DAMAGE ANALYSIS OF DRILLED HOLES AND STANDARD MECHANICAL TEST ON THERMOPLASTIC COMPOSITES USING FINITE ELEMENT METHOD: A REVIEW

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ABSTRACT

The thermoplastic composites abundant utilisation in aerospace, transportation, electronic industry and even in domestic product has increased sharply. The main reason is recycling routes and re-mouldable property, hybrid material solution, transportation solution. Yet the major issue underlying is the mechanics of cutting (drilling operation) and post effects on making drill operation (the actual diameter, surface roughness, damage of plates at end of drill). The characteristics properties such as anisotropy, heterogeneity and fibre orientation makes drilling process complex. The significance of paper is post analysis of drilled holes using Finite Element Method Tools. The survey of standard mechanical test (tensile, compressive and failure mode) of thermo composites is studied.

Keywords: Finite Element method, Thermo composites, ANSYS, Drilling, Mechanical Test, Progressive Damage Analysis

I. INTRODUCTION

Thermoplastic composite material is the mixture of fibres as a reinforcement and plastic or polymer as a matrix to obtain the combined or superior property. The combined material offers high standard mechanical performance characteristics such as high strength to weight ratio, high impact strength, corrosion resistance and damage tolerance. Near- Net- Shape composite manufacturing led to global forecast yearly. The composite market is projected to grow at the rate of 8.13% in next five year. The fabrication and assembly process moves through various joining process such as use of rivets, fasteners, nut and bolts. This assembly operation requires large no of drilled holes. Due to unevenness in texture of composite material and different thermal properties drilling phenomenon becomes cumbersome. To tackle these issues several experiments, soft computing techniques, mathematical modelling, statistical control has been performed and post analysis of drilled holes, cylindricity, surface roughness and diametric parameter has been analysed. To study and optimize the parameters such as cutting speed, feed rate, axial force, torque, chisel edge length, tool diameter various modelling approaches has been used.Kahwash et al. [1] discusses the applications of the different modelling approaches to conventional cutting processes of composites with emphasis on analytical modelling of cutting forces and delamination. Moreover an outline of the modelling approaches has been discussed through paper and supports highest use of empirical model. In simple terms most of the researchers have utilized statistical and mathematical modelling analysis with the help of soft computing techniques.Abrao et al. [2] presented a review paper on drilling fibre reinforced plastic. The main aim is to understand the complex process of machining of composite materials, more specifically on drilling of glass and carbon fibre reinforced plastics. Aspects such as tool materials and geometry, machining parameters and their influence on the thrust force and torque is assessed. In addition the quality of the holes produced is also assessed, with special attention paid to the delamination damage.

