深孔鑽切削加工品質之研究
Investigating the Cutting Quality in Deep-Hole Drilling

計畫編號 **：NSC88-2212-E-009-004**
執行期限 **：87** 年 **08** 月 **01** 日至 **88** 年 **07** 月 **31** 日
主持人：秦繼華　　國立交通大學機械系

1. Chinese abstract

本研究在深孔鑽時，鑽桿支撐移位對軸推力所引起軸孔偏差。移位發生在於夾頭主軸、未定支撐和導套不成一直線。本研究使用 **Euler column theory** 推導軸孔偏差方程式，實驗執行使用 **Gundrill** 和 **BTA** 系統。模擬產生、**Sakuma's method** 和實驗給予比較。

關鍵詞：推力、偏差、未定支撐、導套

Abstract

This study investigates the effect of drill shaft support misalignment on axial hole deviation under the influence of axial thrust force. Misalignments occur in machine spindles, intermediate support locations and pilot bushings. We derive equations for hole deviation using the Euler column theory, report experiments performed using Gundrill and BTA deep-hole drilling systems. Simulation results, Sakuma's method and experimental examinations are also presented in this study.

Keywords: Thrust force, Misalignment, Intermediate support, Pilot bushing, Euler Column theory, Gundrill, BTA.

2. Cause and goal

Deep-hole drilling, the ratio of hole-depth to hole-diameter being greater than 10, produces holes of high accuracy in size, alignment, straightness and surface finish. The deep-hole drill shaft is lengthy compared to twist drill, and its dynamics influences the cutting quality during drilling process. Therefore, the deflection due to lateral bending and vibration of deep-hole drill shaft causes the hole deviation in axial direction. In order to suppress the deflection and improve the hole straightness, pilot bushing and intermediate support are used to stabilize the lengthy drill shaft in deep-hole drilling. However, the assemby accuracy of pilot bushing, intermediate support and machine spindle influence the dynamics seriously. The misalignment in pilot bushing or drill shaft support affects the straightness of drilled hole. Thus, the effects of pilot bushing and intermediate support misalignments on hole deviation in axial direction are discussed in this study.

Frazao *et al*. [1] presented the advantages of a novel three-pad BTA tool over conventional two-pad BTA tools. Experiments showed that the three-pad BTA tool was more stable than conventional BTA tools during deep-hole drilling. The third pad also stiffens the tool thereby improving chip breaking performance and improving the quality of holes produced at high feed rates. Sakuma *et al*. [2] proposed formulas concerning the burnishing action of guide pads and studied the influence of machining conditions such as cutting forces, the burnishing action takes place under a high contact pressure between the bore wall and those regions, and the over-size mechanism of machined hole by the guide pads is discussed. Sakuma *et al*. [3] studied the effects of guide pads on burnishing action and accuracy of machined holes using a specially designed tool, the mechanism and the causes of formation of multi-corner shape in holes with high length-to-diameter ratio are discussed. Sakuma *et al*. [4] investigated the burnishing action occurs on hole wall by guide pads, accompanied with self-guiding action of tool and its effect is studied, and the effects of pilot bushing and intermediate support misalignments on hole deviation. But axial thrust forces exerted on drill shafts were not considered in their study, which implies they considered hole deviation to be dependent upon drill shaft geometrical parameters (see Appendix B). Rao and Shunmugam [5] analyzed axial and transverse profiles of holes obtained from BTA drilling, the results throw more light on the process characteristics and these are useful in the control of the process. Katsuki *et al*. [6] studied the influence of workpiece geometry on axial hole deviation in deep-hole drilling. Katsuki *et al*. [7] investigated the influence of single- and multi-edge tools on hole deviation. Their experimental data and theoretical analyses showed that unbalanced cutting forces due to tool geometry caused hole deviations. They also studied how an inclined workpiece front face and pre-drilled pilot holes affected hole deviation. Hole deviations were found to vary with wall thickness between adjacent holes and the diameters of pre-drilled pilot holes, and parallel hole deviations increased with pilot hole diameters, which hole deviations sharply increased when separating wall thickness between adjacent holes reached a certain value. Stuerenburg [8] studied hole deviation during single-lip deep-hole drilling using an experimental approach; no theoretical considerations were given.

