Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 56 (2016) 109 – 114

www.elsevier.com/locate/procedia

9th International Conference on Digital Enterprise Technology- DET2016 – "Intelligent Manufacturing in the Knowledge Economy Era

Carbon fiber composite materials finite element simulation analysis of cutting force

Mingyang Wu[a], Yongbin Gao[a,]*, Yaonan Cheng[a], Bo Wang[a], Tingyu Huo[a]

[a]*The key lab of National and Local United Engineering for "High-Efficiency Cutting&Tools", Harbin Univ. of Sci. and Tech, Harbin,150080,China*

* Corresponding author. Tel.:18845875031.E-mail address:gyb211@163.com

Abstract

Carbon fiber composite material as an advanced composite material is widely used in aviation, aerospace, defense and automotive, electronic information and high-speed machinery and other civilian areas. Since the carbon fiber composite material having a large strength, anisotropy, and poor thermal conductivity and other characteristics. Especially interlayer low intensity, under the action of cutting force when cutting prone to delamination, tearing and other defects, especially in the process of drilling, processing quality is difficult to guarantee. For this stage of carbon fiber composite material machining problems, in this paper, based on the mechanical properties and the finite element technology of the cutting process, to establish the carbon fiber composite material drilling finite element model, and application Deform-3D finite element simulation software to simulate the drilling process of the carbon fiber composite material, to simulate and analysis drilling force and torque for drilling process and verify the simulation results through experiments. More research has important significance to reduce surface defects and tool development and design of the carbon fiber composite material processing.

Peer-review under responsibility of the scientific committee of the 5th CIRP Global Web Conference Research and Innovation for Future Production

Keywords: Finite element analysis; Drilling force; Drilling experiment; Carbon fiber composite material

1. Introduction

With the continuous improvement of composite materials properties, material machining technologies are increasingly high requirements. Due to the special mechanical properties of the composite materials, resulting in poor cutting performance. It can easily cause large plastic deformation and processing defects during the processing, such as delamination, burrs, etc. Lead to serious tool wear affecting machining precision and efficiency. Using finite element simulation method can observe the physical phenomena in the process to simulate actual system by physical or mathematical models. Realized the visualization of parameters value, it can also be used to predict the surface defects in materials processing, guide the tool design and parameters optimization and optimize the cutting process parameters and so on. Therefore the application of finite element techniques to study the cutting process has a very important significance [1].

In order to study the cutting mechanism of composites materials, the finite element technique was applied to simulate the cutting process of composite materials. Foreign scholars Arola and Ramulu simplified the cutting process of unidirectional composite material to orthogonal cutting model based on finite element theory. The resulting of cutting force simulation and experimental values were compared, proven simulation results and experimental results are similar [2].Mahdi etc. established a two-dimensional, three-dimensional finite element model of composite materials cutting. It is equivalent to an isotropic metal material, analyzes the relationship between cutting force and the fiber direction [3-4].In recent years, with the development of drilling model, drilling model is used in machining and finite element analysis, Chandrasekharan and Gong Ehmann were established drilling model, respectively [5].Carlos Santiuste etc. established a finite element model of two-dimensional cutting for long fiber composite materials that used in

Peer-review under responsibility of the scientific committee of the 5th CIRP Global Web Conference Research and Innovation for Future Production
doi:10.1016/j.procir.2016.10.031

aviation, including carbon fiber composite materials and glass fiber composite materials. By finite element calculate analysis of the influence of the fiber direction to the axial force and the impact on the machining surface quality of processing [6-7].

Now the key research direction for composite materials cutting mechanism is still relying on experimental means, especially carbon fiber composite materials. Application of finite element technology to analysis the cutting force and torque variation during cutting still in the exploratory stage. However, finite element simulation technology for understanding the processing mechanism of the composite materials and promote their efficient, high-quality, high-precision machining has far-reaching significance[8-9]. Therefore, this article focuses on finite element simulation analysis and research of cutting force for the carbon fiber composite materials.

