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Review on the Progress of Damage Suppression in Carbon Fiber Reinforced Composites

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Abstract: *Carbon fiber reinforced plastics (CFRP) is widely used in aerospace, transportation and other fields because of its light weight, fatigue resistance and corrosion resistance. However, due to the low interlaminar strength and poor thermal conductivity of the material, the defects such as delamination and matrix cracking are easy to appear in the processing, which affects the product quality. Many scholars have done a lot of work to suppress these machining damages. In this paper, the machining damage suppression of carbon fiber composites is reviewed from three aspects: new technology aided manufacturing, tool optimization and cutting parameter optimization, progress, damage inhibition mechanism of carbon fibers.*

Keywords: *Damage Suppression, Carbon Fiber, Reinforced Composites, CFRP*

1. Introduction

Carbon fiber reinforced plastics (CFRP) has the characteristics of light weight, excellent corrosion resistance and fatigue resistance. With the increasing application of CFRP, ensuring the machining quality becomes the research direction [1]. Due to its poor thermal conductivity and low interlaminar strength, CFRP is a typical hard to machine material. It is easy to cause delamination, matrix cracking and other damages by traditional processing, as a result, the bearing capacity of the workpiece is reduced. Therefore, it is very important to ensure the machining quality and restrain the machining damage. In view of the development of damage suppression in CFRP machining in recent three years, this paper reviews the new technology aided manufacturing, tool optimization and parameter optimization, and summarizes the advantages and disadvantages of each processing method.

2. Damage formation mechanism

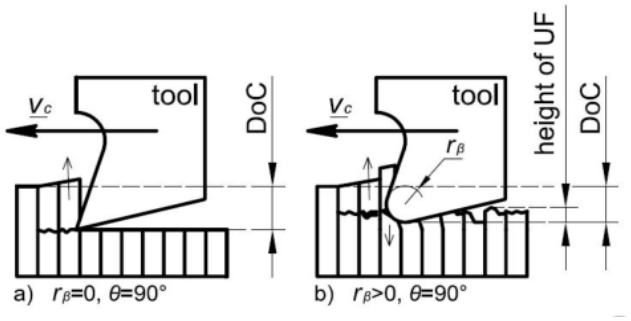

Figure 1: Effect of anterior angle on damage [3]

Due to the particularity of the material, the removal method of CFRP is brittle fracture [2] caused by extrusion, shear and bending. The study of damage formation mechanism can reduce processing defects and provide theoretical basis for reducing processing cost. Because of the low bonding strength between layers, delamination is easy to occur under the action of thrust, and the more severe the delamination at the outlet with weaker support strength [3]. The failure process of material in cutting process is a complex progressive failure process. In the early stage of cutting force, the initial failure is manifested as fiber fracture and matrix crack. With the continuous action of cutting force, matrix crack propagation leads to material performance degradation and workpiece separation. The under plane damage is mainly the matrix tension compression / shear failure under the cutting force, With the increase of cutting force, the failure is more likely to occur, and the depth and area of under-plane damage increase correspondingly

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[4]. Cutting force is an important factor affecting the machining performance of CFRP. The use of special tools can effectively reduce the machining defects caused by cutting force.

3. New technology aided manufacturing

At present, the new technologies to restrain CFRP damage include ultrasonic vibration assisted machining, laser machining and abrasive water machining.[5]w of the poor machining quality caused by tool blockage and sticking, Li Zhe et al. Based on the principle of ultrasonic vibration casing drilling (uvcd) and the theory of acoustic pressure flow, it is concluded that uvcd can greatly reduce the phenomenon of tool sticking and blocking during the cutting process, Improve the quality of hole processing. [6] machining has the characteristics of high precision and flexibility, and is widely used in the milling and drilling of CFRP. The heat released by [6] processing makes the material expand and form defects such as surface damage and delamination.[7]s paper, the laser processing technology of "two picosecond" is proposed, Moreover, the tensile strength and fatigue performance are better than the traditional processing method. [8] aofan (M24) carried out a simulation modeling experiment on the drilling process of carbon carbon composite materials. It was found that the effect of abrasive particles on the material was grinding impact, and the lateral force on the material was small, which could effectively restrain the delamination defects. [9] eyuan (M25) proposed that the CNC ultra-high pressure water cutting machining of CFRP can make the workpiece achieve high dimensional accuracy and surface quality without thermal deformation and delamination. High pressure water cutting has the advantages of high processing efficiency and strong adaptability, but it has high maintenance cost and easy to pollute the environment

