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USING ARAMIS FOR MEASUREMENT OF DEFORMATION OF THIN-WALLED PARTS DURING MILLING

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Abstract

This paper describes deformation measurement of thin-walled parts by ARAMIS measuring system. During the milling, machine and workpiece may deviate from required geometry. Thin-walled parts are primarily used in automotive, aerospace and energy industries. ARAMIS is a system for optical 3D deformation analysis for static or dynamically loaded specimens and components. ARAMIS measuring system can be used for determining the deformation of thin-walled parts during milling.

Key words

ARAMIS, deformation, milling, thin-walled parts, measuring deformation

Introduction

Peripheral milling of flexible thin-walled parts is a commonly required operation. Thin-walled parts are used primarily in automotive, aerospace and energy industries. During the milling, tool and workpiece are in contact. The effect of cutting forces is a deflection from the ideal component shape. The problem during milling of thin-walled parts is chatter. The flexibilities of the cutter and plate produce severe forced and self excited vibration during peripheral milling. Self-excited chatter vibrations occur due to dynamic interactions of the cutting process and structure. Chatter vibrations are initiated by transient vibrations, and their stability depends on the axial and radial depth of cut, cutting speed, workpiece material hardness and structural properties of both tool and workpiece [3].

The peripheral milling of very flexible plate structures made of aluminium alloy is studied in this paper. Some authors have presented the results about milling thin-walled parts. *Budak* and Altintas presented a dynamic model for peripheral milling of very flexible plates [1]. *Ratchev* presented his paper on error compensation strategy in milling flexible thin-wall parts [2].

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Optical measuring system ARAMIS

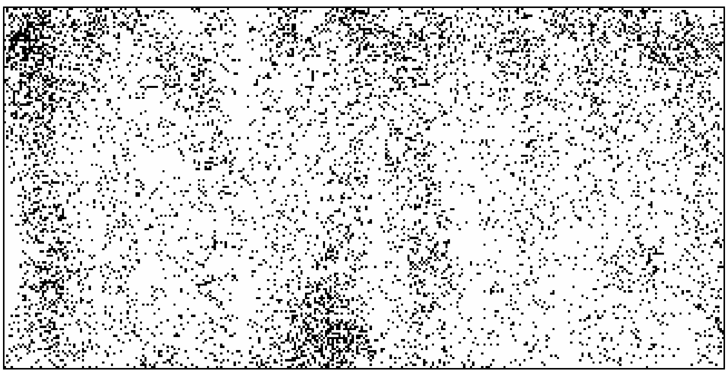
ARAMIS (Fig. 1) is the system for optical 3D deformation analysis [4]. It is ideally suited to measure, with high temporal and local resolution as well as with a high accuracy, three-dimensional deformation and strain in real components and material specimens. For static or dynamically loaded specimens and components, ARAMIS allows for non-contact and material independent determination of 3D coordinates and 3D displacements, 3D speeds and accelerations, plane strain tensor and plane strain rate, material characteristics.

BASIC DATA OF OPTICAL MEASURING SYSTEM ARAMIS [4] Table 1

System Configuration	**5M**
Frame Rate	15 Hz up to 30Hz
Camera Resolution	2448 x 2048 pixels
Measuring Area	mm^2 to > m^2
Strain Measuring Range	0.01 % up to > 100%
Strain Measuring Accuracy	up to 0.01 %
Sensor Dimensions	510 x 230 x 200 mm^3
Weight	3 kg

Fig. 1 *Optical measuring system ARAMIS [4]*

For the 3D deformation and strain measurements, the object to be loaded is viewed by a pair of high resolution, digital CCD cameras. 3D image correlation photogrammetry technology is a unique combination of two-camera image correlation and photogrammetry. A random or regular pattern with good contrast is to the surface of the test object, which deforms along with the object. The deformation of this thin-walled part under different load conditions is recorded by the CCD cameras and evaluated.



Random pattern on surface

Milling thin-walled part and deformation measurement

Milling is a multiple point, interrupted cutting operation. Because of the multiple teeth, each tooth is in contact with the workpiece for a fraction of the total time [3]. The finished surfaces, therefore, consist of a series of elemental surfaces generated by the individual cutting edges of the cutter. Due to the nature of relative contact between the workpiece and the tool, the chip thickness is not constant but starts with a zero thickness and increases in up-milling and starts with a finite thickness and decreases to zero in down-milling. The down-milling (Fig. 3) of thin-walled parts is better than up-milling.

The dimension of workpiece was 100x80x10 mm. The shape of thin-walled part is show in Fig. 2. Material of workpiece was EN-6082 AlMgMnSi1 aluminium alloy which has good machinability.

