DEVELOPMENTS IN LASER SCANNING TECHNIQUES FOR INTELLIGENT MANUFACTURING SYSTEMS

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ABSTRACT

Computer-controlled automated inspection tasks are necessary in the development of intelligent manufacturing systems. The application of low power laser scanning techniques to automated assembly and tool condition monitoring tasks has been investigated with the aim of developing effective tool and process management systems integrated with the manufacturing process. As well as being more cost effective and reliable than human inspectors, automated inspection systems provide the technical feasibility and level of sophistication required for completely unattended operation for extended periods of time.

The laser scanning technique compares favourably with CCD vision systems. It has proved to be more suitable for higher component feed rates and requires considerably less signal processing power. It also has the advantage of being less susceptible to changes in ambient lighting conditions.

The current paper describes the development and application of laser scanners to automated assembly and to the inspection of tools for metal cutting. Both applications demonstrate the potential for such systems to provide a more reliable and cost effective alternative to human inspectors.

KEYWORDS

Laser, Inspection, Intelligent, Condition-monitoring, Cutting-tool, Cutting-insert.

INTRODUCTION

There are many tasks associated with manufacturing or assembly operations for which human labour is not ideally suited. Such tasks, often menial, are usually those requiring constant and consistent vigilance and place unreasonable demands on human operators. As a consequence, errors can and do occur. Routine visual inspection of manufactured parts for the presence of intended features such as holes, threads, chamfers and so on, or tools for the absence of defects are good examples. It is well-established that laser scanning of components can yield much useful data about their physical condition and the present paper describes how this technique has been developed and applied by workers at the University of Hull. Laser scanning has advantages over systems based on CCD imaging in terms of speed of operation, lower sensitivity to ambient lighting conditions and automatic acceptance or rejection of the inspected part without the necessity for involvement of a human operator.

Fig. 1 illustrates the principle layout of the laser scanning system. Essentially, the system exploits the fact that spectral reflectance from a rough surface, monitored by means of a suitable optical system, can form the basis of a suitable device for detection of changes in profile of a component [1,2]. Whilst, in principle, any light source could be utilised, in practice, a low-powered laser is most suitable because it provides a coherent, single wavelength beam. The laser scanning technique involves the analysis of scattered light from moving components and the technology lends itself to a range of well-established signal processing techniques. The distinctive features of the laser scanning method lie in its capability to identify minor variations in components in terms of geometry, surface finish and colour. Individual scanning systems can be readily adapted to meet the requirements of particular automatic inspection tasks, as is illustrated by the following industrial applications.

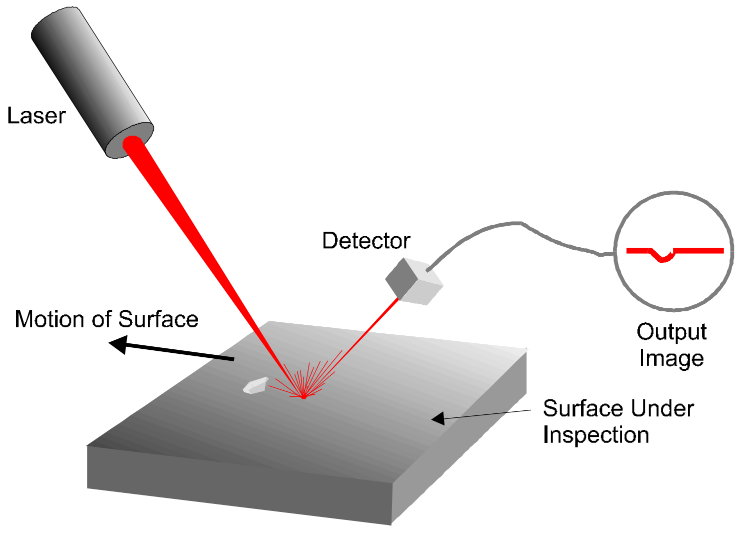

Fig. 1. Laser Scanner System

AUTOMATIC INSPECTION FOR QUALITY CONTROL

This application relates to a requirement to automatically inspect spark plug electrodes for surface defects. The electrodes in question were manufactured by cold forming a bi-metallic slug of copper and nickel alloys. Manufacturing variability problems typically resulted in tears in the nickel outer surface, although gross surface defects were also present. The components were produced in high volumes and it was necessary to consider means of high speed automatic inspection to perform the detection of defects. Fig. 2 contrasts the required quality standard with defective components, having surface tears and gross defects. Fig. 3 shows traces for the defective components resulting from longitudinal scans in a rotary workhead on an assembly machine. Both traces clearly show negative-going spikes relative to the base line average for components of acceptable quality.

