Automation of Visual Inspection with Measurement and Image Processing Technologies

Customers are increasingly demanding product quality not only from a functional aspect but also from a visual aspect, including flawless, beautiful surfaces. To ensure quality, we are conducting a full inspection through a visual check by operators. To achieve more stable quality and deskilling, we are working to develop inspection automation technologies by combining photographing technologies using high-resolution cameras and robots, image processing and artificial intelligence (AI), and other technologies.

Introduction

Customers are increasingly demanding product quality not only from a functional aspect but also from a visual aspect, including flawless, beautiful surfaces. A common practice to ensure quality of appearance is to conduct a full inspection of products through a visual check.

1 Background

Our company, like others, has many visual inspection processes. We check the statuses of attached parts and check the appearance and surfaces of welded sections for any foreign substances, contamination, scratches, deformation, or cracks. Some of these can be judged clearly by visual inspection, while others are judged based on a sensory evaluation according to the perception and experience of the operator making the judgment, which means that such judgments are variable and cannot be quantified. In addition, since the inspection work imposes a high burden because it requires a high level of concentration and stresses operators' eyes, some hard-to-judge objects can only be judged by highly skilled operators.

2 Development plan

To eliminate such variance in judgment based on sensory evaluation and high-burden work as well as to ensure stable quality, automation of human-dependent inspection has arisen as a common need at a variety of our products' manufacturing sites.

Among our products, motorcycles, which are required to have not only advanced functions but also to look beautiful, are often inspected visually by human resources in mass-production processes, including those performed overseas. Therefore, we have decided to start by establishing an inspection automation technology for motorcycles and then are advancing development to gradually expand its use throughout the company.

Among the visual inspections for motorcycles, we consider the three inspections shown in **Fig. 1** (① assembly inspection, ② weld bead inspection, and ③ appearance inspection for scratches) to be needs in common with those of our other products (e.g., jet engines, hydraulic equipment, and railway carriages) [1]. All of these have many inspected objects and inspection items, and moreover they must be performed in a very short amount of time in mass-production processes.

To address such challenges, we aim to achieve high-speed automated judgment by photographing and taking measurements using high-resolution cameras and 3D sensors as well as categorization or detection processing using advanced image processing and AI technologies. By accumulating the obtained data, we can also apply such technologies to traceability and process improvement.

3 Development status

(1) Visual inspection in the engine assembly process

(i) Background

A motorcycle engine is an important component

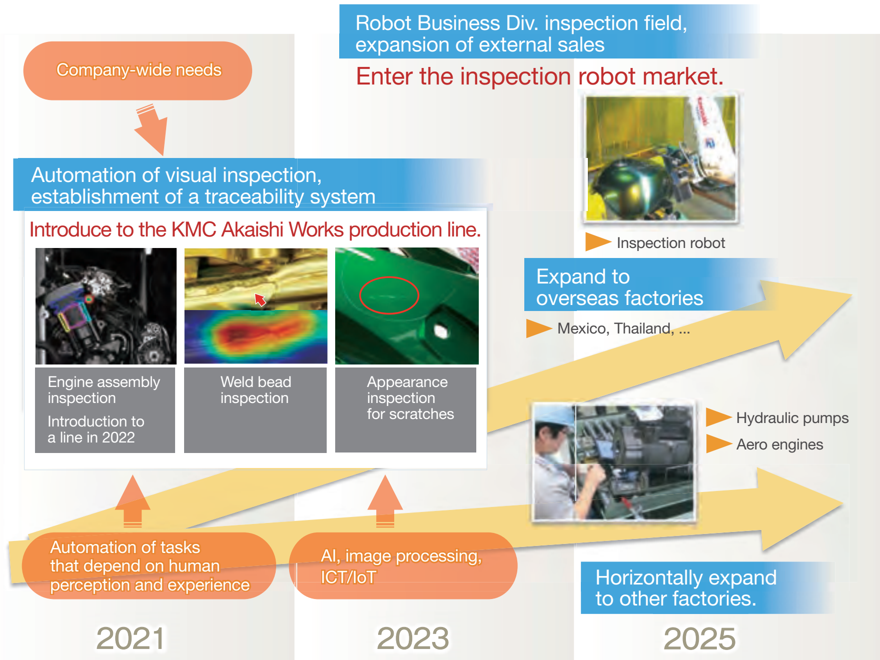


Fig. 1 Roadmap for automating visual inspection

involved in traveling. After assembly, special inspectors perform a full inspection of each engine. Over 100 types of inspection items such as the failure to attach parts, direction of attachment, attachment of incorrect parts, and degree of screw tightening are inspected visually or by direct manipulation with the hands per engine.

