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FINITE ELEMENT MODELLING OF CUTTING FORCES IN DRILLING THERMOPLASTIC COMPOSITES: A REVIEW

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ABSTRACT

Theapplication ofthermoplastic composites has taken a significant pace during last decades.Most development is in transportation sector (automobile and aircraft industry) and electronic industry due to its unique properties such as high strength to weight ratio, high impact strength, corrosion resistance, damage tolerance and recyclability. The most common techniques used in fabrication and assembly are drilling. Drilling induced delamination is the most accountable reason for the rejection of more than 60% components. Several studies have been performed in recent years to tackle this factor. This paper is literature survey on use of finite element analysis tool to observe drilling parameters (feed rate and RPM), principal behind selection of tool (geometry and material) and programming techniques which can be used.

KEYWORDS: Finite Element Method, Principal of drilling, thermoplastic composites

I. INTRODUCTION

Thermoplastic possesses excellent mechanical properties with the combination of fibers such as a glass and carbon. Thermoplastic offers the hybrid material solution. Transport and storage is easy. These materials also have recycling routes and re-moldable property. Thermoplastic when admixture with fibers inherits following properties: anisotropy, heterogeneity and different fiber orientation. Industries from aeronautical, transport and domestic product employ mechanical operation and processes to achieve assembly operation. Use of fasteners such as bolt, screws and rivets are common. Drilling operation is the most crucial of all. Drilling of ferrous material is easy, but same is not possible for composite materials. Fiber pull out at entry and exit, micro cracking, matrix softening due to high rpm, stress concentration are critical factors. The better solution lies in hand of better analytical, mechanical and mathematical experimentation. Various analysts and researchers have provided few significant results which might be used to develop better mechanism.
Singh et al. proposed a finite element approach which is used to study the effect of drill point angle on drilling induced damage while drilling unidirectional glass fiber reinforced plastic laminates. It was obtained that 90° drill point angle given superior result than 104° and 118° [1]. Isibilir et al. formulated a Mechanical

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Langrangian finite element method to simulate the drilling process of UD CFRP. The result obtained shows that cutting parameters have a significant influence on delamination, torque, thrust force and stress. Induced thrust force, torque and delamination increases with feed rate and inversely proportional to cutting speed [2]. Similar damage based fracture mechanics theory is formulated by Durao et al. [3] and Doomra et al. [4].

