LASER SCANNING TECHNIQUES FOR DEFECT RECOGNITION ON CUTTING TOOLS

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ABSTRACT

Low-power laser scanning techniques provide a powerful tool for a diverse range of automatic inspection tasks. They are more suitable for high component feed rates, less sensitive to changes in ambient lighting and their output requires less processing power than CCD vision systems. In earlier papers [1,2], the authors have described typical automotive-related areas of application for laser scanning. The current paper describes recent work concerned with data capture and signal processing techniques necessary for fully automatic inspection systems with particular reference metal cutting machine tools.

INTRODUCTION

It is widely acknowledged that many tasks associated with manufacturing or assembly operations are inappropriate for human labour. Unpleasant, physically-demanding, activities such as spot-welding and spray painting, are good examples of where automation has improved on human performance. Similarly, tasks requiring constant vigilance can place unreasonable demands on human operators and errors can and do occur. Routine visual inspection of manufactured parts for the presence of features such as holes, threads and chamfers or examination of cutting tools for defects are good examples. Laser scanning of components can yield much useful data about their physical condition and earlier papers [1,2] have described 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.

Figure 1 illustrates the fundamentals of the laser scanning system employed. 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 [3,4]. 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 (Figure 1) 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.

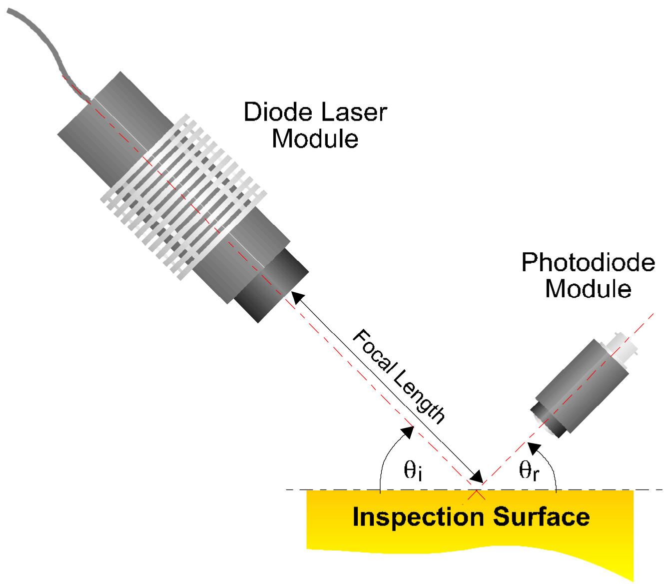

Figure 1: Laser Scattering Principles.

The present paper is primarily concerned with the capture and subsequent interpretation of signals generated by laser scanning and addresses these issues by reference to the development of automated defect detection in cutting tools.

DEFECT DETECTION IN CUTTING TOOLS

Metal cutting machine tools are key elements in many manufacturing systems but the nature and operation of such machines has changed dramatically in recent years with the widespread adoption of computer numerical control and the requirement for unattended operation. It is a simple matter to provide a CNC machine tool with a suitable part program for a particular workpiece and to provide access to cutting tools held in a local store. A problem arises, however, in seeking to ensure that these tools will remain in a suitable condition for cutting over extended periods. Human operators of machine tools always checked the condition of individual tools before use but this is no longer an option with unmanned enclosed systems. One proposed solution to this problem is the application of laser scanning systems to automatically inspect the edges of cutting tools for critical defects i.e. those likely to adversely affect the condition of the workpiece. Prototype systems, for integration with CNC machining centres, have been devised for end users of cutting tools and for the manufacturers of the cutting tools themselves.

INSERT CUTTING TOOL INSPECTION

Cutting tool inserts are now having increased importance in modern production technology, as they fulfil the demand for greater precision and shorter machining times. The requirement for flexible manufacturing of high quality products to be kept within very strict tolerances, calls for constant, accurate, quality control methods. Usually labour intensive, these inspection methods require highly skilled operators to perform repetitive and relatively uninteresting tasks. Consequently an alternative, reliable, in-process quality control inspection device is required for the detection of defects on cutting tools inserts during their manufacture.