(ii) Response

Since 2020, we have considered the automation of 117 inspection items for the Z900RS engine and developed an appearance image photographing system using a camera and pass/fail judgment software that employs image processing. We completed development of the system and software during the first half of 2022 and began trial application to an on-site assembly line.

The appearance image photographing system is equipped with a high-resolution camera that photographs the top and side of the engine, illumination sources, and rotating machinery as shown in **Fig. 2**. Meanwhile, **Fig. 3** shows an example of judgment by image processing in which a pass/fail judgment is made by means of processing logic, such as the degree of matching and color identification according to preregistered part shapes. This has enabled speedy, accurate judgment of various shapes and colors. Currently, 44 items can be inspected; these are processed by the camera's plane recognition. We will improve the performance evaluation and processes while comparing against the visual inspection results. We aim to expand its application to inspections of other models and assembled bodies.

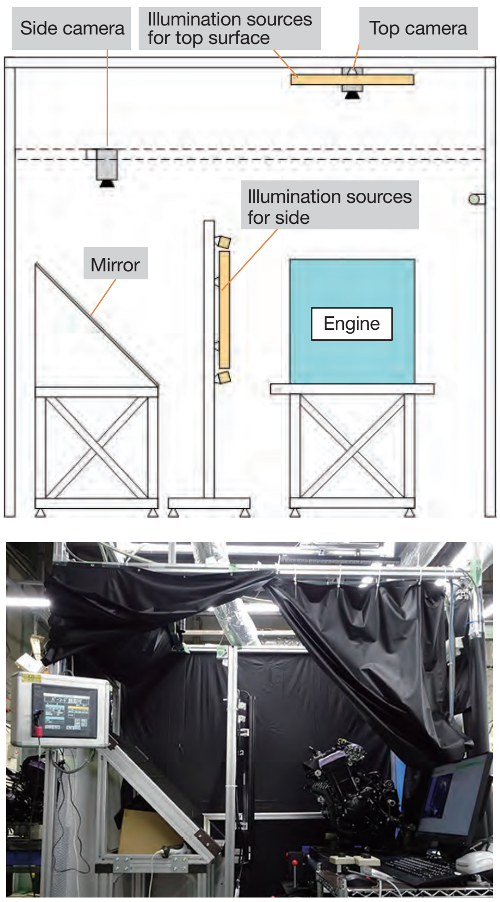
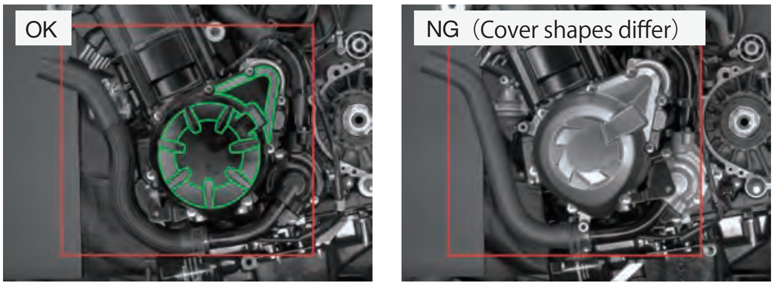
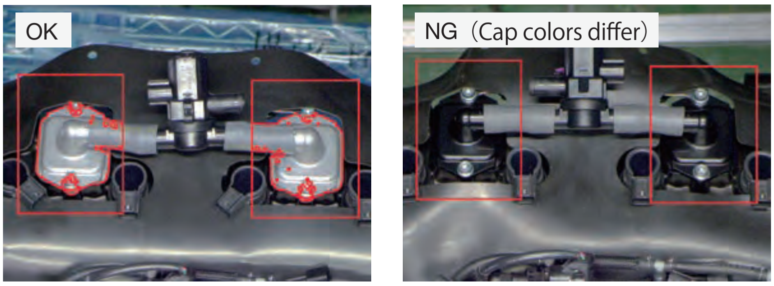