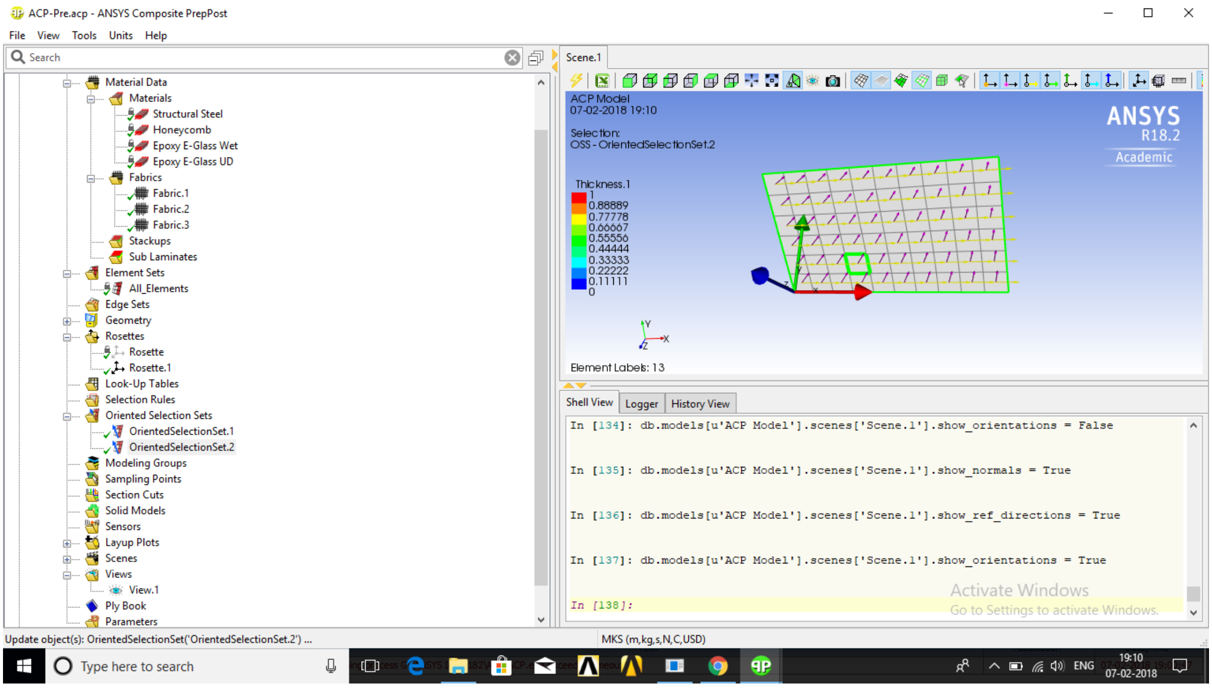

Fig.1 orientation through rosettes

Phadnis et al. used 3-D Langrangian FE Model in drilling of CFRP. The model involved the set of machining parameters such as drill, spindle speed and feed on average critical thrust force and torque during drilling [5]. Usui et al. illustrated a FE model where assumption is that cutting energy is sum of surface energy and friction loss. He predicted many failure modes and damage types in the UD-CFRP. He obtained torque and the thrust force effect with reasonable accuracy [6].Giasin et al. studied the hole quality metrics (surface roughness, hole size, circularity error, burr formation and delamination) and modeling of Johnson and cook model have been proposed [7].Thrust and torque determined by finite element modeling showed good results when compared with the experimental results observed by Teja et al. He observed that utilization of FEM analysis tool will improve the quality of drilled area, if online monitoring is introduced and will remove the complexities, reduce time and computational cost [8]. Kahwash et al. aims to show the current practices used in modeling of cutting FRP. It includes analytical, numerical, mechanistic and empirical approaches based on statistics to obtain optimized parameters [9]. Shetty et al. illustrated the detailed work on machining composites for past 30 years. This survey consists of conventional and numerical simulation [10].

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II. MECHANICS OF DRILLING

II.1. PRINCIPAL OF DRILLING:

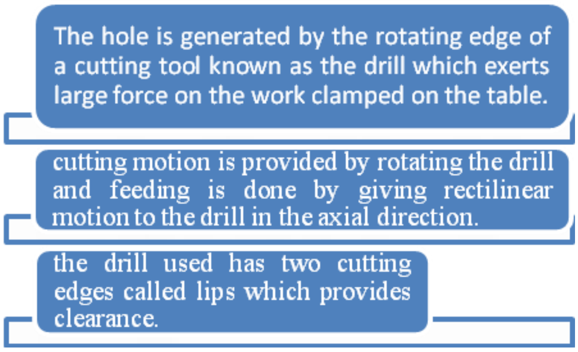

Fig.2 Principal of Drilling

Mechanics of drilling basically involves complex drilling bits tool and geometry. Tsao and Hocheng conducted parametric study on thrust force of a core drill.The experimental results show that reduced thickness of core drill, large grit size of diamond, low feed rate and medium spindle speed are effective in reducing the thrust force [11].Hence we can say that

drilling involves spindle speed, feed rate, and depth of cut as input parameter.The axial force