4. Tool Optimization

The cutting tool rake angle can change the material removal mechanism and change the fiber from crushing / compression failure to shear failure, which can effectively restrain the processing damage [10].[11] ved tool with 130 °top angle and 18 °rotation angle was designed with diamond coated cemented carbide. The experiments show that the groove can promote fiber fracture, reduce heat generation and inhibit delamination. Wang [12] considered the influence of tool structure on the out of plane curvature, and proposed that the multi tooth tool with right-hand micro cutting edge and left-hand micro cutting edge alternately can significantly reduce surface damage than other multi tooth tools. Chen [13] made a comparative experiment on the cutting performance of spiral staggered edge and diamond edge milling cutter in milling CFRP, the diamond milling cutter with segmented cutting edge has better wear resistance and more stable machining surface quality. Hale [14] studies the influence of drill point geometry on the quality of hole in and out based on the macro finite element (FE) model. The results show that the interlayer damage can be significantly reduced by using double angle drill point bit. Kwon [15] used stepped drill to drill CFRP, the experimental results show that it can effectively restrain the delamination of the material at the bit exit. Kong [16] analyzed the characteristics of track drilling and ladder drilling, and put forward a rail drilling reamer (ODR) which combined the advantages of the two tools. The fiber removal mode at the outlet was changed to upward push cutting. The experimental results show that the new tool can significantly reduce the delamination damage.

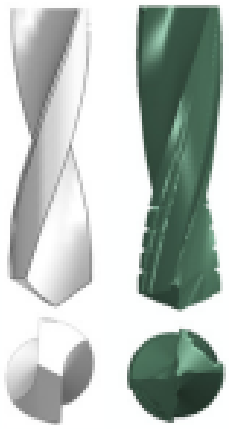

Figure 2: Schematic diagram of grooved tool [13]

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5. Optimization of cutting parameters

Cutting depth, feed rate and cutting speed have significant effects on the damage formation. The deeper the cutting depth is, the more serious the fiber deformation is. The greater the cutting depth is, the greater the fiber deformation is [17]. The feed rate has the most significant effect on the thrust and delamination [18]. The influence of feed rate on cutting force is greater than that of spindle speed, Yan [19] through using twist drill and cemented carbide milling cutter in ud-cfrp machining experiment, it is concluded that the cutting coefficient and edge coefficient of orthogonal cutting of CFRP are closely related to the cutting depth and cutting speed. The optimal process parameters of track drilling are feed speed 0.049 mm / rev and screw pitch of feed screw 3 mm. The cutting speed of [18] is controlled by cutting temperature, Low feed can ensure the quality of the outlet.

6. Conclusion

In recent years, CFRP has been gradually extended from aerospace to civil fields, and the suppression of processing damage has become an important factor in reducing the price of materials. Therefore, this paper reviews the status and progress of damage, and finds that there are still many problems worthy of further study

(1) Laser cutting is easy to produce high temperature and cause carbonization, which will damage the mechanical properties of the workpiece.

(2) High pressure water cutting has great environmental pollution, high processing cost, complex equipment maintenance and strict site selection requirements.

(3) Machining CFRP has serious tool wear, and diamond bit processing leads to high cost, which will be one of the reasons to limit the price reduction of CFRP.

Brief introduction to the author

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References

[1] Abena A, Essa K. 3D micro-mechanical modelling of orthogonal cutting of UD-CFRP using smoothed particle hydrodynamics and finite element methods [J]. Composite Structures, 2019, 218(JUN.): 174-192.