Fig. 2 Automated photographing system for engine appearance



(a) Example of judgment by part shape matching



(b) Example of judgment by color identification

Fig. 3 Inspection of engine assembly with image processing

(2) Bead appearance inspection of welded structure frames

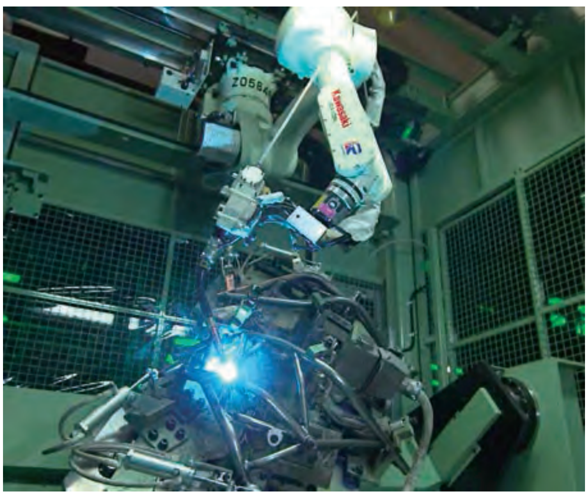
(i) Background

Motorcycle frames are manufactured by welding pipes and small parts such as brackets by the three-dimensional movement of a robot as shown in **Fig. 4**. Since the frame is an important part that functions as a bony structure of the body, welded parts must have sufficient strength and stiffness. Furthermore, in recent models, attractive frames have come to be associated with product design, which in some cases necessitates that the beads be beautiful.

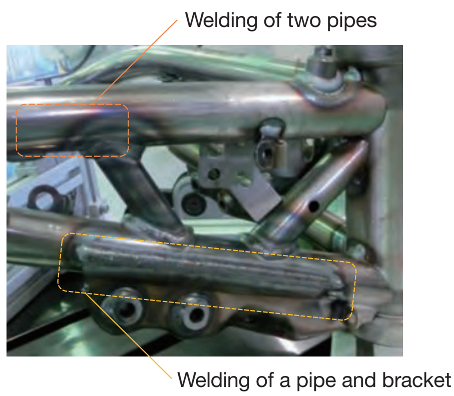
Each frame has over 100 welded sections. Even normal weld beads vary greatly depending on the combination of materials and surface status. Defects are judged instantly by visual inspection conducted by skilled inspectors at a predetermined cycle time. However, it has become difficult to secure inspectors, and thus automation is demanded.

(ii) Response

Welding defects errors vary widely. Some are relatively easy to judge (e.g., displaced beads and perforations), while others are minute and require skill to judge (e.g.,



(a) Robot welding of a frame structure



(b) Frame structure

Fig. 4 Frame structure of motorcycle and robot welding undercuts). In considering how to automate bead appearance inspections, we are working to achieve image judgment using AI because it is difficult to detect variation among beads and various other defects by rules-based image processing, which is used for engine assembly inspections and other inspections.

We have developed a system that automatically photographs a specific weld bead using multiple high-resolution cameras and illumination sources attached to a mount after robot welding. By accumulating images from mass production and using AI to calculate the abnormality level, we are working to achieve image judgment as shown in **Fig. 5**.

(3) Appearance inspection for scratches on fuel tanks and plastic cowls

(i) Background

Parts for motorcycles such as fuel tanks and plastic cowls are elaborate, and they are fully inspected visually for scratches, dents, and other blemishes by operators under special illumination sources conditions. Because such defects are very small and their locations on a large workpiece cannot be predicted, only skilled inspectors can find them. In addition, since part surfaces are complicated and feature curves, they must be inspected by examining the extent of light reflections from various angles, which makes automation extremely difficult.

(ii) Response

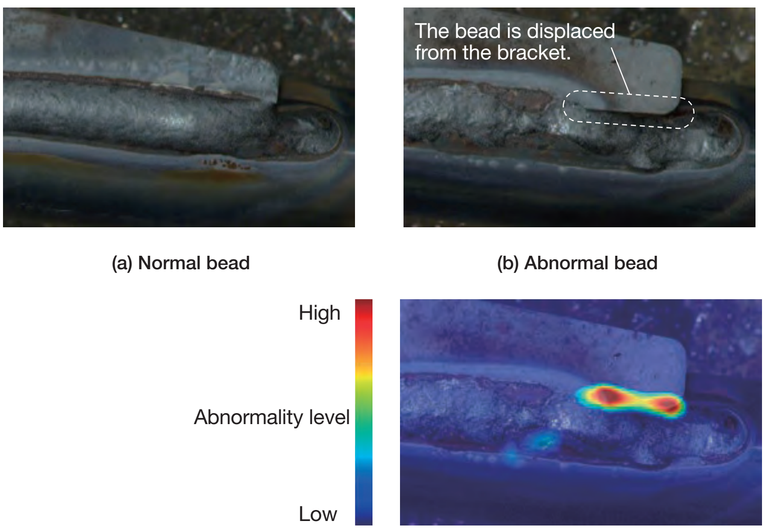
To photograph a surface thoroughly such that defects can be clearly seen, it is necessary to keep constant the angles of the camera, illumination sources, and inspected workpiece surface so that light always reflects under the same conditions. Because the inspection targets are fuel tanks and plastic cowls that have curved, complicated surfaces, we decided to use a scanning photography method that employs a line scan camera, which obtains images of one line only. A photographing system that combines a line scan camera with an illumination source is held by a robot in order to continuously scan and photograph the object such that the distance from the surface and its angle are always constant. Judgment is made by processing such images.