The prototype laser inspection platform utilises a single class II diode laser, focused onto the surface under investigation. Reflected scattered light is collected by a silicon photodiode, amplified, digitised and subsequently analysed. The incident angle of the laser is critical, to guarantee the reflected scatter angle enabling the laser light collection by the photodiode. To exploit the capabilities of this inspection method, the laser beam is tracked around the functional cutting edges of a number of different insert profiles in anticipation of defect detection. A computer controlled three-axis device was designed and built, capable of manipulating the cutting tools under the stationary laser and detector set-up (Figure 2).

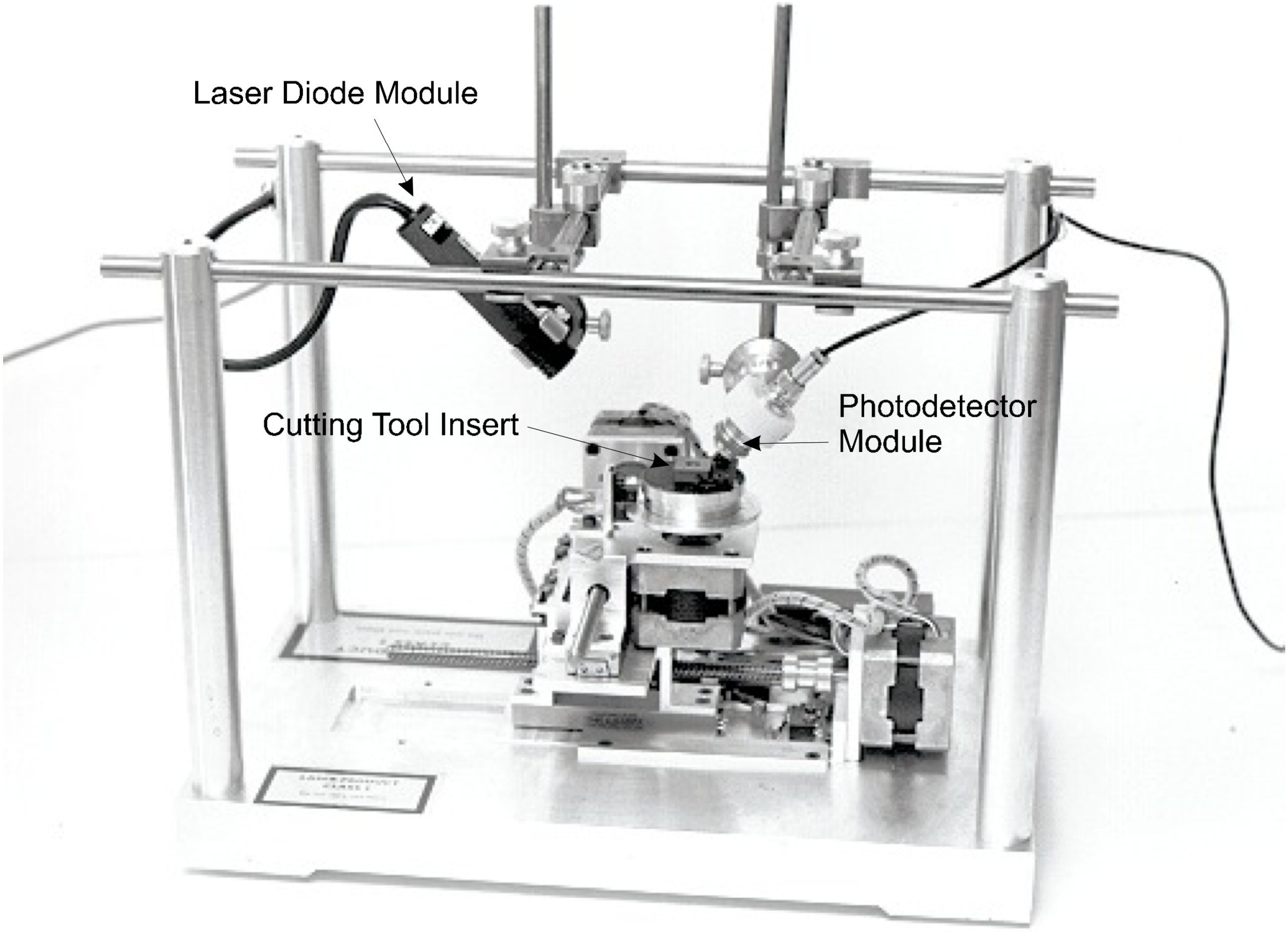

Figure 2: Insert Cutting Tool Inspection System.

The main focus for this work was aimed at producing a flexible inspection device for the detection and identification of defect types associated with newly manufactured cutting tool inserts. In most cases these tended to be chip type defects, caused by the required properties offered by the insert materials; extreme hardness, wear resistance and thermal shock resistance. Although it was not possible to address all the inspection problems for all the insert cutting tool types, a selection of tools were selected to form case study examples, representing typical insert types (Figure 3).

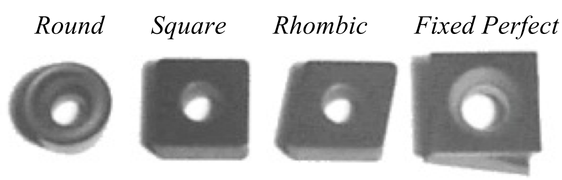

Figure 3: Case Study Cutting Tool Insert Shapes.

In order to successfully discriminate between good and defective inserts, signal processing techniques were applied. These simultaneously increase the signal-to-noise ratio and highlight cutting edge defects. Applying a 10 point averaging function followed by the Least Squares Method enhanced the output significantly, producing a successful signal processing procedure. Combining this procedure with the more traditional SPC functions enabled the formulation of 'master' traces for each insert type, to which defect detecting bands were added. Any response signal falling outside these threshold levels provides an indication of the presence of a single or multiple defects. Due to the complexity and variety of the obtained response signals, the output requirements for the prototype was simplified to an automatic *pass* or *fail* criteria. All inserts which stray from the norm would be considered defective and rely on human intervention for precise defect discrimination.

Figure 4 highlights two defects along one cutting edge of an ISO cutting tool insert. The trace compares the obtained signal to a predefined master trace and incorporates upper and lower control limits. The protrusions lying outside the threshold levels indicate defects of calculated size 420 [m and 336 [m compared to their measured lengths of 410 [m and 320 [m. The allowable tolerances for the defect(s) are 500 [m and as such, a single defect would pass but the combination of presence of both defects would deem the cutting tool defective.