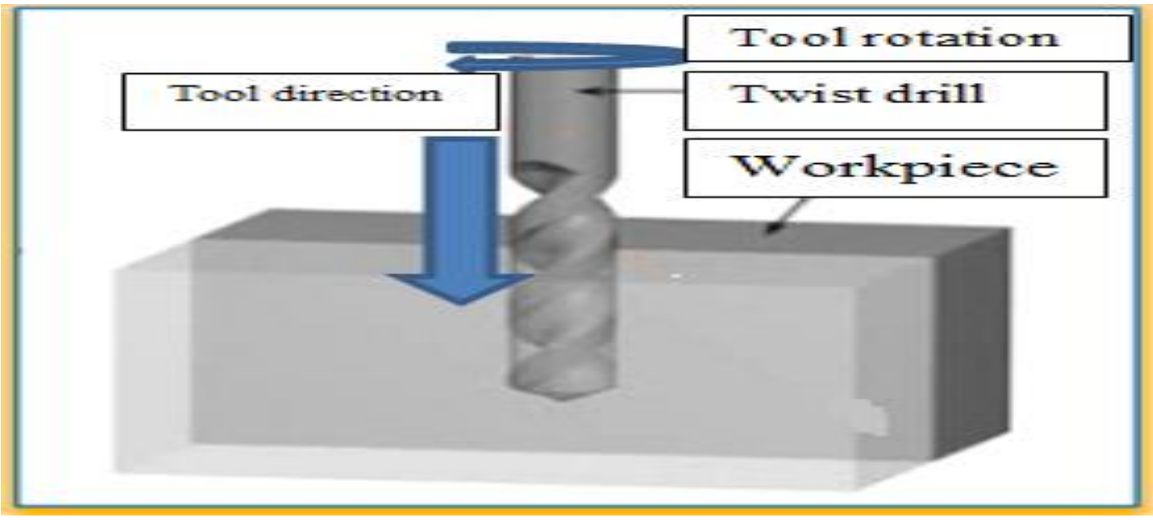

Fig.3 Process of Drilling

is exerted by the spindle on the specimen. The better edge of drill bit results in the mechanics of drilling. Material mechanical and physical property decides the cutting operation and dependence of parameter.

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II.2 VERTICAL MACHINING CENTER WORKING PRINCIPLE:

Vertical machining centre use the servo feedback mechanism as its electronic control unit. The basic principle matches with mechanics of drilling. Basic fact is that an automatic control system provides superior control at the end.

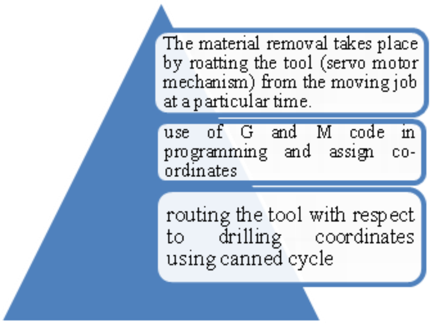

Fig.4 Working Principal of Vertical Machining Centre

Programming techniques helps us to control and route the tool and drilling process parameter. Nagaraja et al. performed an experiment with soft computing techniques during drilling of bi-directional CFRP. He used response surface methodology and genetic algorithm to compare the results and optimize parameter. Result shows genetic algorithm as a better option [12].

III. TOOL SELECTION AND GEOMETRY ANALYSIS

Tool geometry and material selection is an essential aspects in mechanics of cutting .Tool geometry of drill bits such as clearance angle, lip angle, web width, chisel cutting edge, diameter of drill decides the types of material to be cut.

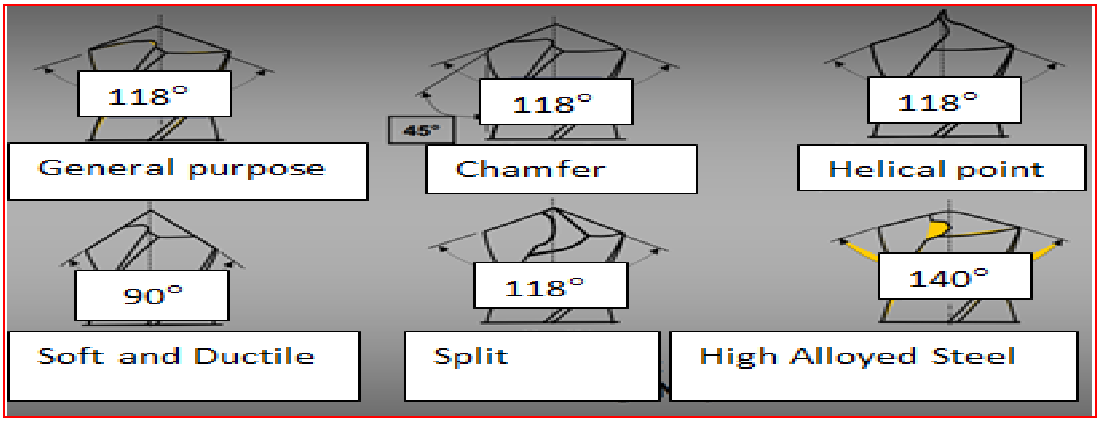

Fig.5 Drill Point Angles

Durao et al. have given drilling tool geometry evaluation techniques for reinforced composite laminates and compared their geometries.

Fig.6 Drill Bits Being Used in Aerospace Industry

For the experimental condition presented the most adequate tool for higher feed rates is the twist drill with a 120 degree point angle. Special step drill could also be a good option [13].