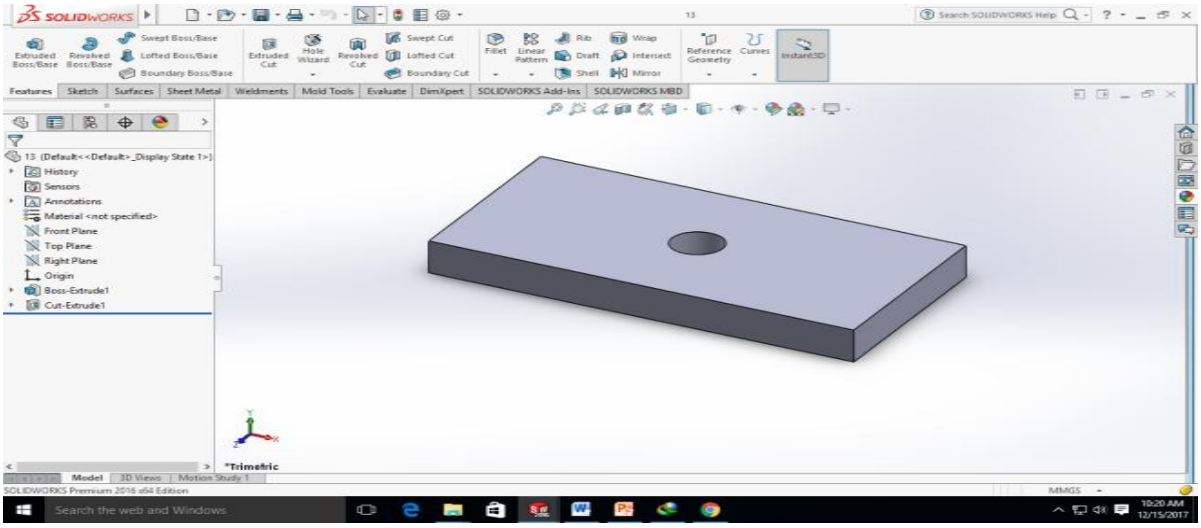

Fig. 1 Specimen for progressive damage analysis

Singh et al. [3]presented a mathematical model to assess the dynamic drilling phenomenon of fibre reinforced plastic composites. He proposed that Transfer function can be established by doing experiments using step input. Third order model represents the dynamics of drilling in better way than lower order model. Therefore conversion of third order function in three first order differential equation is necessary to visualize the impact of results. Delamination is a major concern in drilling of thermoplastic composites. It can be described mainly at two places. One at the entry point of drill tool called entry level delamination or pull in delamination. Other is at exit of the tool when there is no backup support called pull out delamination. In 1990 R. Robert [4] presented a modern approach to drill optimisation on printed circuit board. He used Taguchi model to optimize the temperature parameter of drill bit and provided a theory to further look at.

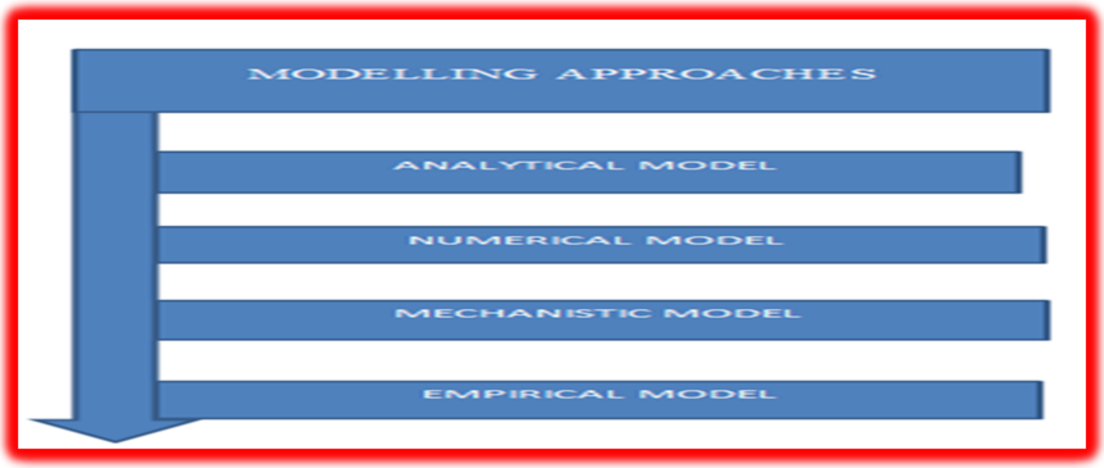

Fig.2 modelling approaches given by Kahwash[1]

II. DRILLING OF THERMO COMPOSITES:

Drilling induced damage due to sudden striking of tool and vibration results in rejection of material and loss of huge investment cost and time. To control these critical issues we need to address the basic principle of drilling phenomenon. The basic principle of drilling is "a metal cutting process in which rotation of cylindrical tool takes place at a high RPM or speed in order to create a desired hole in a work piece".These basic principles require use of other parameters also. In association with these Abrao et al. [2] illustrated the basic principal parameter aspects while drilling fibre reinforced plastic. Fig. 3 classifies these in to three categories.Taso and Hocheng [5] tried to illustrate the major analytical aspects such as practical use of special drill bits, pilot hole and back-up plate, and the employment of non-traditional machining method.