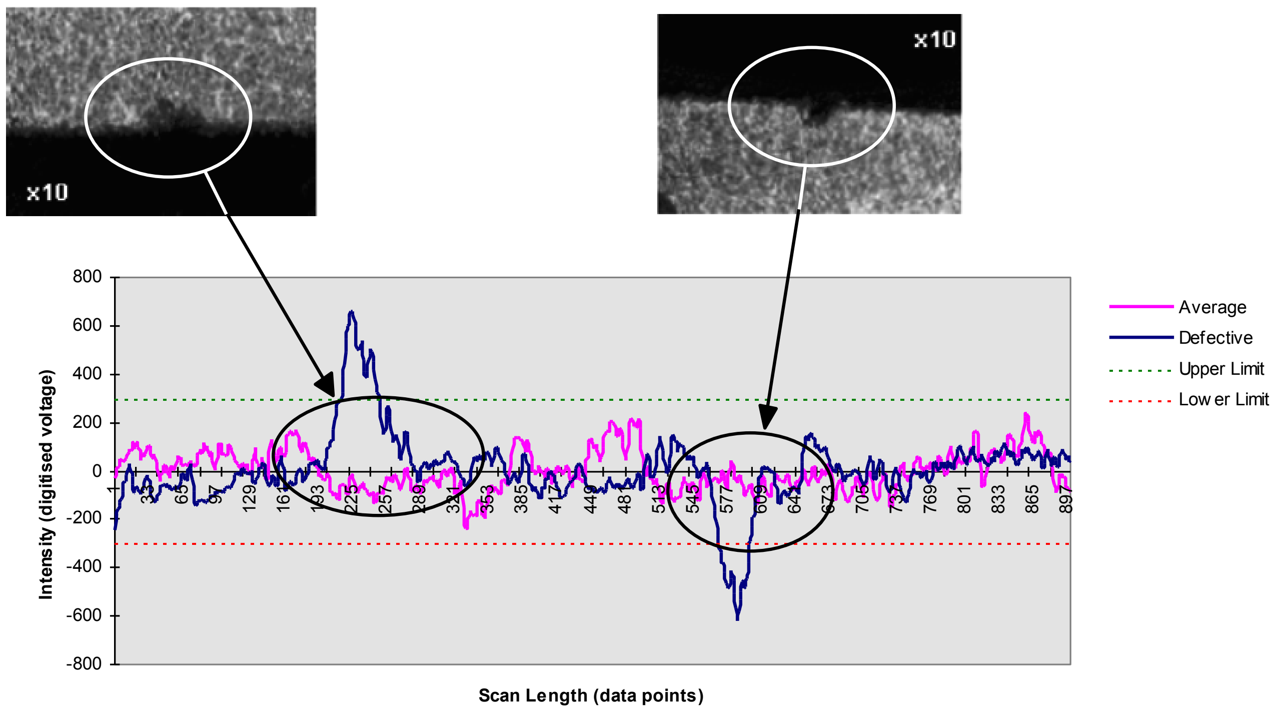

Figure 4: Typical Trace Showing Presence of Chip Type Defects.

The application of new technology to this field of manufacture presented in this work, demonstrates significant improvements over current inspection techniques, and provides high speed detection of previously difficult to detect defects. Defects from 50 [m upwards can be reliably and automatically detected at high speeds.

MONOLITHIC CUTTING TOOL INSPECTION

The in - service inspection of cutting tools (Figure 5) varies distinctly from the automatic inspection of cutting tool inserts during manufacturing since the nature and magnitude of the defect in the latter is largely inconsequential, whereas these parameters will form the basis of determining the action to be taken on the former. By comparatively analysing the response signal from cutting tools which are in - service with a master tool trace, the length of a defect and its position in relation to the critical tolerance zone along the cutting edge of the tool can be determined in addition to the depth of flank wear (VB) and loss of tool tip (VS).