Technologies that employ a line scan camera and photograph the surface conditions by moving a photographing system or targeted workpiece already exist. However, it has been difficult to apply these to inspections of parts having complicated shapes due to reasons such as being limited to linear operation or being limited to operating at a constant low speed.

(iii) Development of high-speed curve photographing technology

To solve such challenges, jointly with the Robot Business Division, we have developed a new technology for our robots, the tool tip movement output function, to realize high-speed photographing along complicated curves.

This tool tip movement output function enables the robot controller to automatically output a signal pulse for photographing according to the movement of the tool tip (line scan camera photographing position), which is attached to the robot arm, as shown in **Fig. 6**. A complicated scanning movement along the curves is generated using KCONG [2], which is offline teaching software for robots. As shown in **Fig. 7**, KCONG generates a movement path that places the line scan camera and illumination sources at appropriate positions



(a) Normal bead

(b) Abnormal bead

(c) Abnormality map calculated by AI

Fig. 5 Evaluation example of weld bead image by AI

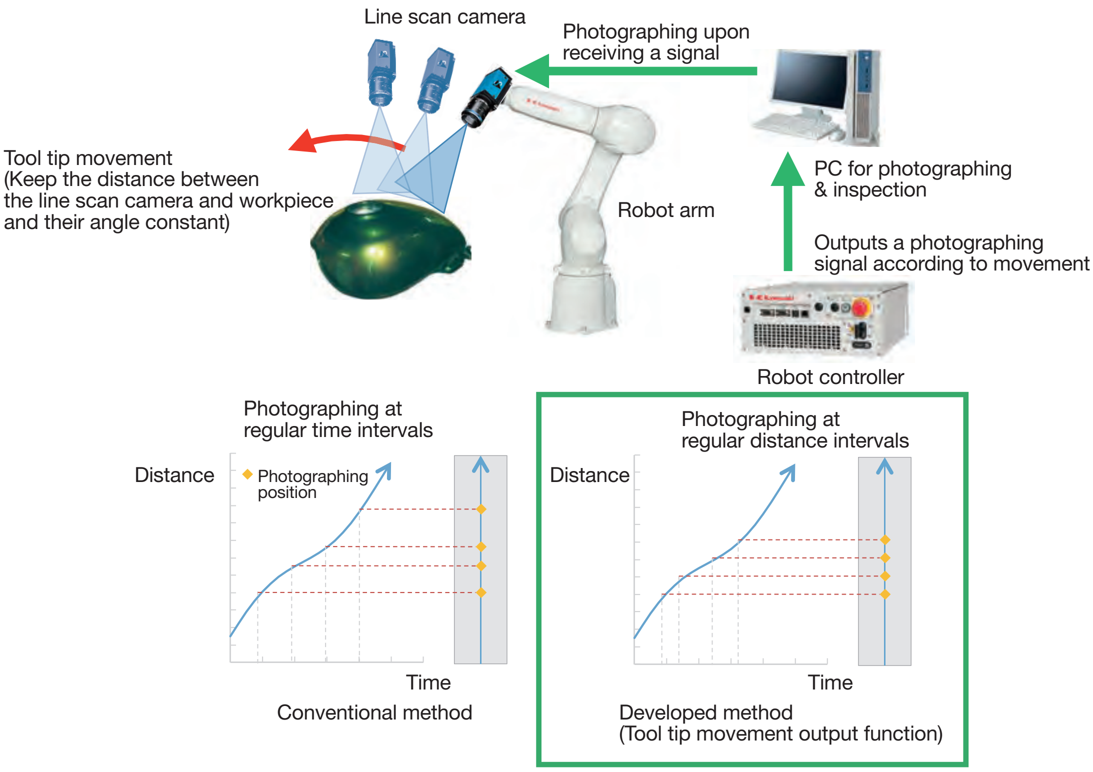


Fig. 6 Tool tip movement output function

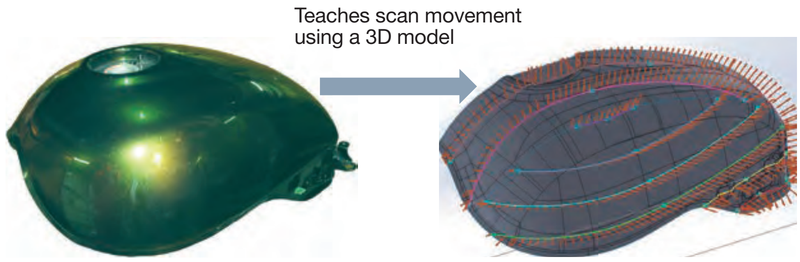


Fig. 7 Offline teaching of scanning points of fuel tank

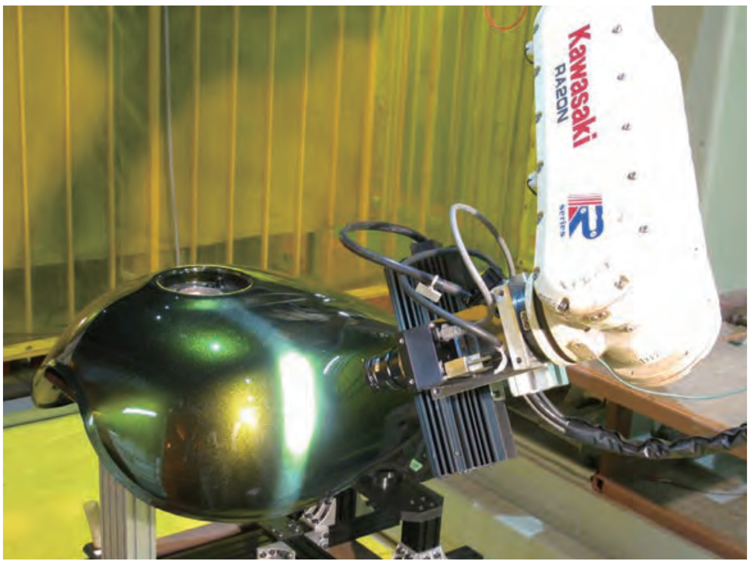
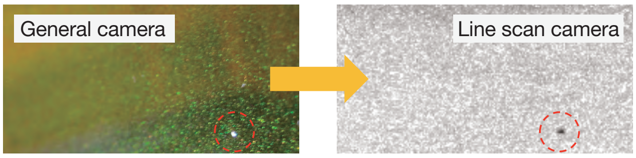
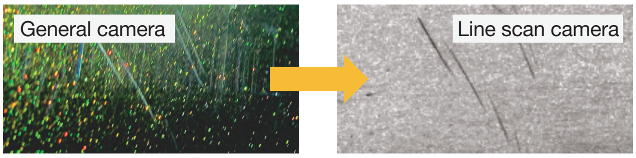


Fig. 8 Scanning of surface appearance with robot



(a) Results of photographing of a bump



(b) Results of photographing of line scratches

Fig. 9 Results of photographing of defects with line scan camera

in appropriate postures with respect to the fuel tank 3D model. In this way, highly accurate continuous photographing of a complicated workpiece can be realized at high speed.