IV. CO-RELATION OF THRUST FORCE WITH RPM, FEED RATE AND DAMAGE ANALYSIS

The relation between different mechanical parameter is a matter of huge experimentation, investigation and analysis. Revolution per minute, feed rate and thrust force are directly related to each other. At the beginning of drilling process for the first cut drilling speed should be high, depth of cut and feed rate should be low for better finishing cycle. At mid of process all the parameters can be increased. At the exit point speed of cut should be controlled. Moreover a backup plate is required to drill thermo composites.

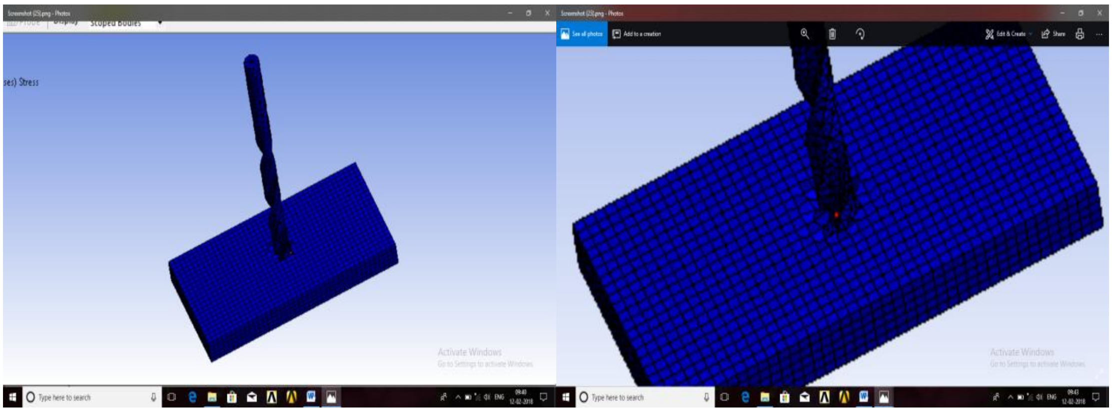

Fig.7Drilling Damage at Entry

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Several researchers worked on to optimize the cutting parameters and investigated the effects on thrust force and torque. They found that uncontrolled effects of parameter led to fibre pull out at entry and exit. Also micromechanical damage and average surface roughness of hole were largely deviated.

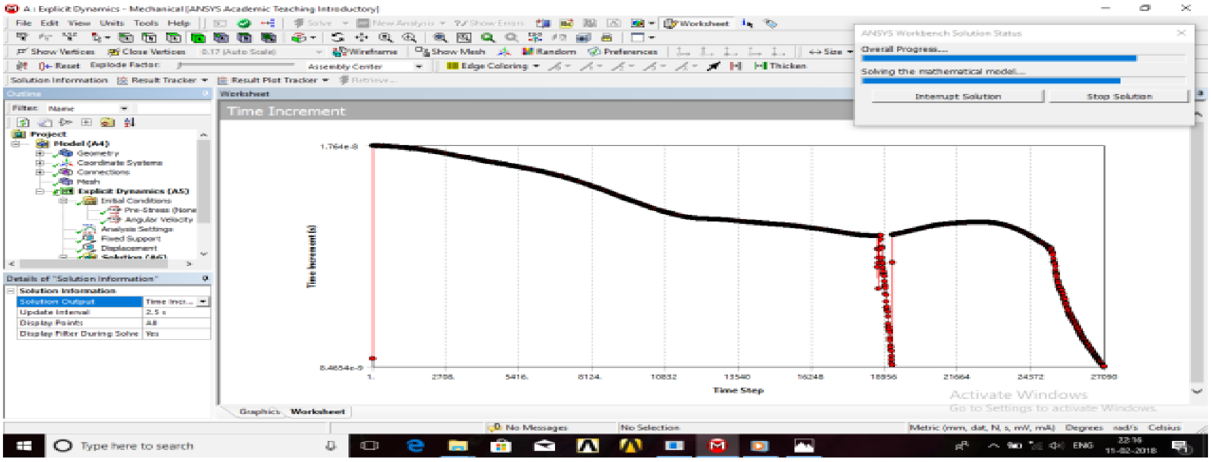

Fig.8 Time Increment graph showing drill mechanism

Relative significance of drilling parameters on the thrust force and torque is as significantly