[2] An Q, Cai C, Cai X, et al. Experimental investigation on the cutting mechanism and surface generation in orthogonal cutting of UD-CFRP laminates [J]. Composite Structures, 2019, 230: 111441-.

[3] Geier N, Davim J P, Szalay T. Advanced cutting tools and technologies for drilling carbon fibre reinforced polymer (CFRP) composites: A review [J]. Composites Part a Applied Science and Manufacturing, 2019, 125:105552.

[4] Xu HongzhangMilling force analysis model and surface damage formation in side milling of CFRP unidirectional plate [D] Liaoning: Dalian University of technology, 2020

[5] Li Zhe, Wang Xin, Zhang Yi, et alMechanism and experiment of efficient chip removal in drilling with CFRP ultrasonic vibration sleeve grinding [J] Journal of Beijing University of Aeronautics and Astronautics, 2020 (1): 12

[6] Lu Ruihu, Hou HonglingLaser cutting of carbon fiber composites [J] Forging equipment and manufacturing technology, 2020, 55 (5): 6

[7] Ouyang W, Jiao J, Xu Z, et al. Experimental study on CFRP drilling with the picosecond laser "double rotation" cutting technique [J]. Optics & Laser Technology, 2021, 142(4): 107238.

[8] Zhu Chaofan, Chen Xiaochuan, Bao JinsongSimulation modeling and experimental study of laser and water jet combined drilling process for carbon carbon composites [J] Modern manufacturing engineering, 2020 (1): 8

[9] Wei, Wang Gang Study on processing method of carbon fiber reinforced composites [J]Aging and application of synthetic materials, 2021, 50 (3): 4

[10] Shu L, Li S, Fang Z, et al. Study on dedicated drill bit design for carbon fiber reinforced polymer drilling with improved cutting mechanism [J]. Composites Part a Applied Science and Manufacturing, 2020, 142: 106259.

ISSN 2706-655X Vol.4, Issue 7: 48-51, DOI: 10.25236/IJFET.2022.040710

[11] Sugita N, Shu L, Kimura K, et al. Dedicated drill design for reduction in burr and delamination during the drilling of composite materials [J]. CIRP Annals, 2019, 68(1): 89-92.
[12] Wang F, Zhang B, Jia Z, et al. Structural optimization method of multitooth cutter for surface damages suppression in edge trimming of Carbon Fiber Reinforced Plastics [J]. Journal of Manufacturing Processes, 2019, 46(Oct.): 204-213.
[13] Zadafiya K, Bandhu D, Kumari S, et al. Recent trends in drilling of carbon fiber reinforced polymers (CFRPs): A state-of-the-art review [J]. Journal of Manufacturing Processes, 2021, 69(1–4): 47-68.
[14] Hk A, So A, Yj A, et al. Thermal influence on surface layer of carbon fiber reinforced plastic (CFRP) in grinding[J]. Precision Engineering, 2020, 65: 53-63.
[15] Hale P, Ng E G. 3D Finite Element Model on Drilling of CFRP with Numerical Optimization and Experimental Validation [J]. Materials, 2021, 14(5): 1161.
[16] Kong L, Gao D, Lu Y. Novel tool for damage reduction in orbital drilling of CFRP composites – ScienceDirect [J]. Composite Structures, 2021.
[17] Shen Y, Yang T, Liu C, et al. Cutting force modeling in orthogonal cutting of UD-CFRP considering the variable thickness of uncut material [J]. The International Journal of Advanced Manufacturing Technology, 2021(1-4).
[18] Yan X, Zhang K, Cheng H, et al. Force coefficient prediction for drilling of UD-CFRP based on FEM simulation of orthogonal cutting [J]. International Journal of Advanced Manufacturing Technology, 2019(9-12).
[19] Elgnemi T, Songmene V, Kouam J, et al Experimental Investigation on Dry Routing of CFRP Composite: Temperature, Forces, Tool Wear, and Fine Dust Emission[J]. Materials 2021, 14(19): 5697.