Fig. 8 shows continuous photographing of a curved surface using a robot, while **Fig. 9** shows images of photographed defects. If a glossy fuel tank with a complicated shape is photographed using a general camera, part of the photographed image develops blurs, and the surface gloss affects the image as shown in the left photo in **Fig. 9**. However, by using a line camera to scan along the curve, we succeeded in clearly photographing minute defects of approximately several hundred μm. Going forward, we will develop image processing that performs defect detection and validate it with various workpieces.

Conclusion

To respond to the decrease in the number of skilled operators and to ensure stable quality, including that of products manufactured overseas, we are developing inspection automation technologies using state-of-the-art cameras, sensors, image processing, and AI technologies. We are first establishing such technologies for motorcycles and putting them into practical use. We will expand their use to domestic factories and then overseas factories as well as expand their applications horizontally to our various products. We will actively apply inspections using new robot technologies to our own factories as well as externally.

References

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Yuki Hanawa
Automation System Department,
System Technology Development Center,
Corporate Technology Division


Kazunori Hara
Automation System Department,
System Technology Development Center,
Corporate Technology Division


Michitaka Maegawa
Automation System Department,
System Technology Development Center,
Corporate Technology Division


Tomoaki Kawa
Automation System Department,
System Technology Development Center,
Corporate Technology Division


Takashi Mitsui
Production Engineering Department,
Production Division,
Kawasaki Motors, Ltd.


Yuki Hosomi
Production Engineering Department,
Production Division,
Kawasaki Motors, Ltd.


Professional Engineer (Mechanical Engineering)
Satoru Yamasumi
GI System Department,
General Industrial Robot Group,
Robot Business Division,
Precision Machinery & Robot Company