QUB - Mechanical and Aerospace Engineering PhD Project
2019-2020

Title: Advanced manufacturing of aircraft composite structures

Project description:

The increased use of anisotropic CFRP stacked in layered combination with aluminium and titanium in aircraft structures has created enormous challenges for the industry due to the difficulties arising from drilling these heterogeneous materials [1, 2]. The difference in modulus of elasticity and coefficient of thermal expansion of each material, composite or metallic, induces undesirable hole tolerance variations throughout the stacked materials. Other problems encountered during drilling include rapid tool wear, CFRP damage, poor surface finish and burr formation due to the disparity in material properties [3-6].
Currently, these multilayered stacks which include layers of CFRP, titanium and aluminium of variable thicknesses are arranged and then fastened together following a multi-shot machining process which involves a series of drilling, reaming, disassembly, deburring and reassembly operations [7]. Alternatively, drilling through multilayered material stacks in a single-shot process to produce high quality, burrless holes with acceptable tool wear removes the need for multiple operations and manufacturing stages, and reduces cost and cycle times [8]. But this single-shot process requires a high performance automated manufacturing system, which offers high flexibility and high dynamic responses. The orbital drilling is considered as one of the best choices to perform the hole making on stacked AL/CFRP/Ti due to lower cutting forces/temperature and high efficiency. However, the main material damage of such kinds of materials including delamination and burr formation will affect the hole making quality. In addition, the geometric error of hole diameter easy encountered during orbital drilling include the insufficient size of hole diameter, hole diameter at stacked AL/CFRP/Ti exit less than hole diameter at CFRP entrance [9]. Because there are wave texture at the surface layer of CFRP hole and tool runout during orbital drilling, the roundness in orbital drilling of CFRP is large than the roundness in conventional drilling of CFRP [10,11]. Although a number of research efforts have been directed to this research area, most of them are empirical and the machining mechanism and surface integrity are still unclear. Fundamental characteristics of orbital drilling process for AL/CFRP/Ti stacks will clarify the mechanism of surface damage and thus to avoid its completely unacceptable occurrence in drilling or orbital drilling processes.

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2. Denkena, B., Boehnke, D., Dege, J. H., Helical milling of CFRP-titanium layer compounds, CIRP Journal of manufacturing Science and Technology, 1(2), 64-69,2008.

3. Brinksmeier, E., Fangmann, S., Rentsch, R., Drilling of composites and resulting surface integrity, CIRP Annals-Manufacturing Technology, 60: 57-60, 2011.

4. Cong, W. L., Pei, Z. J., Deines, T. W., Liu, D. F., Treadwell, C., Rotary ultrasonic machining of CFRP/Ti stacks using variable feedrate, Composites Part B: Engineering, 52: 303-310, 2013.

5. Ni, W.Y., Orbital Drilling of Aerospace Materials SAE Aerospace, Heat Treatment 2012，03-12, 2007.

6. Whinnem, E., Lipczynski, G., Drilling Mixed Stack Materials for the BOEING 787. Self, 1: 1855, 2010.

7. Shyha, I.S., Soo, S.L., Aspinwall D.K., et al. Hole quality assessment following drilling of metallic-composite stacks, International Journal of Machine Tools and Manufacture, 51(7-8): 569-578, 2011.

8. Avila, M., Gardner, J., Reich-Weiser, C., et. al., Strategies for burr minimization and cleanability in aerospace and automotive manufacturing, SAE Technical paper, 2005-01-3327, 2005.

9. Zhou L, Ke Y, Dong H, et al. Hole diameter variation and roundness in dry orbital drilling of CFRP/Ti stacks[J]. The International Journal of Advanced Manufacturing Technology, 2016: 1-14.

10. Wang B, Gao H, Bi M, et al. Mechanism of reduction of damage during orbital drilling of C/E composites[J]. Jixie Gongcheng Xuebao(Chinese Journal of Mechanical Engineering), 2012, 48(15): 173-181.

11. Li Z, Liu Q. Surface topography and roughness in hole-making by helical milling[J]. The International

Journal of Advanced Manufacturing Technology, 2013, 66(9-12): 1415-1425.

Aims and Objectives:

The aim of the project is to explore intrinsic mechanisms and relationships between orbital drilling process parameters and geometrical accuracy, mechanical properties as well as surface integrity of holes in AL/CFRP/Ti stacked composites, the crucial fundamentals leading to realization of optimized machining processes deploying advanced robotic automation. The outcomes of the project will provide the concrete theoretical and technical foundations and bring significant benefits to the development of automated drilling equipment and processes.

Objectives:

To characterise the geometric accuracy and surface integrity of the machined hole by high precision instruments such as CMM, TalySurf, sophisticated interference microscope, X-ray tomography, AFM.

After comprehensive performance indices for evaluating the quality of a machined hole being proposed as the criteria, the machining parameter optimization will be performed by maximizing the drilling efficiency.

Key skills required for the post:

Students with at least an upper second (2:1) class degree in a relevant discipline (e.g., Mechanical, Aerospace, etc) are invited to apply. Research experience or a Master's degree in a related area and record of publications would be highly beneficial.

Key transferable skills that will be developed during the PhD:

Literacy and numeracy, Time management and organisation, Oral and written communication, Teamwork, Creative problem-solving, Initiative and enterprise, Critical and analytical thinking, Ability to apply discipline, knowledge and concepts, Information gathering, evaluation and synthesis, and interpersonal skills Adaptability

Lead supervisor:	Dan Sun <d.sun@qub.ac.uk>
Other supervisor(s):	Giuseppe Catalanotti <G.Catalanotti@qub.ac.uk>
Guaranteed stipend:	£15,009
Conditional top-up available:	This project will be part of a major H2020 project "European and Chinese Platform for Stacked Aero-Structure Drilling Process and Equipment". Block funding is available to cover the training and consumables. As part of the training, the student will have the opportunity to be seconded in our Chinese partner institutions for up to 12 months, where the cost of travel and living expenses will be fully subsidized (up to 2000 Euros / month).

PhD students in the School have the opportunity to apply to be demonstrators on undergraduate modules. Compensation for this can amount to in excess of £2,400 per year.

Queens University Belfast is a diverse and international institution which is strongly committed to equality and diversity, and to selection on merit. Currently women are under-represented in research positions in the School and accordingly applications from women are particularly welcome.