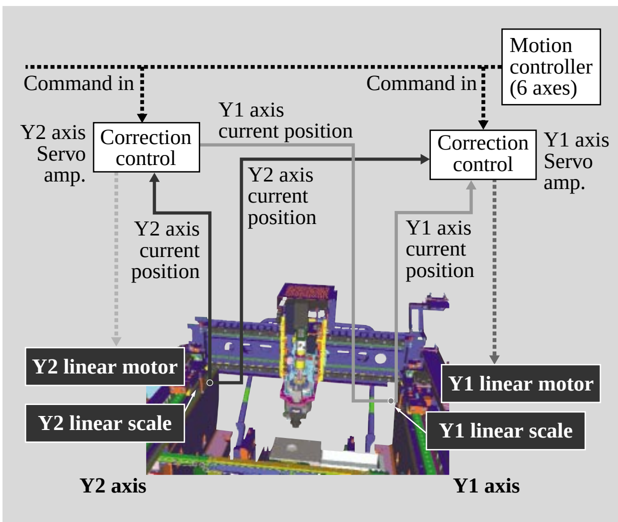

Fig. 7—Inter-axis Correction Control by Both-side Linear Motors.
Respective positions of Y1 and Y2 axes are monitored and synchronized with each other.

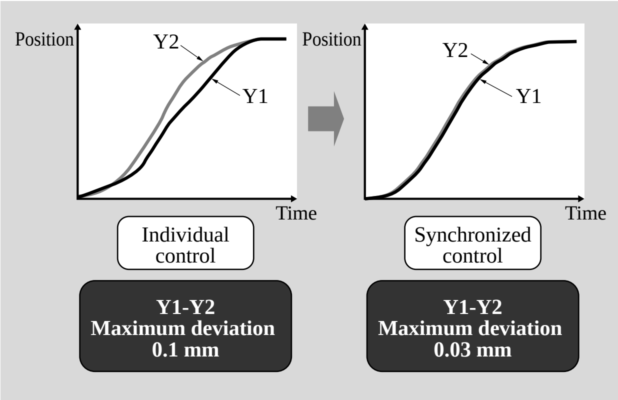

Fig. 8—Results Using Inter-axis Correction Control by Both-side Linear Motors.
The inter-axis correction reduces the maximum deviation between Y1 and Y2 axes to less than 0.03 mm.

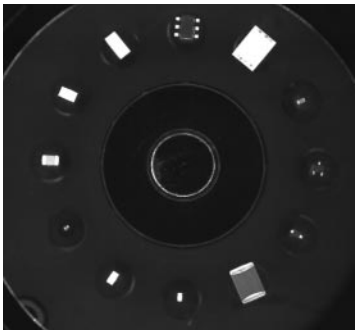

Fig. 9—Example of Component Recognition Imaging.
Supporting gang fly recognition of 12 components simultaneously, image processing takes approximately 5 ms per chip.

simultaneously (a typical image is shown in Fig. 9) while maintaining the maximum speed of 2 m/s. Image processing (determining whether a chip is present and its shape, and calculating X, Y, and θ positions) takes approximately 5 ms per square chip, thus resulting in a system that generates zero wait time in the square chip placement sequence. Component images are taken by cameras used for board recognition that are mounted on each head, and at the same time, images of reference marks on the component recognition scope side are also captured. Using these marks to correct any misalignment due to the movement of the beams, the GHX-3 achieves excellent accuracy of ±0.005 mm and repeatability for high-speed placement.

High-density Mounting of Small Electrical Parts

Current 01005 and 0201 microchips are very small and their impact resistance is limited, so a particular concern in assessing placement quality is defective and fractured chips. When defects can be attributed to the placement equipment, it is usually because the part does not reach the upper surface of the printed solder paste or because not enough placement force has been applied. Fractures, on the other hand, occur when too much placement force is applied in pressing the part into the solder. In other words, too much placement force results in a fracture and too little placement force results in a defect. It is essential to control the pick and board height (the component placement force on the surface of the board) to prevent these problems to ensure reliable placement and quality. The challenge is compounded because the dimensions of components vary from lot to lot and for vendor to vendor even for the same sized part, and board height also varies due to warpage. We succeeded in developing sensitive adaptive height control for measuring and accommodating these variations. The GXH-3 implements the following three capabilities to deal with these height-related problems.

(1) Board warpage (height to the top of the board) is measured and feedback results used to set the placement height.
(2) Thickness of the picked component (height to the bottom surface of the component) is measured and feedback results used to set the placement height.
(3) Impact force is restrained during pick and place.