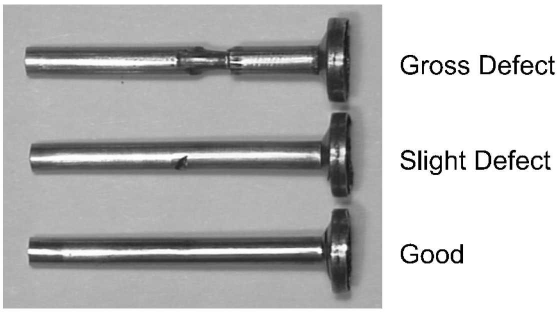

Fig. 2. Range of Electrodes: Good and Defective

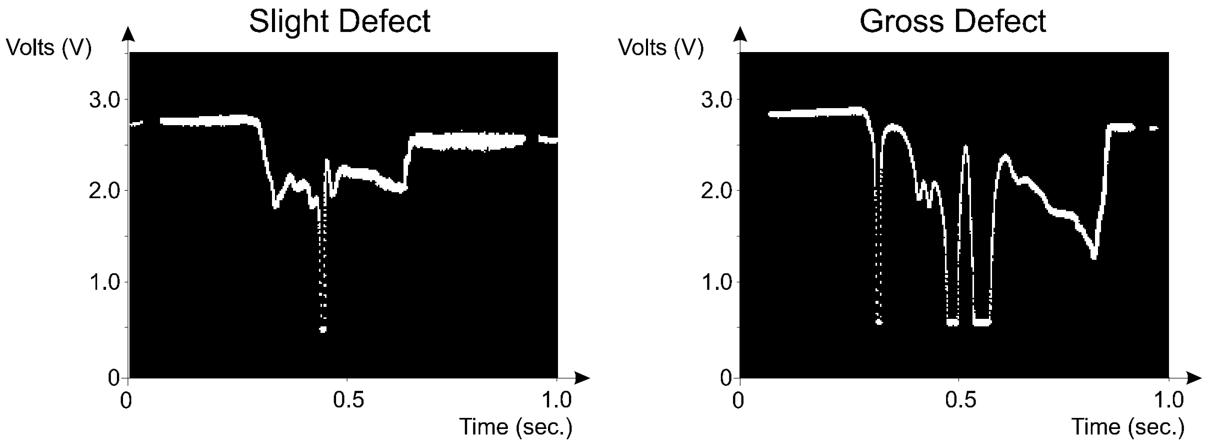

Fig. 3. Typical Traces Corresponding to Defective Electrodes

Fig. 4. Range of Components Successfully Orientated using Laser Scanning

Fig. 4 shows a range of metallic and non-metallic components that have been successfully orientated using the laser scanning technique. Several of these would not be amenable to manual orientation because of problems associated with reliably detecting the presence of features or discriminating between features. In every case, the laser scanning system proved to be capable of operating quicker and more reliably than human operators.

AUTOMATIC INSPECTION OF CUTTING TOOLS DURING MANUFACTURE

Indexable cutting tool inserts are widely used in manufacturing industry because of the obvious need for tool refurbishment. They are manufactured to high standards of dimensional accuracy and must be free from edge defects likely to adversely affect the quality of the machined workpiece. Inserts are typically produced by a powder metallurgy route involving sintering, grinding/polishing and coating. Whilst these processes can be largely automated there is still a requirement for human intervention to ensure that only those inserts free of defects proceed from one stage of manufacture to the next. Defects typically arise from handling of the inserts and the most commonly-occurring form is edge chipping, which can cause premature failure of the inserts in service. Such defects are usually in the range of 50-300 μm.

Automated systems based on low-powered laser diodes and single site photodetectors offer low cost, high speed insert inspection, with low laser-related hazards. However, such systems are strongly dependent on accurate manipulation of inserts with respect to the laser/detector to ensure the acquisition of valid data. Fig. 5 shows a prototype system capable of inspecting a representative range of insert geometry.