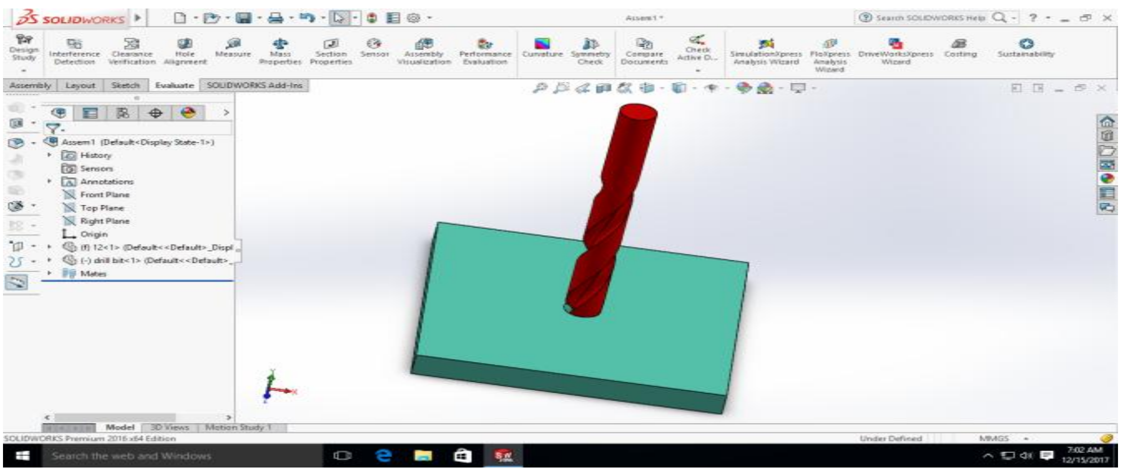

Fig.3 drilling process shown from strike of chisel edge.

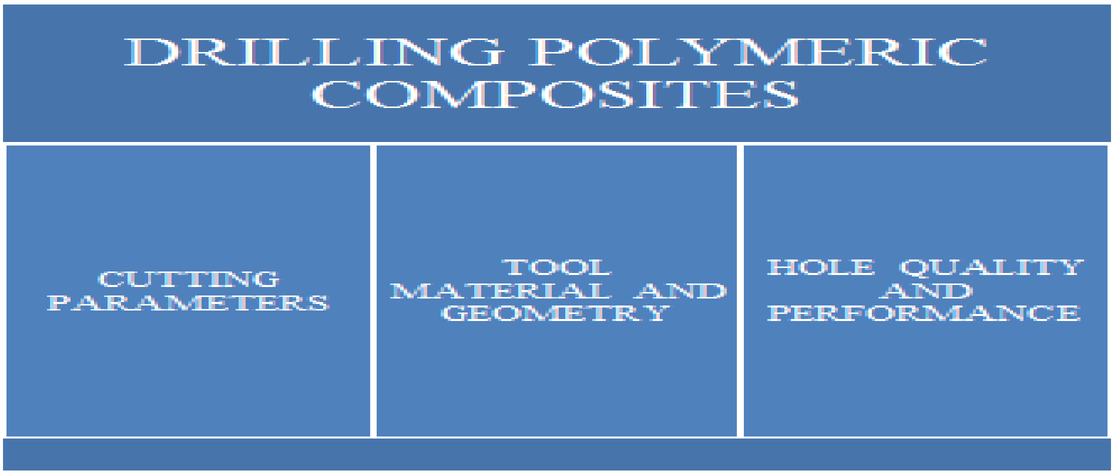

Fig. 4 Principal Aspect Parameter by Abrao et al. [2].

Through schematic diagram Tsao and Hocheng [6] shows the use of dynamometer setup and backup plate use. Lachud et al. [7] conducted an experiment and propose a model which directly correlates with the axial penetration of the drill bit to the delamination for the last few plate. Takabi et al. [8] presents a comprehensive survey to analyse the cutting effect of tissue in bone. Fracture toughness is used to describe the drilling process and Johnson-cook model for analysis using Ansys tool software. M.R. Wisnom [9] provided the application of cohesive zone interface elements to model discrete matrix dominated failure in polymer composites.This can accurately represent the physicalmechanisms controlling damage development and failure; hence give excellent simulations of a wide variety of phenomena including delamination, laminate in-plane failure, and behaviour at notches, impact damage and structural failure due to debonding.