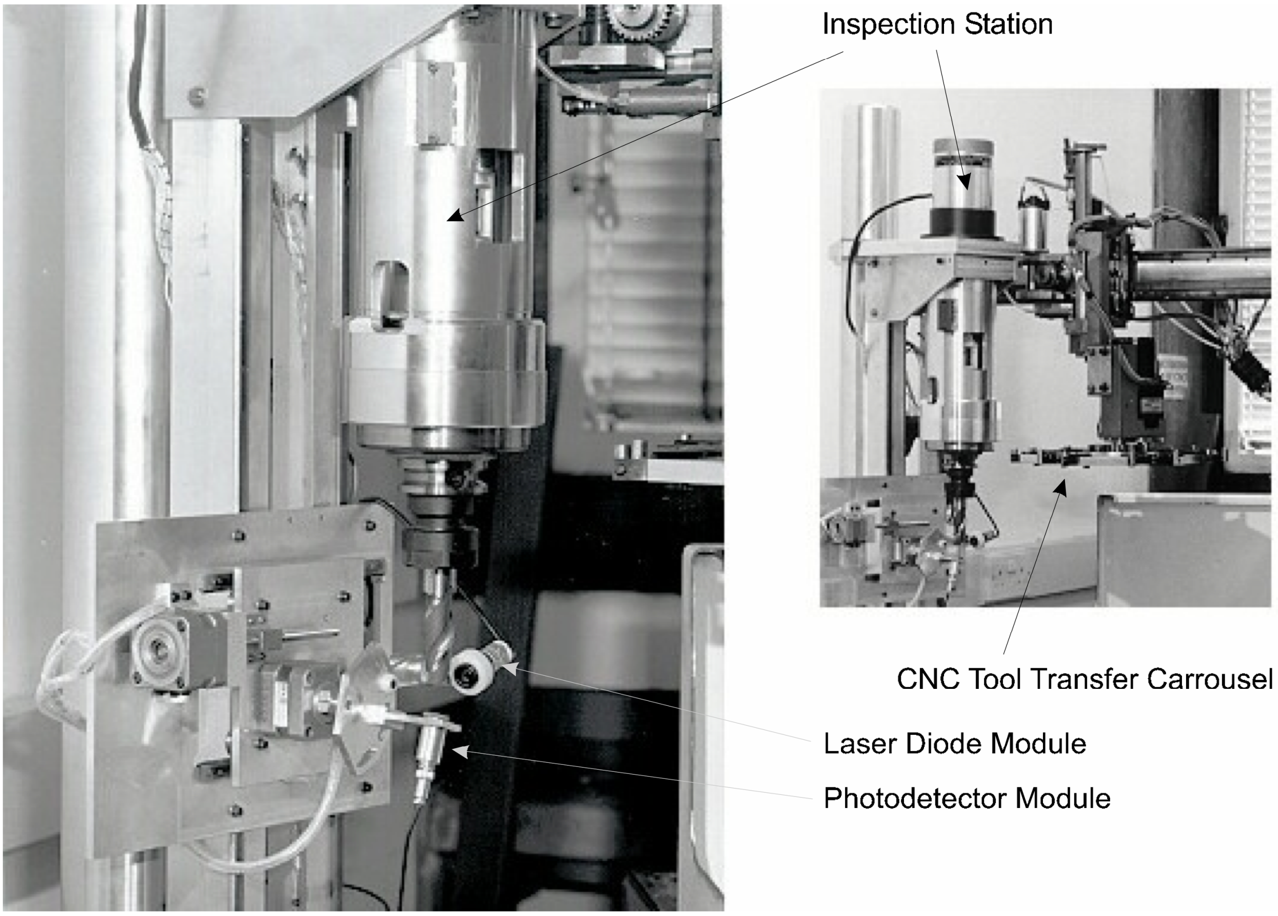

Figure 5: Monolithic Cutting Tool Inspection System.

The data required analysis by digital signal processing, primarily in order to smooth the signal, but also to eradicate the effects of machine vibration and other forms of signal interference as well as to cross correlate the master trace with the response trace. This form of computer controlled information synthesis is utilised in order to automatically determine whether the cutting tool is no longer suitable for continued machining, based on the wear limits being exceeded by the response trace, or if it is still fit for continued machining. In either case, the tool status, which includes the action to be taken as well as its location in the automated tool changer, is displayed on the machine control unit, until such time as a human operator is able to deal with the outcome.