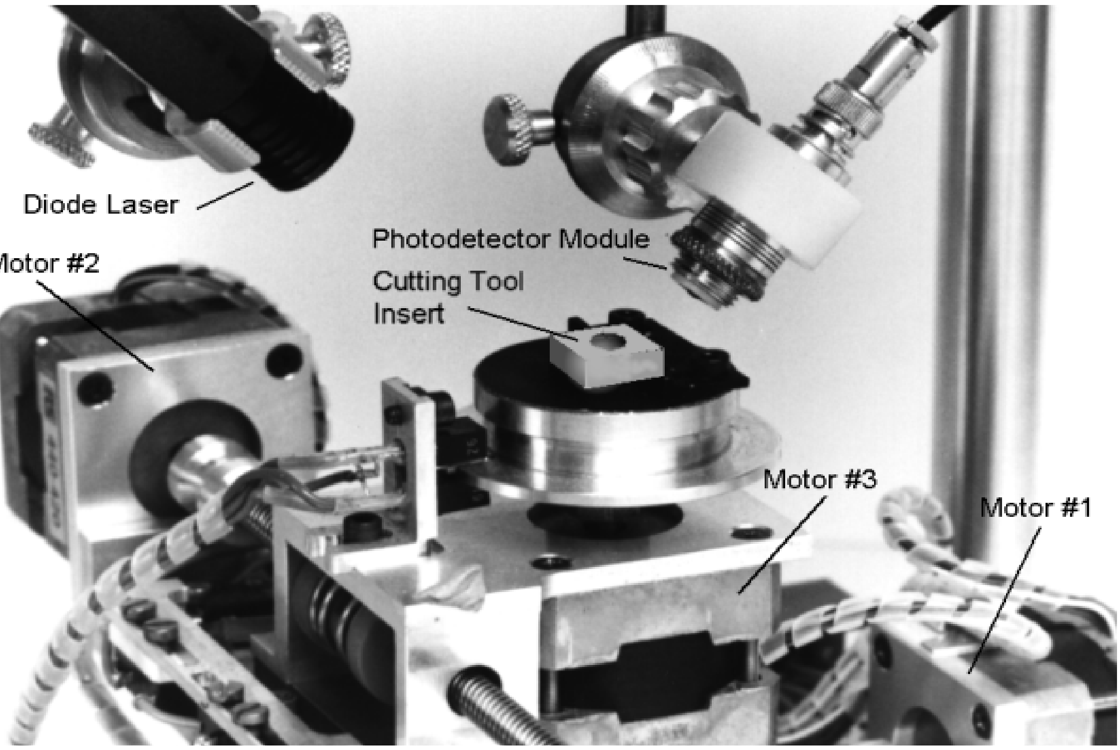

Fig. 5. Scanning Apparatus for Cutting Tool Inserts

Inspection is obviously concentrated on the functional edges of the inserts. The laser diode and photodetector are held at predefined angles and manipulated by means of a computer-controlled (X,Y,θ) platform. The beam of the 1mW, 670nm (visible red) laser diode is focused onto a reference point ahead of the edge to be scanned. A move sequence, related to the insert geometry, is then initiated such that each edge of the insert is scanned and the reflected signal stored. Analogue signals from the photodetector are amplified to give voltages in the range 0-10V and subsequently digitised and analysed by computer.

Fig. 6 shows the scanning system output for the edge of an insert exhibiting chipping defects. Post processing is employed to enhance the signal data obtained from scanning the edges. A series of averaging functions followed by linear interpolation reduces signal noise and flattens the trace to enable automatic interrogation of the data. The scanner compares each new trace with a predefined master trace, set within control limits. Fig. 6 shows the control limits, together with the master trace, superimposed onto the response signal from a particular ISO insert. The cutting edge is split into specific tolerance zones, as indicated on the output trace. Irregularities exceeding the control limits represent defects whose length can be measured from the trace. In this example, the allowable limit for a single chip or multiple chippings within zone III is < 0.6mm, therefore, the cutting tool is within acceptable limits.

