The Japan Society for Precision Engineering

Introduction of JSPE Best Paper Awards 2013

1. Development of an Outlier Reduction Method Intended for Confocal Profiling Sensor

Hiroya FUKATSU, Kazuhisa YANAGI

J. JSPE, Vol.79, No.3, pp.248-252

This paper presents a novel technique for reducing the influence of such speckle phenomenon on the confocal optical system. Its measurement principle has been applied to non-contact displacement sensors. Both the height and lateral resolutions of confocal displacement sensors on the market are regarded as practically small enough. However, those sensors are inevitably influenced by speckles of reflected light and so they tend to detect unreasonable profile signal.

This paper presents a novel technique for reducing the influence of such speckle noise. Its actual effect was analytically explained through the numerical simulation. Finally, the experimental results using the developed confocal profiling sensor revealed that the outliers can be fully corrected and the confocal sensor gives the same measured profile as that by a stylus instrument.

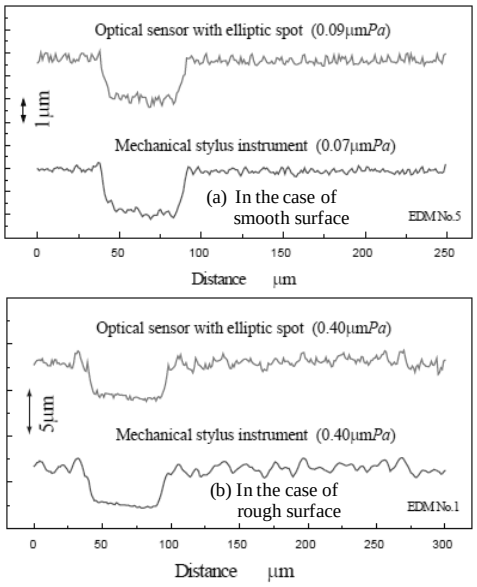


Fig.1 Comparison of measured profiles between the developed system and a stylus instrument

2. Development of Laser-Machinable Glass by Electric Field-Assisted Solid-State Ion Exchange - Numerical Analysis of Drift-Diffusion Behavior of Metal Ions in Glass Material -

Souta MATSUSAKA, Tomoko KOBAYAKAWA, Hirofumi HIDAI, Noboru MORITA

J. JSPE, Vol.79, No.5, pp.455-459

In order to improve the laser micro-machinability of borosilicate glass, the glass surface was doped with metal (silver or copper) ions by electric field-assisted solid-state ion exchange. Doped ions drifted and diffused into the glass substrate under a DC electric field. The drift-diffusion behavior of metal ions in glass was numerically analyzed using standard explicit finite-difference method. The calculated penetration depths of both silver and copper showed good agreement with experimentally measured values. However, there was a difference between measured and calculated ionic fluxes, especially for the early-stage of ion exchange. This discrepancy was likely to be caused by an imperfect initial contact between metal foil and glass substrate. Therefore, the increase in electric current path with ion exchange time was necessary to be taken into consideration. The modified calculation enabled more accurate estimation of ionic penetration depths.

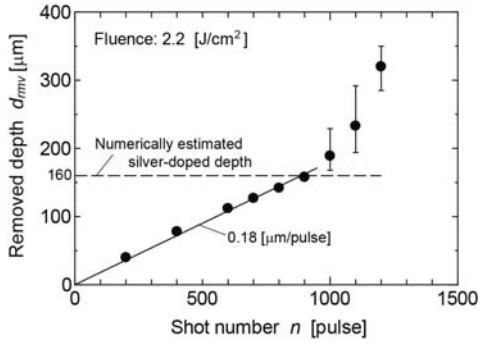


Fig.2 Change in removed depth with laser shot number for silver-doped glass. Irradiated energy density was 2.2 J/cm^2.

3. Suppression of Regenerative Chatter Vibration in Multiple Milling Utilizing Speed Difference Method - Analysis of Double-sided Milling and Its Generalization to Multiple Milling Operations

Eiji SHAMOTO, Tatsuya MORI, Burak SENCER, Norikazu SUZUKI, Rei HINO

Precision Engineering, Vol.37, No.3, pp.580-589

This paper presents a new method and its analysis to suppress regenerative chatter vibration in simultaneous multiple milling with a flexible mechanical structure. Precision steel plates are conventionally finished by one-sided face milling with a rigid electro-magnetic chuck. However, it is difficult to obtain the desired flatness with this method since the thin workpiece deforms to fit the chuck surfaces when chucked. The authors have solved this problem to realize both high accuracy and productivity by applying the simultaneous double-sided milling technique utilizing the developed speed difference method, in which the regenerative chatter is cancelled by rotating two milling cutters at different speeds on both sides of the workpiece. The present study represents an analytical model of the simultaneous double-sided milling including the regenerative chatter vibration effect on the process. Machining experiments are conducted to validate the developed analytical model. Experimental results match with the

analytically predicted ones proving that the proposed model accurately predicts the regenerative stability limits in double-sided milling. The results also show that the developed speed difference method can provide great advantage to increase the chatter stability and carry great potential to enhance the productivity in machining of flexible thin workpieces. Furthermore, simultaneous multiple-spindle machining methods have become much desired in mass manufacturing systems as they prove higher manufacturing efficiency. The proposed speed difference method is extended and generalized to those multi-spindle simultaneous milling operations with flexible mechanical structures. Analytical derivations and the foundation are presented here on how to calculate the necessary speed differences between milling spindles to suppress regenerative chatter vibrations.