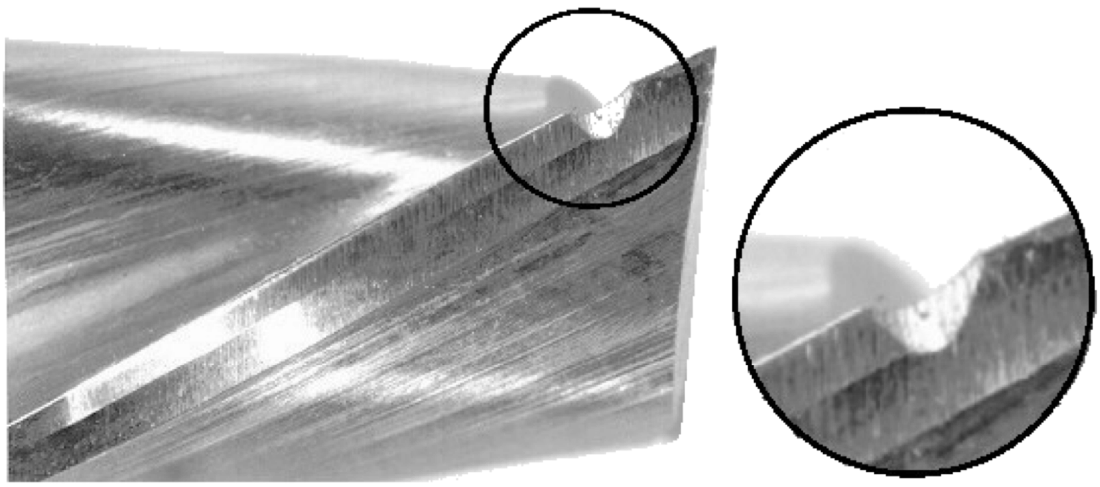

Figure 6: Monolithic Cutting Tool with a Chip Type Defect Introduced.

Two examples are shown in Figures 6 and 8 of the types of damage which could be found on slot drill cutter after normal operation. The first (Figure 6), highlights a chip type defect, **mm in length on one of the cutting flutes. In this case, the defect is easily identified on the trace (Figure 7). Similarly, Figure 8 shows some flank wear on the cutting flutes. Again the pattern representing the wear mechanism is easy to identify when compared to the master trace (Figure 9).

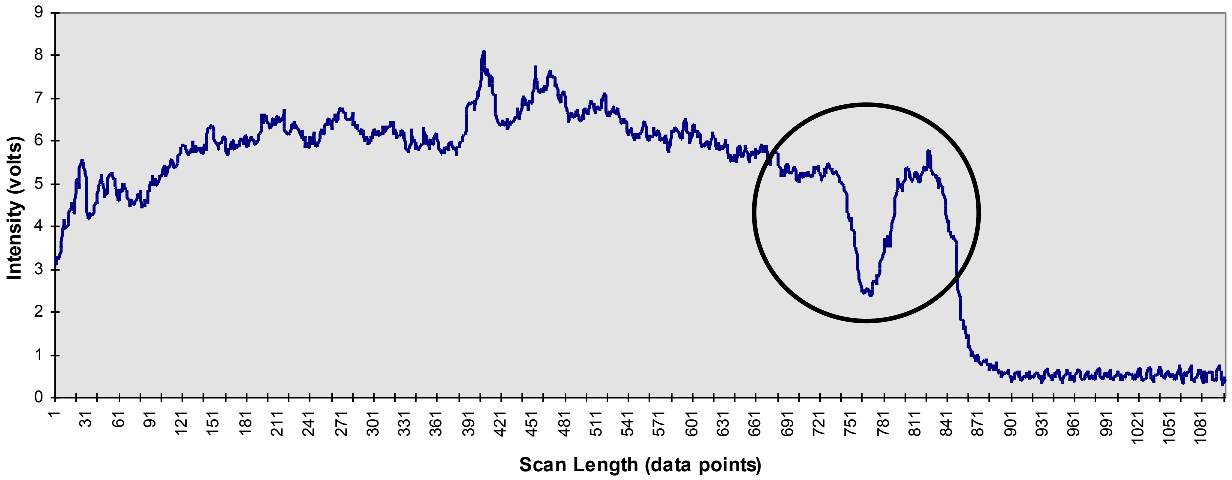

Figure 7: Response Signal from the Chip Type Defect.