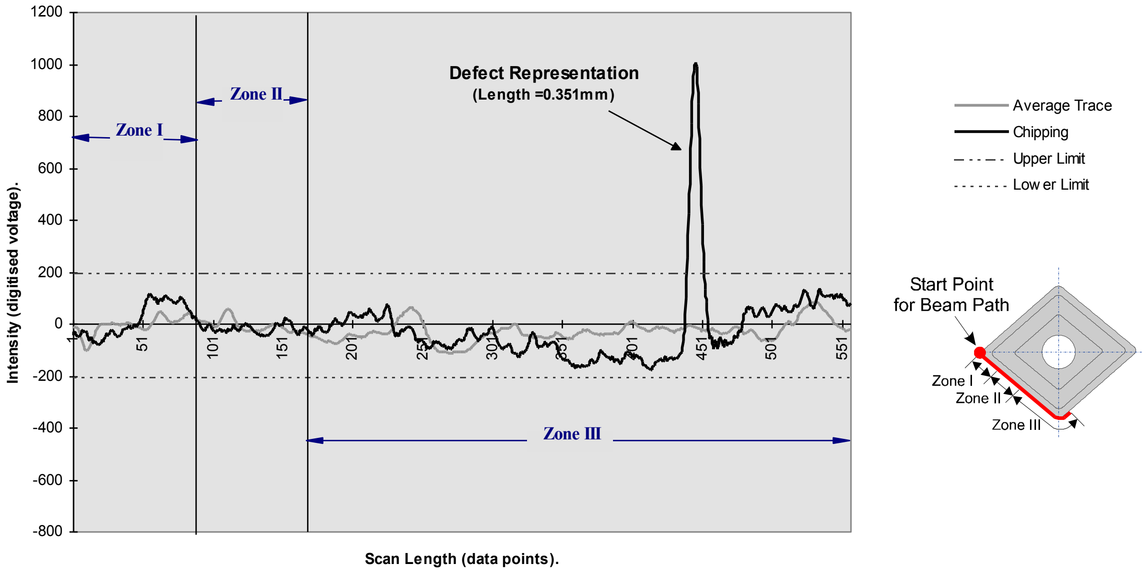

Fig. 6. Trace Highlighting a Chip Type Defect on a Rhombic Cutting Tool Insert

IN-SERVICE INSPECTION OF CUTTING TOOLS

The rapid increase in manufacturing automation by the application of CNC machine tools has placed a heavy demand on cutting tools. With fewer direct operators employed, automatic systems are required to ensure that not only are the correct tools selected for particular operations but also that they are in a suitable condition. Failure to do so will result in disruptive rework or scrapped components.

Laser scanning provides a good basis for cutting tool inspection systems [3] that are based in a toolroom or, more usefully, integrated with a CNC machine tool. Fig. 7 & Fig. 8 show a demonstration system designed to operate in conjunction with the automatic tool changer of a small CNC machining centre. The tool changer has been modified to allow tools to be transferred, in their tapered holders, into an inspection station. The four-axis laser/detector system is driven by computer-controlled stepper motors along the cutting edges of the tool according to a pre-defined program or ‘move template’.