III. DRILLING ASSISTED TOOLS AND GEOMETRY

The most critical issues to address while drilling or machining composites are tooling material composition, geometry and amount of heat build-up while operating. The friction caused by drilling thermoplastic composites results in intense heat as there is no chips to absorb it and carry it away. Tool wear is another major concern. Composite material requires extra sharp cutting edges and consistent tool geometry specific to components we are processing.

Fig. 5 Material aspects from common industrial use.

Tsao and Hocheng [10] performed a parametric analysis on thrust force of core drill. Core drill helps in reducing the delamination by distribution of thrust force toward the drill periphery.

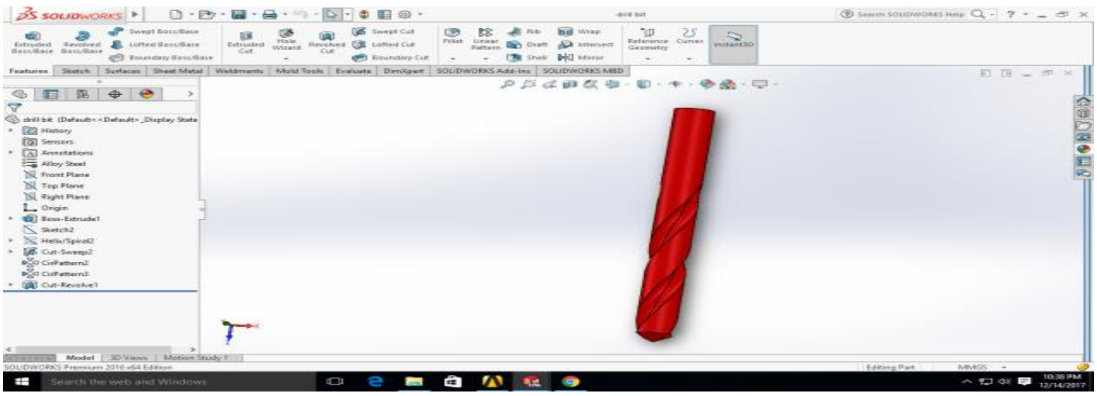

Fig. 6 Types of tool (right hand or left hand) twist drill.

Reduced thickness of core drill, large grit size of diamond, low feed rate and medium spindle speed are effective in reducing the thrust force. Grit size is the important parameter and a correlation is obtained through regression analysis. In another observation author has conducted analysis of thrust force and surface roughness by using candle stick drill. The experimental results indicate that the feed rate and the drill diameter are the most significant factors affecting the thrust force, whilethe feed rate and spindle speed contribute to the surface roughness. Correlation is shown using multivariable regression analysis and radial basis function network (RBFN) [11].Durao et al. [12] shows mixed- mode damage model to see the delamination onset and propagation using twist drill and c-shaped drill. He considered drill as a rigid body. The author worked on the comparative study different tool point geometries and feed rates. Twist drill with 120°is a better option for high feed rate [13]. Singh et al. [14]approached finite element method to study the effect of drill point angle and found that

90˚drill point angle provided superior results. Impact of double cone drill on the cutting forces and machining quality is given by Zitoune et al. [15] using parametric analysis.

IV. HOLEQUALITY ASSESMENT TECHNIQUES AND MECHANICAL TEST

The major parameter affecting the quality of hole is surface roughness, circularity, delamination at entry and exit, cylindricity and burr formation.after controlled drilling.