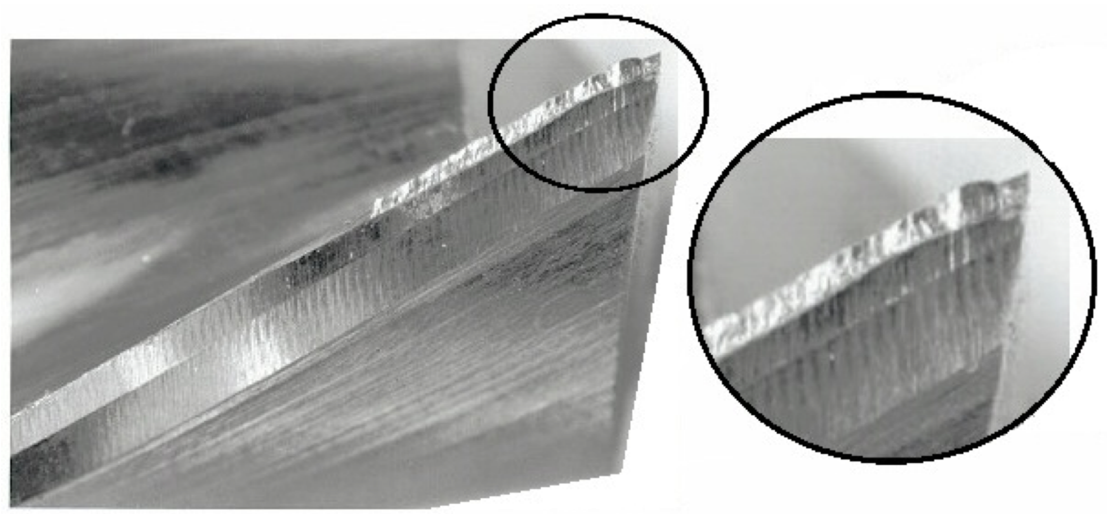

Figure 8: Monolithic Cutting Tool with Flank Wear Highlighted.

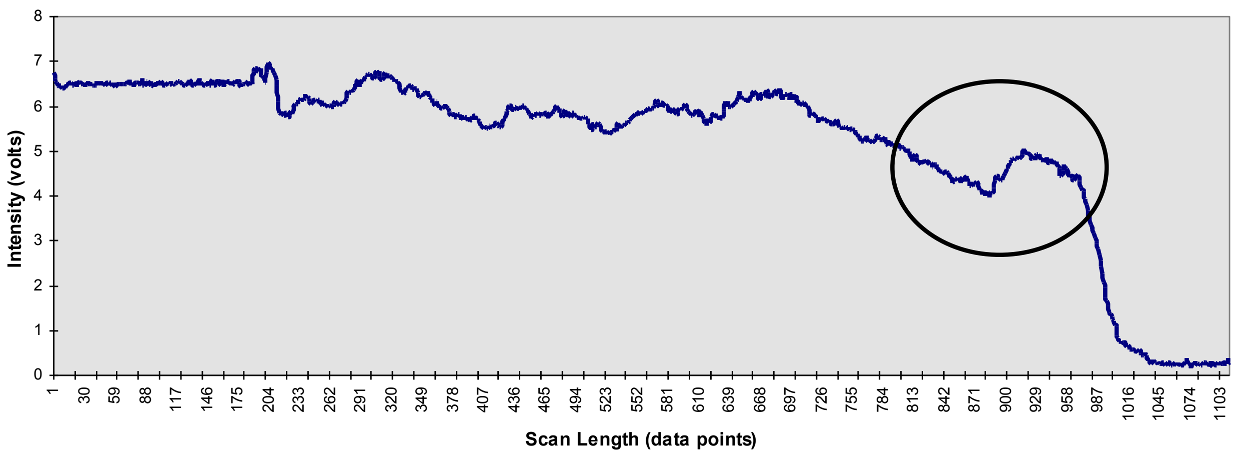

Figure 9: Trace Showing Presence of the Flank Wear.

CONCLUSIONS

It has been shown that with this simple laser inspection technique, high speed, accurate inspections can be carried out where monotonous inspection has previously taken place.