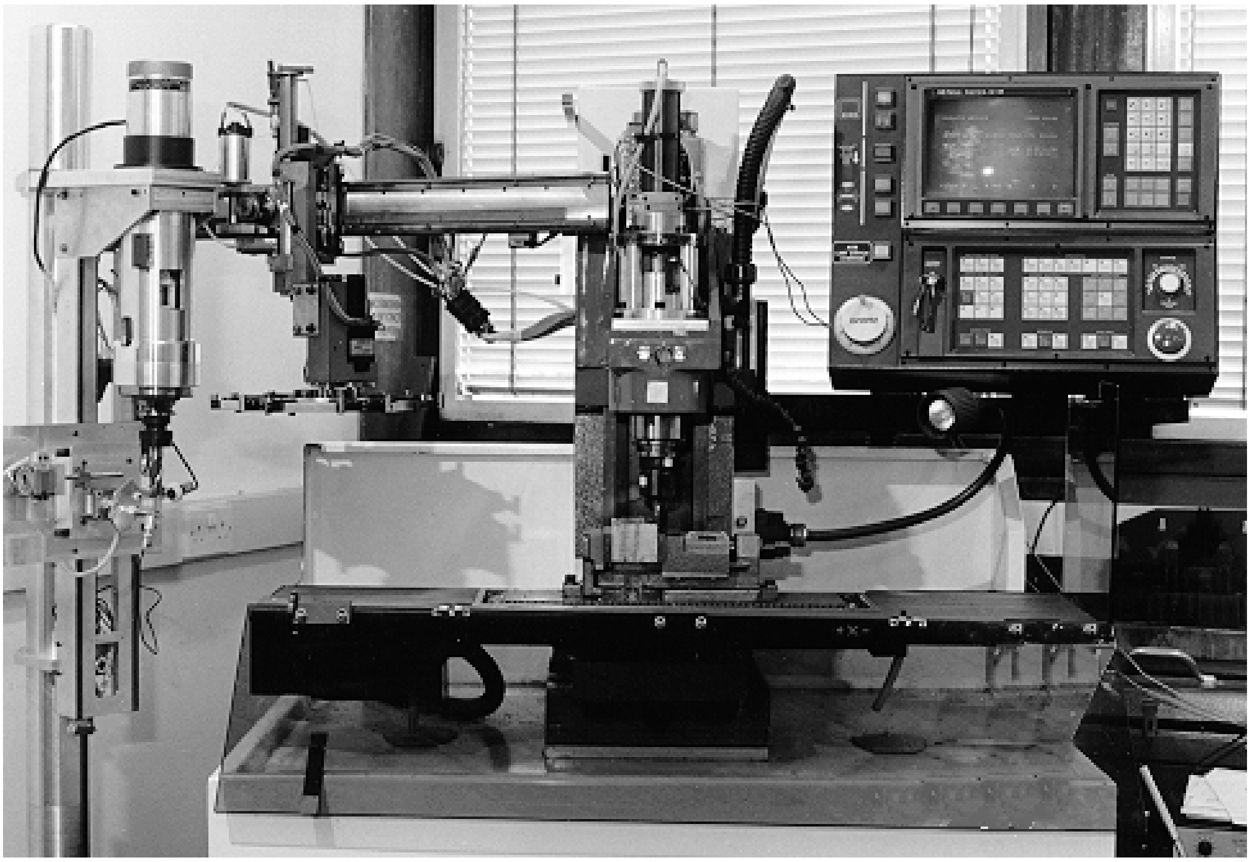

Fig. 7. Integration of the Laser Inspection Apparatus with a CNC Machine Tool

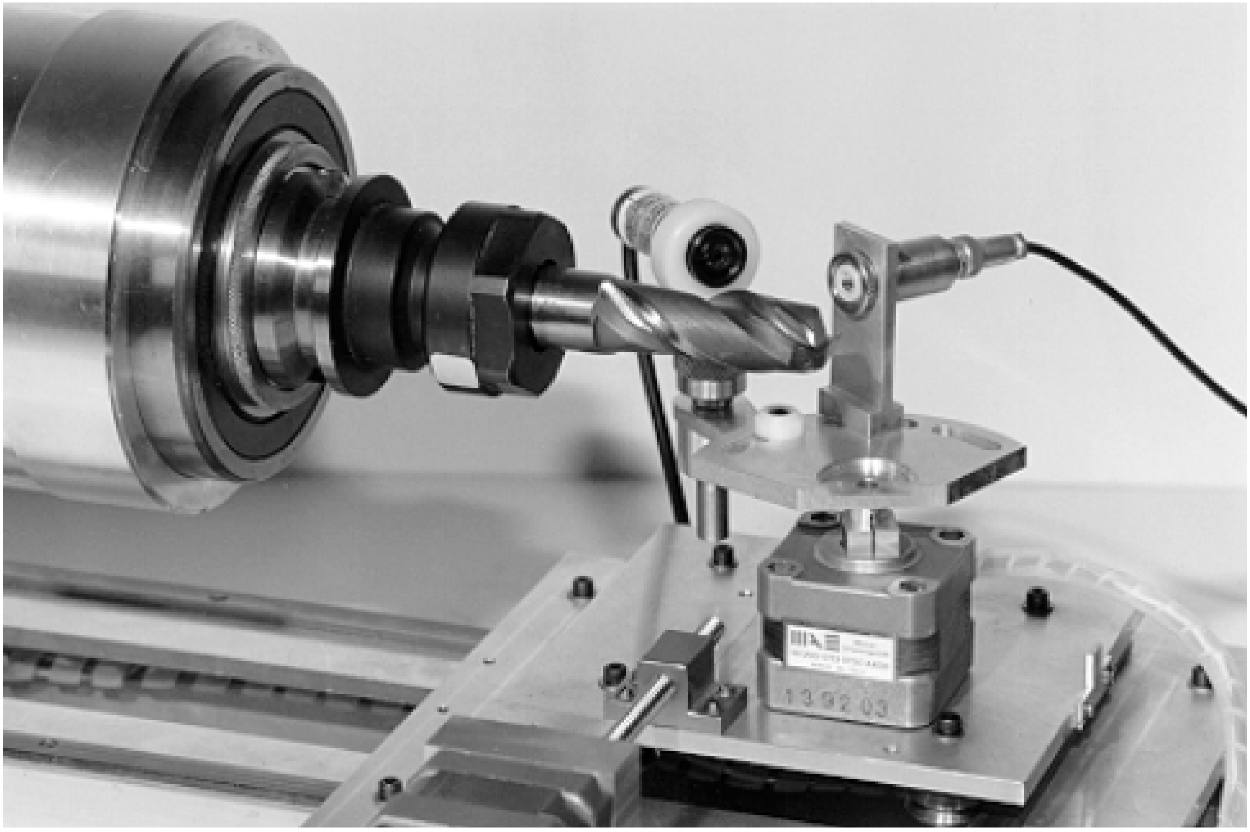

Fig. 8. Close-up of the Scanning Head

As with the previously-described system for tool inserts, the scans are compared with a master trace and the degree of severity of any edge defects assessed in terms of their likely effect upon workpiece surface condition. The tool database in the memory of the Machine Control Unit (MCU) can be updated to register that a tool is defective and unfit for further use (Fig. 9). Selection of such tools would be inhibited and 'sister' tools selected instead, subject to availability.

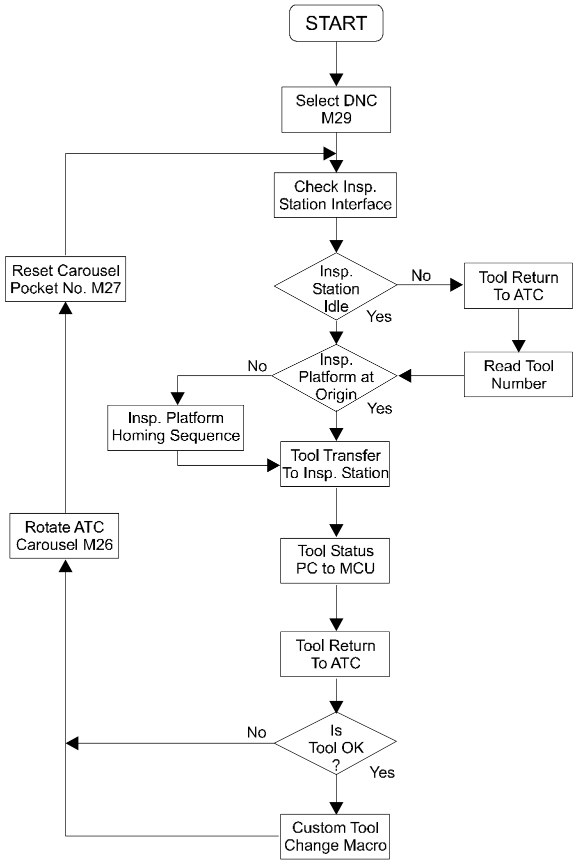

Fig. 9. Flow Chart for Custom Numerical Control Command

The principles demonstrated can be readily applied to full-size machining centres with local access to several hundred tools. The scanning time for a single tool is typically 1 - 2 minutes but tools can be scanned in a variable sequence designed to ensure that they will have been inspected well in advance of their requirement for a machining operation.

CONCLUSIONS

Laser scanning provides a powerful tool for use in automatic feature recognition and inspection systems. It is already used, with considerable success, in some industrial applications, primarily those associated with component orientation, but its potential for reliably detecting defects remains largely untapped. There is clearly a need for more intelligent signal processing procedures to enable an automatic inspection system to consistently discriminate between acceptable and unacceptable defects. The solution to this particular problem almost certainly lies in the application of fuzzy logic techniques [4] at the signal comparison stage and this aspect is being actively pursued. A further area of application, currently under investigation, is concerned with the use of the inspection technology to assist visually-handicapped production workers to perform tasks which would otherwise be too challenging or hazardous.

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