Board height feedback

A laser displacement gauge mounted on component mounting head measures the board height where the part is to be placed prior to placement, and the feedback results are used to set the placement height. This measured value is used to control the downward lower limit during placement of the component, to ensure accurate and reliable placement that is adjusted to board warpage as depicted in Fig. 10.

Feedback on height to bottom of component

A line sensor mounted on the component mounting head measures the height to the bottom surface of the component. This measured value is used to control the downward lower limit during placement of the

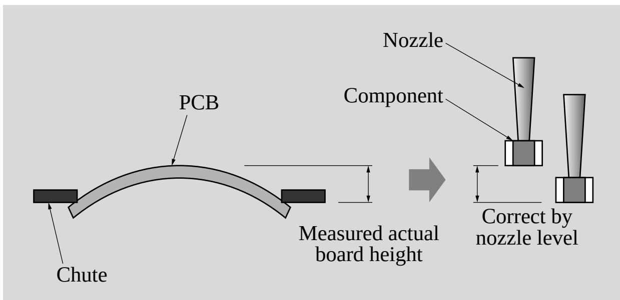

Fig. 10—Board Height Feedback.
Placement height is determined adapted to board warpage.

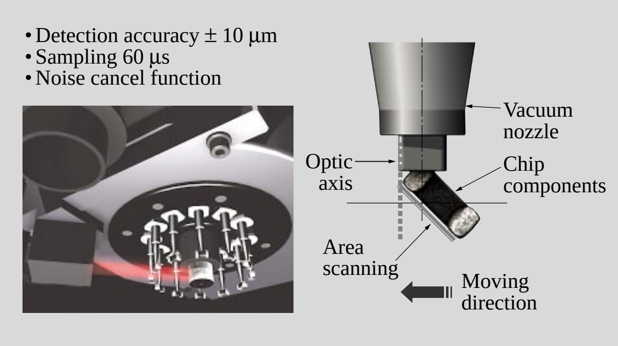

Fig. 11—Height to Bottom Surface of the Part Feedback.
Checks the presence of components, inspects components, and discards defective parts. Also measures the height to the bottom surface of normal parts, and provides the information as feedback to determine the placement height.

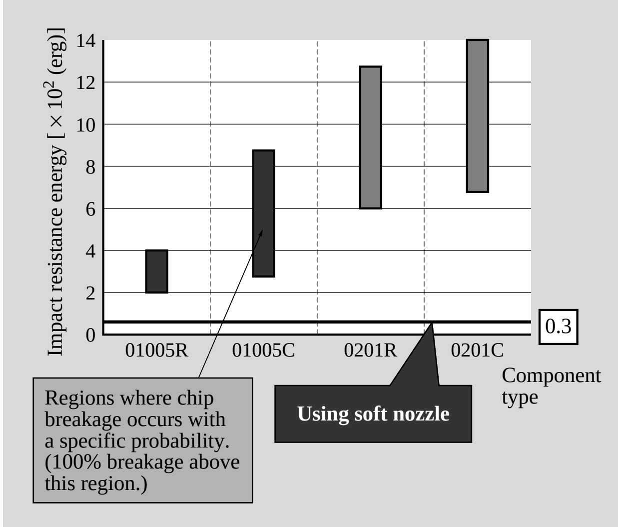

Fig. 12—Small Electrical Parts Brakeage Regions.
Even for 01005R (0.4 mm × 0.2 mm resistor) parts with the smallest impact resistance energy, the impact force is cushioned by the soft mounting nozzle.

component and properly set the mounting level to ensure accurate and reliable placement as shown in Fig. 11.

Soft mounting nozzle

When performing high-speed pick and place operations, the impact force is cushioned by the soft mounting nozzle featuring a spring mechanism at the tip of the nozzle which prevents defective or fractured parts. At the same time, enough placement force is applied so the problem of parts being carried away does not occur (see Fig. 12).

Software Contributions to Better Productivity

Gains in productivity come not only from improvements in hardware productivity, but software also has a critically important role to play. As an aid to start up production in the least amount of time, a number of NPI (new product introduction) tools have been developed and made available including a CAD (computer aided design) conversion, offline library instruction, and offline placement coordinate instruction systems. Productivity enhancement also comes from multi-product line balance and optimization software that saves valuable production time and reduces setup time.

All sorts of conditions had to be taken into account in developing the optimization software — various types and sizes of components, the nozzles being used, potential interference between opposing heads, and so on — to determine the optimum arrangement of component pickup nozzles, arrangement of part in the component feeding section, the part pick and place sequence, the Y-axis board position, and the production sequence.