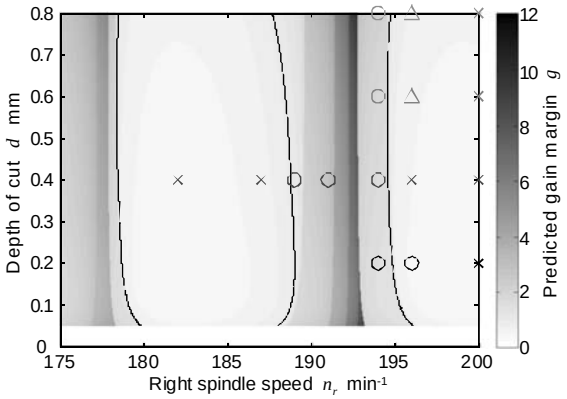


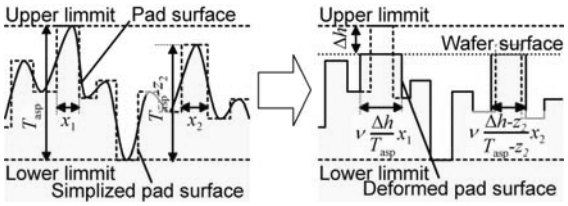
Fig.3 Predicted gain margin, chatter stability limits, and experimental results

Introduction of JSPE Numata Memorial Paper Awards 2013

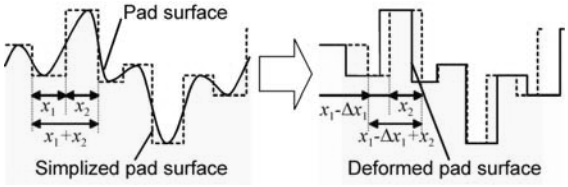
1. Elasto Hydrodynamic Lubrication Analysis of CMP Process with Consideration of Micro Asperity Contact of Polishing Pad

Yohei HASHIMOTO, Norikazu SUZUKI, Masakazu ASABA, Rei HINO, Eiji SHAMOTO
J. JSPE, Vol.79, No.1, pp.73-80

A soft EHL analysis model of Chemical Mechanical Polishing (CMP) is developed in the present study. Since a surface of a polishing pad is filled with micro asperities due to conditioning, the polishing pad deforms in a nonlinear manner by contacting to a wafer. A viscosity of the polishing pad also affects stress concentration beneath the edge of the wafer. In order to take into account both effects, damping behavior of the polishing pad and macroscopic characteristics of the polishing pad asperity deformation are considered at the same time in the proposed analysis. Based on the traditional contact model, i.e., Greenwood-Williamson model, nonlinear elasticity of the surface asperity layer of the polishing pad is formulated, and Arbitrary Lagrangian-Eulerian (ALE) method is applied to deal with dynamic structure analysis. A series of three-dimensional EHL analysis was conducted using the proposed model. Effects of viscosity of the polishing pad and the nonlinear elasticity caused by the polishing pad asperities on distributions of contact stress and fluid pressure were examined. Analytical results indicated that both distributions greatly depend on the viscosity and the nonlinear elasticity of the polishing pad, and thus the consideration of nonlinear viscoelastic behavior in the pad-wafer contact is important to predict the polishing pressure distribution, especially beneath wafer leading edge.



(a) Vertical deformation



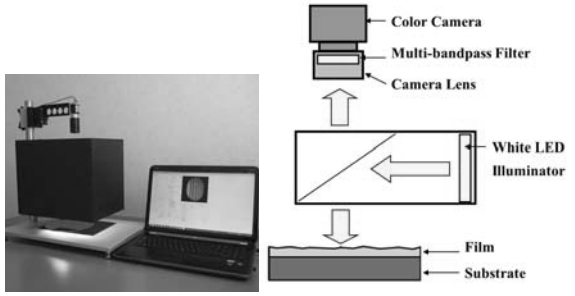
(b) Horizontal deformation

Fig.4 Schematic illustrations of asperity deformation

2. Wide-view Transparent Film Thickness Measurement System by Interference Color Analysis

Katsuichi KITAGAWA, Masafumi OTSUKI
J. JSPE, Vol.79, No.11, pp.1078-1082

Conventional transparent film thickness measurement methods such as spectroscopy are essentially capable of measuring only a single point at a time, and their spatial resolution is limited. We have developed a wide-view film thickness measurement system based on an extended global model-fitting algorithm developed for three-wavelength interferometric surface profiling. It estimates the film thickness distribution from an interference color image captured by a color camera with three-wavelength illumination. The basic performance was experimentally proved, and the system was successfully applied to measure the air gap thickness of Newton's rings and the thickness of a vertical flowing soap film. Its key features are : (1) high spatial resolution, (2) high-speed measurement, (3) low cost and simple optics, and (4) no preliminary calibration required.



(a) Outlook of apparatus (b) Optical configuration

Fig.5 Wide-view thickness profiler