In deep-hole drilling, axial hole deviations are affected by misalignment of drilling setups, tool geometries, workpiece shapes among other factors. Therefore, this study was focused on investigating the effects of misalignments of pilot bushing and intermediate supports of deep-hole drill shaft subjected to axial thrust forces on axial hole deviations. We derive the equations for hole deviation using Euler column theory. Experiments were performed using Gundrill and BTA deep-hole drilling systems. Simulation results, Sakuma's method [4] and experimental examinations are also compared.

3. Conclusion and discussion

In this study, theoretical models of axial deviations of machined holes caused by pilot bushing and intermediate support misalignments were formulated and investigated experimentally. The following conclusions can be drawn according to the present results:

(1) From simulations and experiments, the axial hole deviation is influenced dominantly by pilot bushing and intermediate support misalignments. On the same misalignments and drilling conditions, The weight of pilot bushing is larger than intermediate support in producing hole deviation.

(2) The rigidity of BTA drill shaft is larger than Gundrill. Therefore, the axial hole deviation of BTA drilling is smaller than Gundrill. From the axial hole deviation concept, as far as possible use BTA drilling. And smaller tool diameter has less rigid; hence, the inclination of tool shaft is larger when axial thrust force is applied. So, the lower feed rate is chosen to reduce the

axial hole deviation.

(3) The comparisons of hole deviation among simulating results, experimental values and Sakuma's method [4] shown that simulation results are more in good agreement with experimental results than Sakuma's values.

(4) The insufficient for Sakuma's model is that his model could not apply to predict the axial hole deviations both pilot bushing and intermediate support misalignments existing simultaneously. Therefore, the proposed models in this paper are more useful than Sakuma's method under various misalignments to predict the deviation of machined hole in engineering application.

4. References

[1] J. Frazao, S. Chandrashekhar, M. O. M. Osman and T. S. Sankar, On the design and Development of a New BTA Tool to Increase Productivity and Workpiece Accuracy in Deep Hole Machining, *The International Journal of Advanced Manufacturing Technology* 4, 3-23 (1986).

[2] K. Sakuma, K. Taguchi and A. Katsuki, Study on Deep-Hole-Drilling with Solid-Boring Tool – The Burnishing Action of Guide Pads and Their Influence on Hole Accuracies, *Bulletin of the JSME* **23**, 1921-1928 (1980).

[3] K. Sakuma, K. Taguchi and A. Katsuki, Study on Deep-Hole-Drilling Boring by BTA System Solid-Boring Tool – Behavior of Tool and Its Effect on Profile of Machined Hole, *Bulletin of the Japan Society of Precision Engineering* **14**, 143-148 (1980).

[4] K. Sakuma, K. Taguchi and A. Katsuki, Self-Guiding Action of Deep-Hole- Drilling Tools, *Annals of the CRIP* **30**, 311-315 (1981).

[5] P. K. Rao and M. S. Shunmugam, Analysis of Axial and Transverse Profiles of Holes Obtained in BTA Machining, *International Journal of Machine Tool & Manufacture* **27**, 505-515 (1986).

[6] A. Katsuki, K. Sakuma, K. Taguchi, H. Onikura, H. Akiyoshi and Y. Nakamuta, The Influence of Tool Geometry on Axial Hole Deviation in Deep Drilling: Comparison of Single- and Multi-Edge Tools, *JSME International Journal* **30**, 1167-1174 (1987).

[7] A. Katsuki, H. Onikura, H. K. Sakuma, T. Chen and Y. Murakami, The Influence of Workpiece Geometry on Axial Hole Deviation in Deep Hole Drilling, *JSME International Journal* **35**, 160-167 (1992).

[8] H. O. Stuerenburg, Zum Mittenverlauf beim Tiefbohren, Dissertation, University of Stuttgart (1983).

[9] N. R. Bauld, Mechanics of Materials, First Edition, Wadsworth, Inc., Monterey, California (1982).

[10] Rotating Tool, p. 179, Sandvik Coromant, Printed in Denmark (1997).