Just looking at the mounting sequence, a grouping of mounting point factorials exists, and creating optimum data is exceedingly difficult. Working on an algorithm in collaboration with Hitachi, Ltd.'s Production Engineering Research Laboratory, we built on a number of existing tools including the approximate method, the greedy method, and local search to develop a unique algorithm (that applies the meta heuristic method) that finds the optimum solution among a host of variables in the least time (see Fig. 13).

Productivity for a production line consisting of multiple units of equipment is determined by the number of boards produced in a unit of time, so even if the production time for a single unit is speeded up, the productivity of the line as a whole is determined by the production time of the slowest piece of equipment. In this kind of environment, the multi-product line balance software balances production time between equipment units, thus making it possible to create optimum production data for the entire line. Moreover, by entering data not just for a single product but for multiple products, the best placement of parts, nozzle set sharing, and production sequence can also be optimized so as to minimize the changeover time.

APPLICATION EXAMPLE

Based on actual measured productivity results for the GXH-3 and assuming a single unit operating at the maximum throughput of 95,000 chips per hour

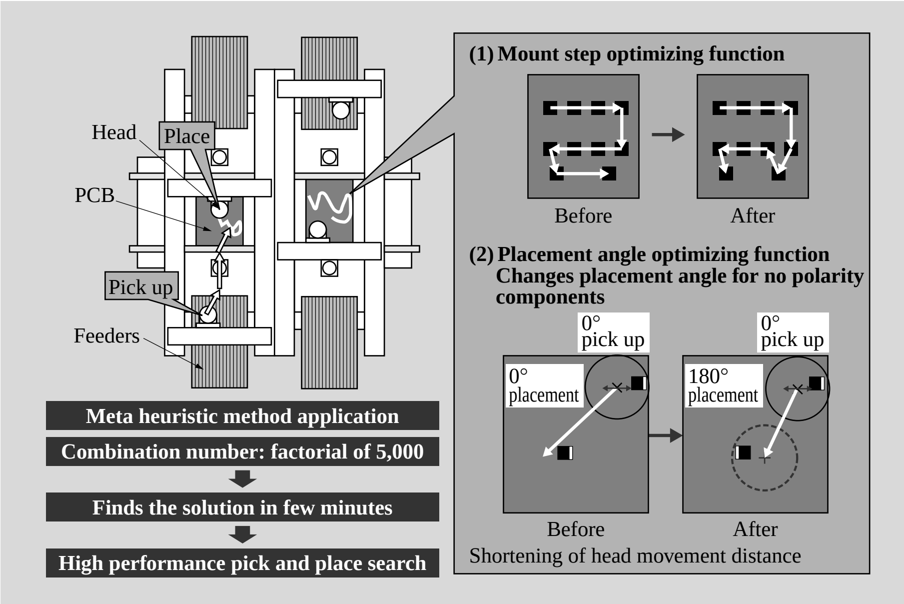

Fig. 13—Optimization Algorithm.
Applying the meta heuristic method, optimum solutions are obtained in the least time and high performance pick and place sequence searches can be performed.

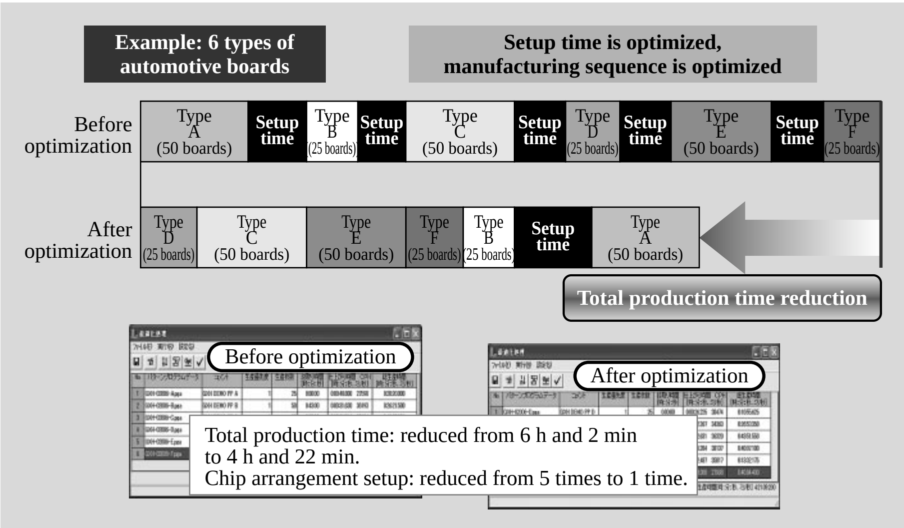

Fig. 14—Improved Productivity with the Multi-product Line Balance Software.
This shows an example where the number of setup has been reduced from 5 to 1, and total production time including setup has been reduced by 30%.