Specification of input parameter

01	Length(mm)	100
02	Width(mm)	100
03	Height(mm)	10
04	Hole diameter(mm)	12
04	No of nodes	73701
05	No of elements	15858
06	Applied load(KN)	100
07	Minimum stress(MPa)	.000516
08	Maximum stress(MPa)	0.015
09	Minimum strain energy(J)	.000437 51
10	Maximum strain energy(J)	.000006283

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Fig.9 input parameter

investigated statistically. The investigation shows that feed rate at exit need to be reduced. Feed rate and point angle of drill bits govern the thrust force behavior in drilling composites. Feed rate is the most influencing parameter followed by spindle speed and drill diameter is least influencing on the thrust force proposed by M. Ramesh et al. using quadratic response models[14].

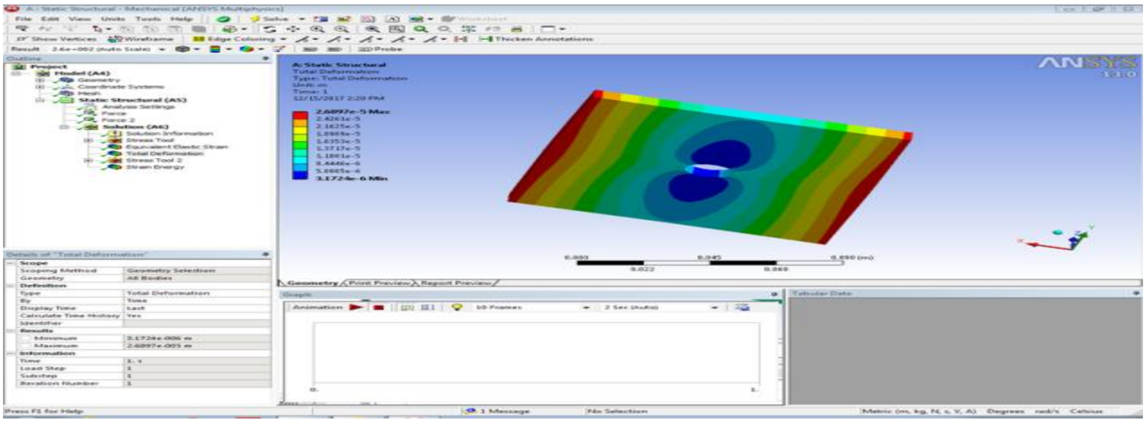

Fig.10 Total deformation through ANSYS test

Transfer function can be established using state space modeling (mathematical modeling) to capture dynamics of drilling have been demonstrated by Singh et al [15]. He stated that third order function is required for thrust force and feed rate analysis. Experimental and numerical study of drilling of carbon fiber reinforced plastic with AL alloy stacks has been formulated. Use of double cone drills induce less thrust force compared to standard twist drill. Critical thrust force is responsible for delamination [16]. Assessment in drilling of C/SiC composites using brazed diameter drill has been observed. Result obtained provided that drilling is difficult due to anisotropic behavior. Use of supportive plate is advised [17]. With axial force there is circumferential moment which contributes to delamination [18]. Surface texture of drilled holes is analyzed using profilometry and scanning electron microscope [19].

Optimization of process parameters in drilling composites using statistical model (Taguchi, ANOVA, Box-Henken model, Grey Relational Analysis) is studied [19, 20, 21, 22, 23, 24, 25, and 26].

Research in this field is limited .The scope of further development is there, as validity of highest level have not been analysed on present modeling. Damage assessment, drilling tool geometry evaluation, numerical simulation based model have been studied to check the near-net-shape condition of composites.

V.CONCLUSION

The paper aims at drawing following conclusion:

- The report **"**Composites Market by Fiber Type (Glass, Carbon), Resin Type (Thermoset and Thermoplastic), Manufacturing Process (Layup, Filament Winding, Pultrusion), Application (Transportation, Aerospace & Defense, Wind Energy), Region - Global Forecast to 2022"**,** The composites market is projected to grow from USD 72.58 Billion in 2016 to USD 115.43 Billion by 2022, at a rate of 8.13% between 2017 and 2022. Hence machining procedure and upgrading technology research process should be carried at large pace.

- Feed rate and rpm are the main parameters affecting thrust force. FE analysis too validated the use in several papers studied.
- High rpm results in delamination at exit of drilling process. Tool geometry such as clearance and drill bit angle is in direct relation with delamination and material damage.

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