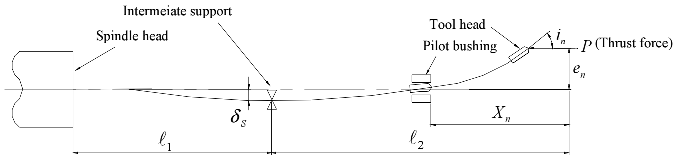


Fig. 1 Drill shaft support misalignment in deep-hole drilling

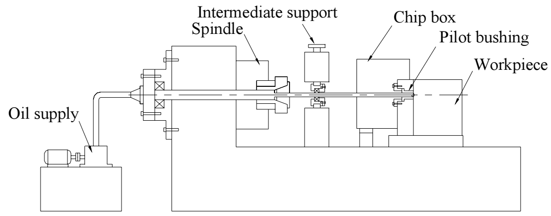


Fig. 2 Gundrill deep-hole drilling system

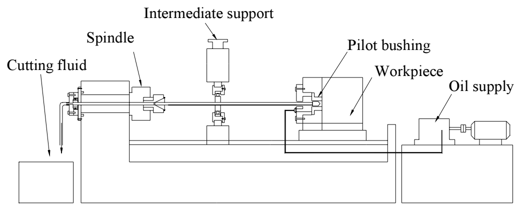
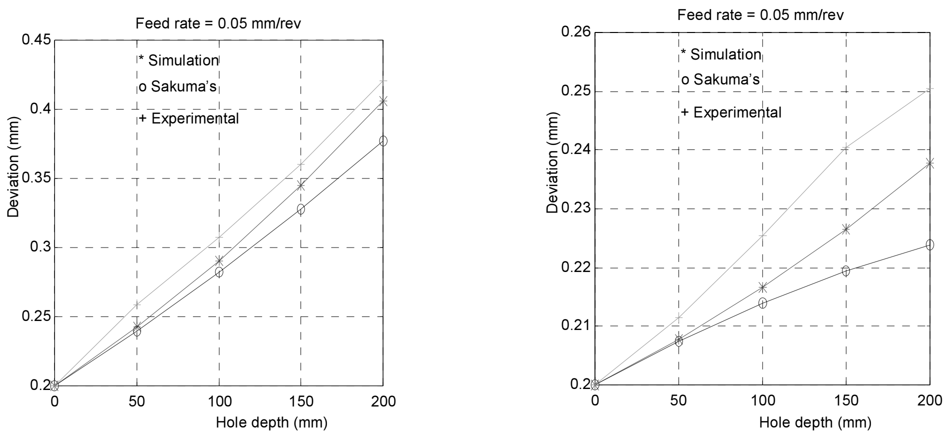
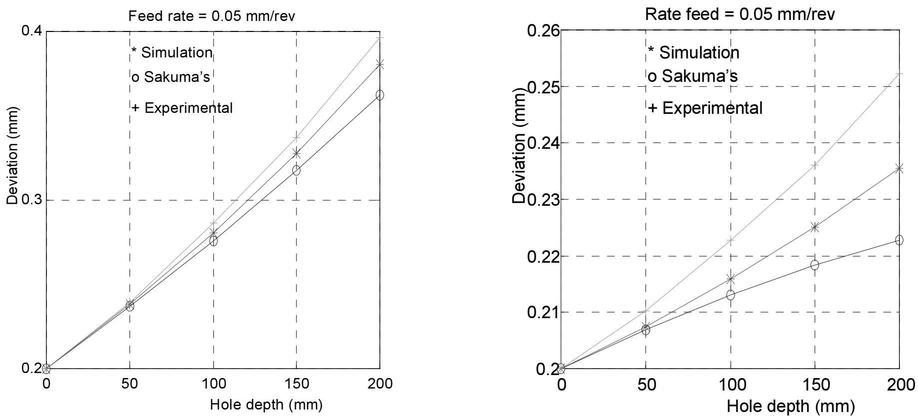


Fig. 3 BTA deep-hole drilling system



(a) Intermediate support misalignment: 0.1 *mm* (b) Intermediate support misalignment: -0.1 *mm*

Fig. 4 Gundrill axial hole deviation, pilot bushing misalignment: 0.2 *mm*, tool diameter: 11.52 *mm*, tool length: 1115 *mm*



(a). Intermediate support misalignment: 0.1 *mm* (b) Intermediate support misalignment: -0.1 *mm*

Fig. 5 BTA drill axial hole deviation, pilot bushing misalignment: 0.2 *mm*, tool diameter: 19.90 *mm*, tool length: 1200 *mm*