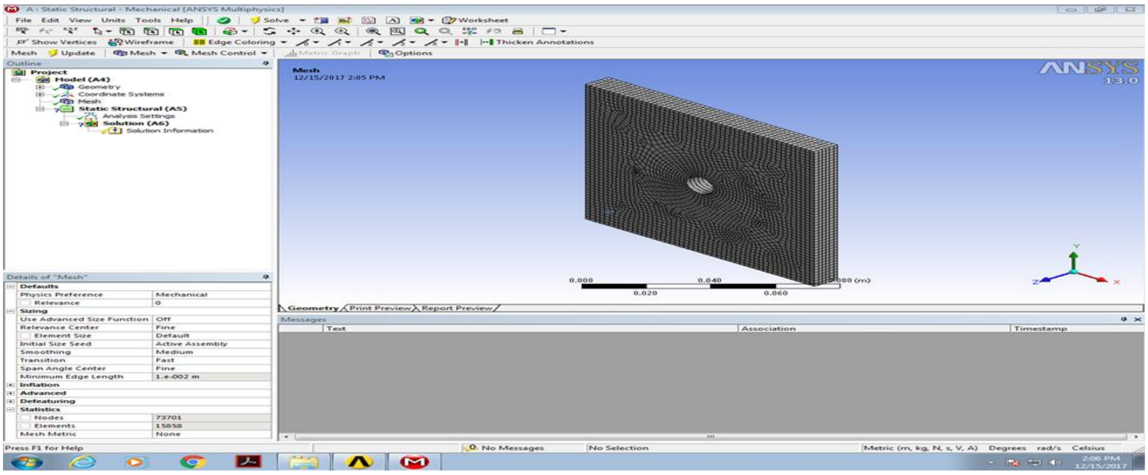

Fig.7 Fine Meshed specimen

Delamination and hole quality measurement techniques are scanning electron microscope, optical microscope, profile projector, radiography, ultrasonic c-scan. These can be used to take digital image and analyse the damages.

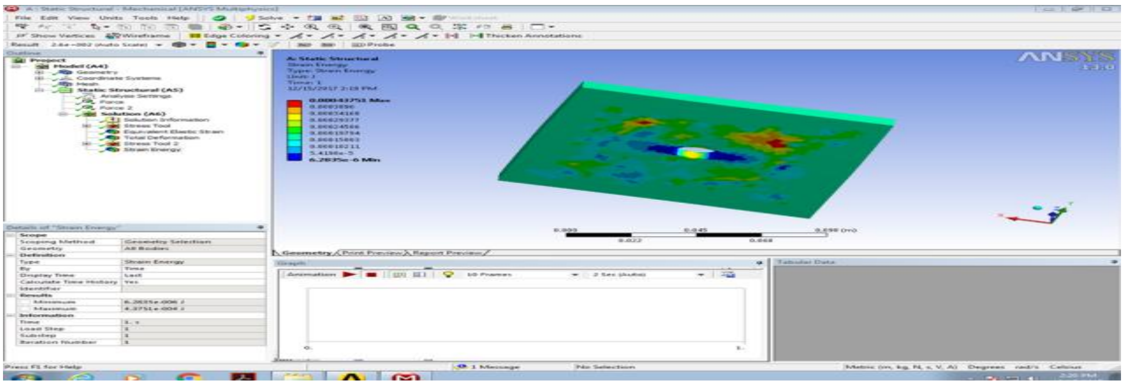

Fig.8 Strain energy throughout the specimen

Giasin et al. [16] investigated the hole quality parametrics using finite element analysis of GLARE material. He chose parameter such as surface roughness, hole size, circularity error, burr formation and delamination and used surface profilometryand optical scanning techniques to obain the desired result.

Material specification of polypropylene

01	Temperature range	200-250 °C
02	Tensile strength	32 MPa
03	Flexural strength	41MPa
04	density	.905g/cubic centimetre

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Fig.9 Polypropylene material specification

