International Journal of Machine Tools & Manufacture 108 (2016) 66–73

Contents lists available at ScienceDirect

International Journal of Machine Tools & Manufacture

journal homepage: www.elsevier.com/locate/ijmactool

Short Communication

The effects of dub-off angle on chip evacuation in single-lip deep hole gun drilling

G.L. Tnay [a], S. Wan [b], K.S. Woon [a], S.H. Yeo [c,*]

[a] Singapore Institute of Manufacturing Technology, Singapore
[b] Institute of High Performance Computing, Singapore
[c] School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore

ARTICLE INFO

Article history:
Received 18 February 2016
Received in revised form
25 May 2016
Accepted 27 May 2016
Available online 28 May 2016

Keywords:
Deep hole gundrilling
Chip evacuation
Dub-off angle
Computational fluid dynamics
Chip trajectories

ABSTRACT

Without proper chip evacuation, gun drills will fail under intense thermal and mechanical loading during deep hole drilling of high temperature superalloys like Inconel 718. In gundrilling, the efficiency in evacuating chips is governed by the geometry of gun drills that defines the hydraulic boundary conditions for coolant and chip flow. In this paper, we propose a novel computational fluid dynamics (CFD) model that is capable to simulate and quantify the chip transportation behavior under high pressure coolant for drill geometry optimization. This is demonstrated through a case study on improving the shoulder dub-off design of commercial gun drills, which have a high tendency in trapping chips at the hole bottom. A more effective design criterion for the shoulder dub-off is thus proposed.
© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Gundrilling is a machining process to produce deep holes with length to diameter ratios greater than 10. The hole diameter range from 1 to 40 mm are usually constructed by gun drills with a single lip design, consists of an outer and inner cutting edges located asymmetrically over the drill diameter. Material removal achieved by the cutting edges will be breaking into smaller segments known as chips and evacuated by the high pressure coolant. As illustrated in Fig. 1, high pressure coolant is supplied through internal conduits of the drill bit to the bottom of the hole, which will subsequently diverts rapidly towards the shoulder dub-off to facilitate the breaking of the chips and carry them out of the cutting zone through the v-channel flute.

Chip evacuation has a direct impact on wear rate, failure mode and life span of gun drills [1]. Chips that are not effectively evacuated will inhibit the cooling of cutting edges where heat is generated by continuous chip flow through friction. While, lubrication on the bearing surfaces will be detrimentally affected without adequate exposure of the chip formation zone – leading to excessive burnishing against the hole. As a result, the overall cutting performance will deteriorate with the drastic increase in torsional load and followed by rapid development of drill degradation [2]. To improve chip evacuation through drill design and process parameter, the understanding of chip transportation behavior is critical. Osman and Chahil [3] investigated the effects of the interface in between the drill tip and v-channel flute with an open hydraulic circuit. Three types of coolant hole configurations namely single-hole, two-hole and kidney-shaped were studied. The results showed that the two-hole design gave the best performance due to minimum hydraulic pressure loss as compared to other designs. Following that, Astakhov et al. [4] developed a close circuit apparatus that was capable to measure coolant pressure at the bottom of the hole. It was discovered that pressure distribution around the drill tip is strongly influenced by the bottom hole geometries. As the shape bottom hole is defined by the designs of the drills, the authors concluded that the respective chip transportation behavior is also directly governed by the various drill designs. In a more detailed study, Astakhov et al. [5] focused their investigation on the effects of shoulder dub-off ranging from -9° to $+20^{\circ}$ as shown in Fig. 2. It was reported that the lost in coolant pressure can be improved by increasing the dub-off angle to $+20^{\circ}$. Although the results were sound, the actual increase in chip evacuation efficiency was not known since all the experiments were conducted without chips.

Realizing the constraints of experimental techniques from the literature, the present study is focused on the development of a realistic computational fluid dynamics (CFD) model to study chip flow trajectory of chips in gundrilling. Our goal was aimed to establish qualitative understanding of the effects of drill geometries through CFD simulations, which enables the improvement of chip evacuation efficiency through drill geometric optimization. In this paper, such capabilities are demonstrated with a focused case study on shoulder dub-off design for its significant influence on

* Corresponding author.
E-mail address: MSHYEO@ntu.edu.sg (S.H. Yeo).

http://dx.doi.org/10.1016/j.ijmachtools.2016.05.008
0890-6955/© 2016 Elsevier Ltd. All rights reserved.

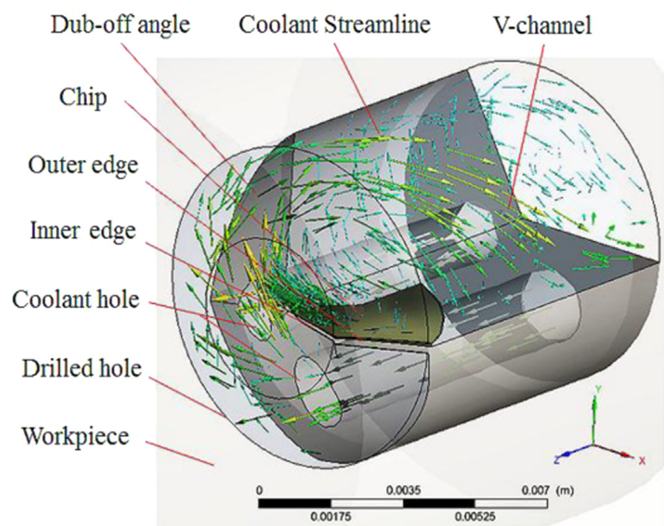

Fig. 1. High pressure coolant application in deep hole drilling using single-lip gun drill.

coolant flow in the vicinity of the cutting zone, as motivated by its significance in previous studies [4,5].