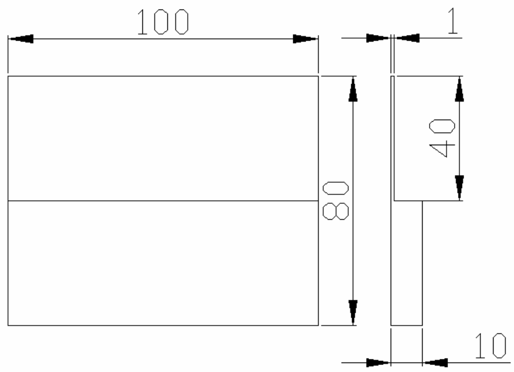


Fig. 2 *Shape of thin-walled part*

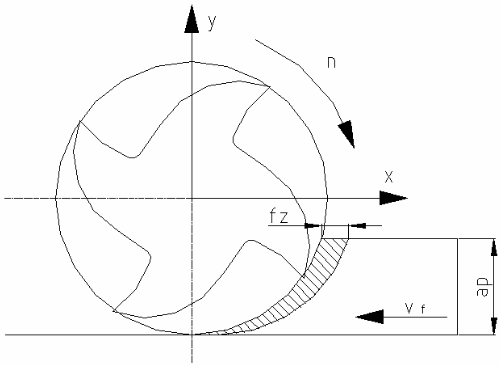


Fig. 3 *Down-milling*

The workpiece is a 10 mm thick aluminium plate. It was cantilevered by clamping one end in a vice with a clamped length of 27 mm and a width of 100 mm. The cutting tests were carried out on a 5-axis high-speed milling centre HSC 105 linear. The free-end was down-milled **(**Fig. 3) using a bull nose end mill, helical 30°, two-flute tool with a diameter of 20 mm with MEGA-T coating. Overhang of tool was 55 mm. For the experiment, the following parameters were used: depth of cut (DOC) 10 mm, cutting speed 314 m/min, width of cut (WOC)1 mm without cutting fluids. 3D optical measuring system ARAMIS was used for deformation measurement.

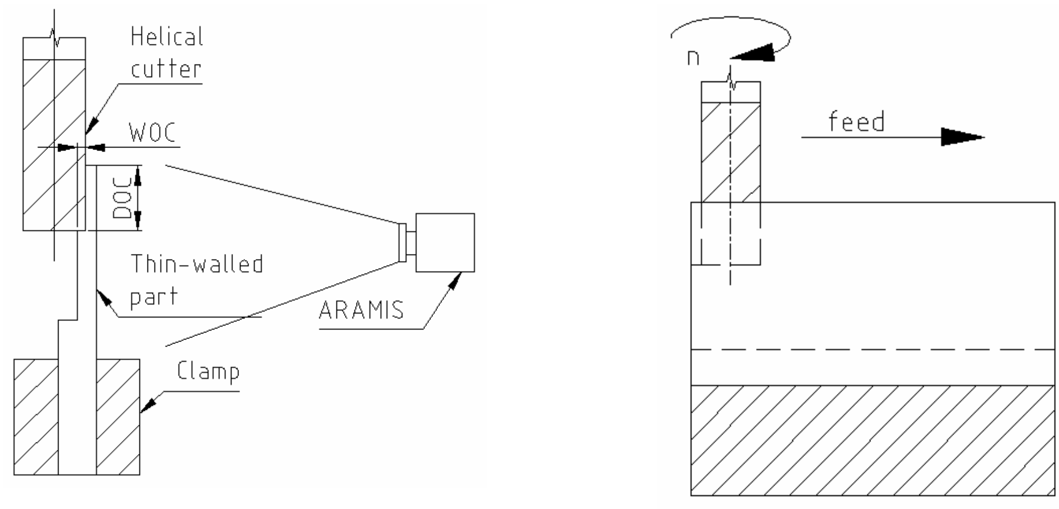


Fig. 4 *Measurement set-up*

Experimental results

Figures 5, 6, 7 shown colour deviations maps in various positions of cutters. At the first immersion, the deformation of parts at the beginning can be seen. The maximum deviation during milling was 2.5 mm. The maximum deviation was caused by the parts vibration, this vibration was accompanied by unpleasant sound. This deviation of parts was changed during cutting, just moves with the cutter. After milling, the maximum deviation was to a value of 0.01 to 0.05 mm.