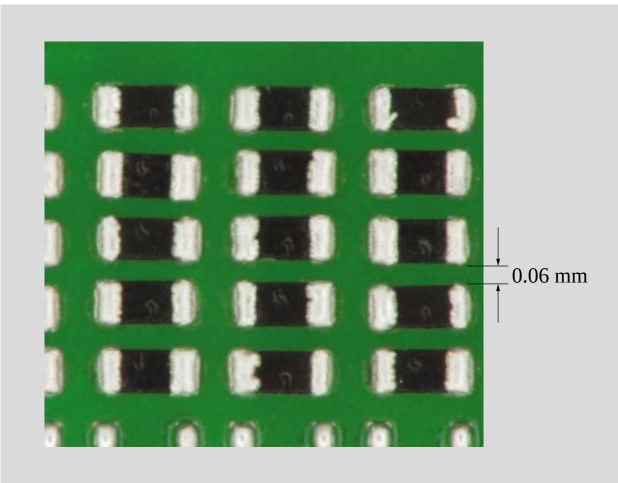

Fig. 15—Example of 01005R Placement after Reflow.
The chip is placed with 0.06 mm gap in the Y direction.

(representing a 20% improvement over previous mounters), we would expect to see a 10% improvement on mobile phone manufacturing lines, an 8% improvement on flat-screen TV lines, a 12% improvement on modular board lines, and a 9% improvement in throughput on digital vehicle equipment lines.

Moreover, taking the manufacture of digital automotive equipment as an example, we estimate that by utilizing the multi-product line balance software, the number of line setups can be greatly reduced, for a gain of close to 30% in productivity (see Fig. 14).

Preliminary findings suggest that the high-density mounting technology incorporated in the GXH-3 could also be applied to picking and placing 01005 components with a gap requirement of 0.06 mm (see Fig. 15).

CONCLUSIONS

This paper provided an overview of Hitachi's latest modular direct drive mounter GXH-3 that supports excellent productivity and high-density mounting of electronic components.

In pursuit of even better productivity and quality, we are now working on a number of capabilities that may be incorporated in future placement systems including equipment self diagnosis and self restoration capabilities, realtime monitoring of the operating status and stable operation of equipment, and preventative maintenance systems that provide quality-related feedback.

While the manufacturing of printed circuit boards presents challenges to the preparation of social infrastructure due to the reduction in placement costs, we will witness major shifts in production areas starting with mobile phones and digital automotive devices in China and quickly spreading to the other so-called BRIC countries (Brazil, Russia, India, and China), and even to the next tier of VISTA countries (Vietnam, Indonesia, South Africa, Turkey, and Argentina) while observing balance between manufacturing costs and distribution costs. Hitachi is committed not only to upgrading and improving equipment performance, but also to address service structure and operability requirements tailored to the culture, quality of workforce, and environment of different regions around the world. By focusing on insightful marketing and product development that rapidly addresses evolving modes of productions, next-generation equipment requirements, and our customers' needs, Hitachi High-Tech Instruments Co., Ltd.'s goal is to offer the best and most productive solutions available.

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ABOUT THE AUTHORS

Hideaki Fukushima

Joined Hitachi High-Tech Instruments Co., Ltd. in 2003, and now works at the Chip Mounter Design Department, the Design Division. He is currently engaged in the development of modular mounters.

Yoshinao Usui

Joined Hitachi High-Tech Instruments Co., Ltd. in 2003, and now works at the Mechanical Development Group, the Chip Mounter Development Department, the Design Division. He is currently engaged in the development of mechanical parts of modular mounters.

Ikuo Takemura

Joined Hitachi High-Tech Instruments Co., Ltd. in 2003, and now works at the Control System Development Group, the Chip Mounter Development Department, the Design Division. He is currently engaged in the development of electrical parts of modular mounters.

Shigeo Katsuta

Joined Hitachi High-Tech Instruments Co., Ltd. in 2003, and now works at the Application Software Development Group, the Chip Mounter Development Department, the Design Division. He is currently engaged in the development of application software of modular mounters.