2. Carbon fiber composite materials mechanical properties analysis of drilling process

2.1. Distribution of cutting forces during drilling process

The drilling of carbon fiber composite material cutting force distribution diagram is shown in Fig.1. On the main cutting edge of drilling bit with different points, the rake angle is constant changing, which is from positive to negative gradually, from the most outside point of main chip edge to chisel edge, and on the chisel edge negative rake angle has reached the maximum.

The line speed of drilling bit at chisel edge is low, therefore it can not directly play a role in cutting, but mainly relying on the compression of carbon fiber composite materials to make deformation, when the material deformation reaches the compressive strength limit of materials it will be broken and separated. Therefore, the chisel edge and negative rake angle sections chips generated in a manner are similar to fiber comminuted, and it is different from the fiber cutting type of the positive rake angle part. The force of chisel edge and the main cutting edge at the negative rake angle acting on the carbon fiber composite material can consist of the two directions forces: one is Fv1 along the cutting direction force, another is Fz1 axially downward force, due to Fv1 is small, so Fz1 is a major component which is one of the main sources of the axial force and has an effect on the process of downward pressing force to the workpiece, and it is also one of the main reasons for causing delamination, tearing defects. The positive rake angle part of the main cutting edge is the main component of removing material, Fz2 acts on the upper part of the laminated layer, not only making peel it up, but also one of the main reasons causing delamination and tearing.

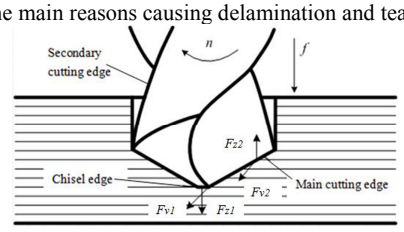

Fig. 1. Drilling CFRP cutting force distribution.

2.2. The stress and strain analysis in the process of drilling composite materials

Machining process is a process of elastic-plastic deformation coupling, and with large deformation and large strain, the linear relationship of elastic-plastic cannot explain composite material cutting process, because the composite material is composed of reinforced phase and matrix, at this point the relevant content of nonlinear finite element should be considered it is different from the way of the linear finite element stress and strain. Aimed at cutting process simulation of composite materials, also included the shock, collision, forming etc. the analysis of dynamic problems,elastic-plastic stress-strain relationship model is the most classic material nonlinear mechanical problems, it has become the indispensable model in finite element analysis material nonlinear problems ,and now this module is used in a large number of computer-aided systems software.

Theory of elasticity with respect to the plasticity theory is relatively simple, because it obey generalized Hooke's law, such as (1) equation:

$$\sigma = E\varepsilon \quad (1)$$

wherein σ - stress of the material, E - the elastic modulus, ε -strain values.

3. The cutting process of finite element simulation

3.1. The establishment of the material constitutive model

Finite Element Analysis of a number of areas currently being used in engineering design and analysis, from car manufacturing to aerospace, machinery manufacturing and processing almost all areas are inseparable from the finite element technology. Popular finite element software include: ANSYS, ABAQUS, MARC, Deform-3D and the like. Deform-3D is a simulation system based on industry relevant for the analysis of metal forming and heat treatment processes, including imported models, meshing, adding constraints, post-processing step. Finite Element Simulation of machining is an extremely complex process, not only need to have knowledge of the theory of finite element basis, while closely related to the mechanics, in the application of simulation software, to combine elastic mechanics, knowledge of fracture mechanics and plastic mechanics In the heat conduction and tribology aid achieve simulation. Carbon fiber composite material cutting simulation process is based on the theory of elastic-plastic deformation of materials, this paper finite element simulation software Deform-3D conduct drilling process simulation, analysis of variation in the drilling process drilling force and torque.

Due to the finite element simulation software Deform-3D provided in the material library does not include the carbon fiber composite material models, it is necessary to establish a new material model, then the need for mechanical and physical properties of the material-related parameters. The constitutive model of metallic materials include: Young's modulus, Poisson's ratio, thermal expansion coefficient, thermal conductivity, heat capacity, radiation and the like. For special structure of carbon fiber composites, and traditional metal materials different, it is difficult to determine the constitutive relation. According to a feature flow stress-strain curve, choose empirical formula as an effective means of building a carbon fiber composite material constitutive model,