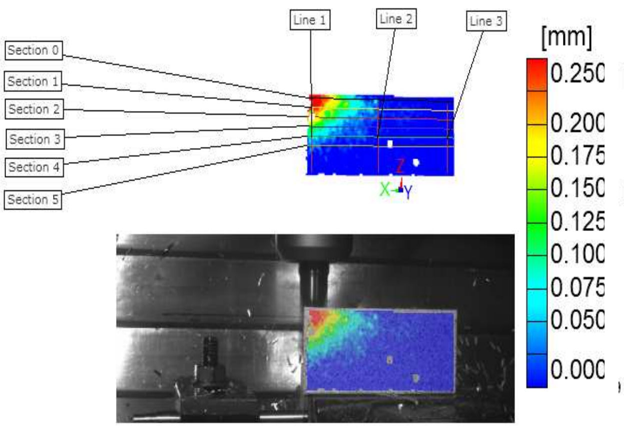


Fig. 5 *Colour deviation map of thin-walled part when tool is in starting position on part*

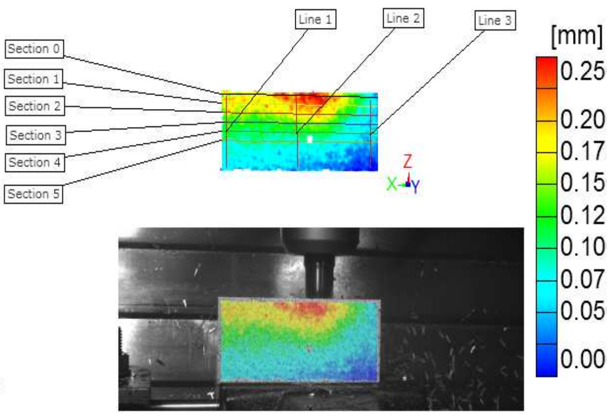


Fig. 6 *Colour deviation map of thin-walled part when tool is in middle position on part*

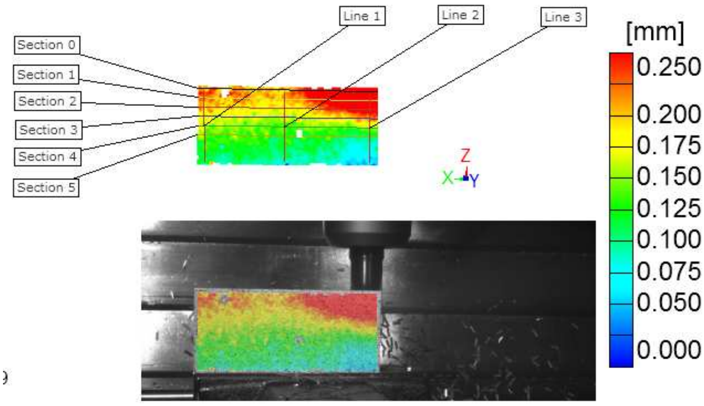


Fig. 7 *Colour deviation map of thin-walled part when tool is in end position on part*

From the measured data, displacement of points in parts can be graphically evaluated. Chosen points and their layout are shown in Figure 8. The result of the experiment was the graph of displacement of measured points (mm) and time (s) shown in Figure 9. Displacement measured points were evaluated with regard to the fixed points. Colours of points correspond to colour curves measured by determining the change in position of point in time. The maximum deformation reached endpoints (red and blue points). These are places where the cutter enters and exits from thin-walled parts. Prerequisite for the experiment was that the greatest deformation will be around the end points.

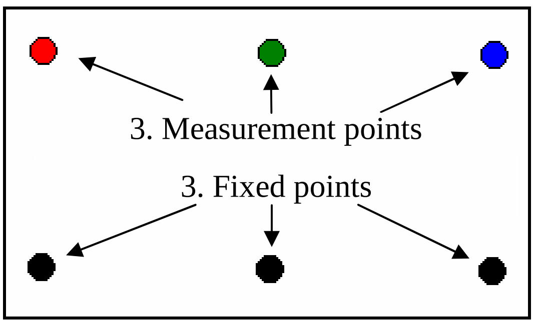


Fig. 8 *Position of measurement points and fixed points*

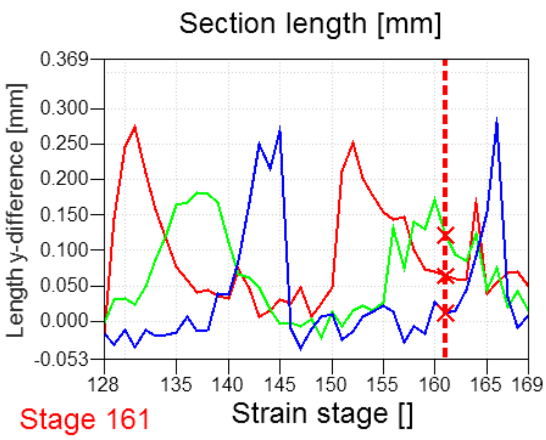


Fig. 9 *Result from ARAMIS software*

Scientific asset

The asset of this paper is the presentation of the new method of measuring deformation of thin-walled parts. This method is used for real-time measurement. It is possible to compare the results from ARAMIS with FEM analysis.

Conclusion

The issue of thin-walled milling is very extensive. The article deals with one of the main aspects of the production of thin-walled parts, and especially with their deformation during milling. Method of monitoring strain components in real-time using 3D optical system ARAMIS was first used in experiment. The results of the experiment make it possible to better understand the behaviour of thin-walled components during milling.

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