2. Methodology

To simulate chip flow trajectory, the force and torque acting on the chips in high pressure coolant are computed based on the control volume method [6]. During the setup, a typical gun drill chip and gun drill bit are imported into ANSYS CFX 14.0 and prescribed as stationary solids. The flow domain is then extracted from the hole, gun drill and chip and subsequently meshed by the CFX solver. In order to accurately capture the boundary layer region, face sizing with 0.1 mm element size and five inflation layers on the chip surfaces are introduced. Following that, boundary conditions of pressure at the inlet and outlet of the domain are defined, as shown in Fig. 3. No slip wall boundary conditions were applied to the flow domain and drill surfaces.

After the force and torque values are computed, the lateral displacement and rotation of the chip are then determined from the equations of motion:

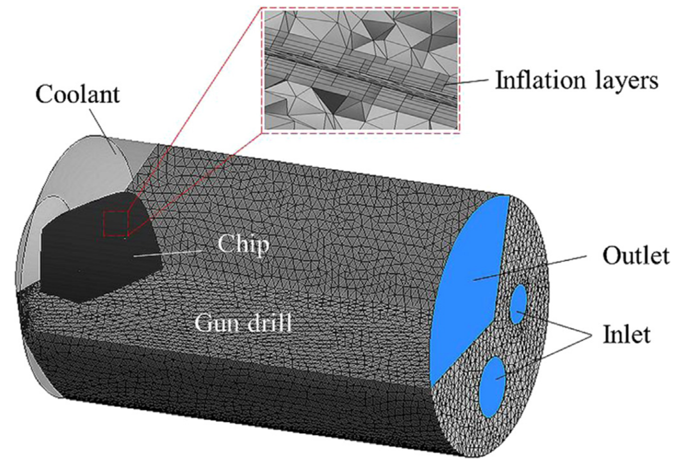

Fig. 3. Meshing of chip, gun drill bit, boundary and inflation layers.

$$\sum F{=}ma{=}m\frac{dv}{dt};\ \frac{dx}{dt}{=}v \tag{1}$$

where, F is the net force, m is the mass of the body, a is the acceleration of the chip, $\frac{dv}{dt}$ is the derivative of velocity with respect to the each time step, v is the velocity of the chip, and $\frac{dx}{dt}$ is the derivative of displacement with respect to the each time step.

Eq. (1) can also be expressed in three axes of components as follows:

$$\sum T_{x'} = I_{x'}\frac{d\omega_{x'}}{dt} - \omega_{y'}\omega_{z'}(I_{y'} - I_{z'}) \tag{2-1}$$

$$\sum T_{y'} = I_{y'}\frac{d\omega_{y'}}{dt} - \omega_{z'}\omega_{x'}(I_{z'} - I_{x'}) \tag{2-2}$$

$$\sum T_{z'}{=}I_{z'}\frac{d\omega_{z'}}{dt}{-}\omega_{x'}\omega_{y'}\left(I_{x'}{-}I_{y'}\right) \tag{2-3}$$

where, $T_{x'}$, $T_{y'}$, $T_{z'}$ are the torques acting on the particle, $I_{x'}$, $I_{y'}$, $I_{z'}$ are the principal moments of inertia, $\omega_{x'}$, $\omega_{y'}$, $\omega_{z'}$ are the angular velocities, and $\frac{d\omega_{x'}}{dt}$, $\frac{d\omega_{y'}}{dt}$, $\frac{d\omega_{z'}}{dt}$ are the derivative of the angular velocities with respect to the each time step. All the values are acting around the principal axes. The new position and orientation of the

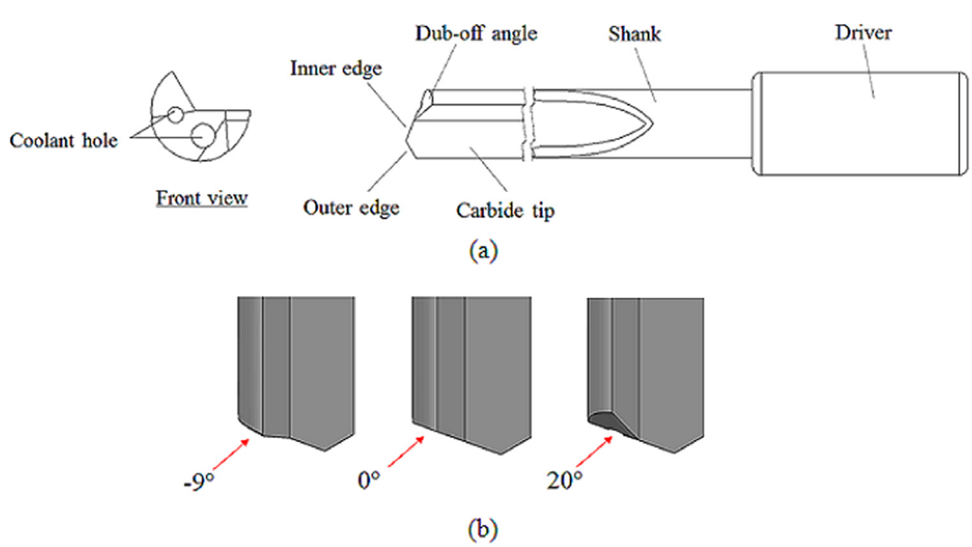

Fig. 2. Study of the effects of shoulder dub-off on coolant flow behavior. (a) Components overview of a single-lip gun drill; and (b) Varying dub-off angle from −9° to +20°.

Download English Version:

https://daneshyari.com/en/article/780413

Download Persian Version:

https://daneshyari.com/article/780413

Daneshyari.com