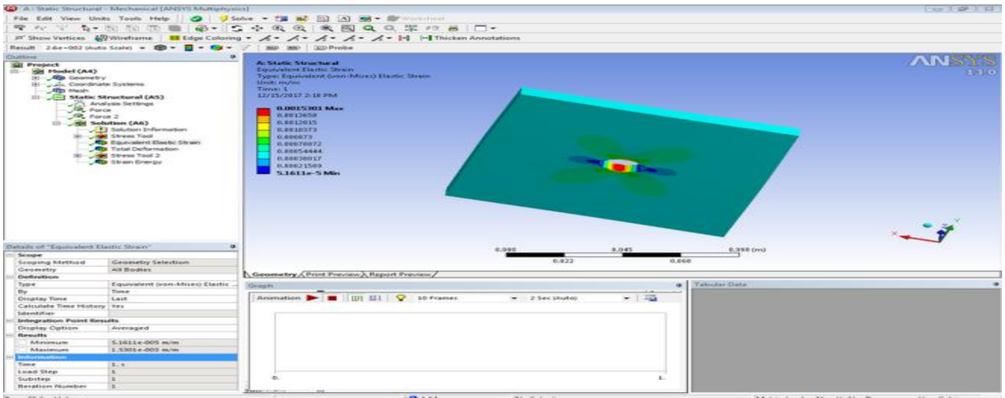

Fig.10Stress concentration at hole

Teja et al. [17] developed a finite element model to assess the drilling effects of composites using LS-DYNA Solver.

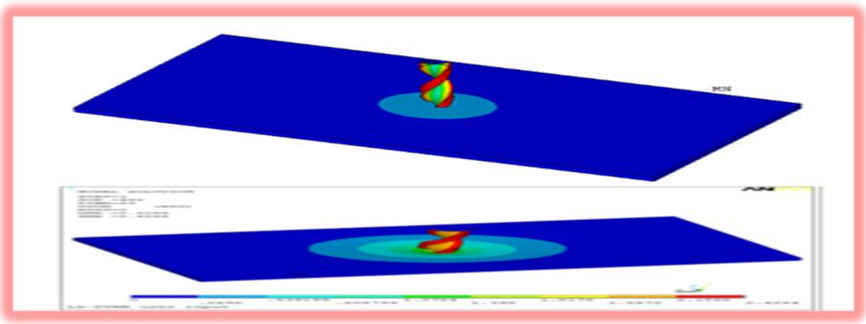

Fig.11 delamination at entry and exit modelled by Teja et al. [17].

Durao et al. [18] formulated the procedure to analyse the texture characteristics of hole using digital image analysis using radiography and compared it with mechanical test. Bangoli et al. [19] presents an evaluation of the low velocity impact behaviour and the post-impact fatigue behaviour of GLARE laminate adhesively bonded to a high strength aluminium alloy substrate as a fatigue crack retarder. Impact on aluminium substrate caused damage to plate where the impact energy is between 10-50 joules. For fatigue testing of composites Leevers et al. [20]performed a high rate fracture toughness testing of composites.Fracture toughness was calculated from failure time using a velocity dependent 'key curve' correction, assuming a constant elastic modulus.

V. CONCLUSION

The paper presents the overview of assessment of hole parameters with mechanical test using finite element analysis and drawn the following observation:

- An approach model needs to be chosen in order to optimize the parameter affecting the results. Mechanistic, analytical, mathematical, soft computing approaches helps in extracting the near results.
- The use of finite element analysis is limited in field of advanced material. Hence further investigation need to be done and development of dynamic analysis tool is necessary.
- The factors that affect hole quality is tool geometry, material composition, and selection of proper tool to machine a particular specimen. A better selection of drill bits helps in good result as in case of twist drill.
- Larger development is needed towards computing model and automated control.

REFERENCES

[1] Kahwash,F., I. Shyha, A. Maheri,2015," Modelling of cutting fibrous composite materials: current practice", Procedia CIRP 28 , 52 – 57.

[2] Abrao ,A.M., P.E. Faria , J.C. Campos Rubio , P. Reis , J. Paulo Davim,2007," Drilling of fiber reinforced plastics: A review" Journal of Materials Processing Technology 186: 1–7.

[3] Singh, I., N. Bhatnagar, P. Vishwanath, 2008,"Drilling of Uni-Directional Glass Fiber Reinforced Plastics: Experimental and Finite Element Study",Materials and Design 29, 546–553.

[4] Roberts, (1990),"A Modern Approach to Drill Optimisation", Circuit World, Vol. 16 Iss 3 pp. 14 – 16.

[5] Tsao, C.C., H. Hocheng, 2005,"The path towards delamination-free drilling of composite materials",Journal of Materials Processing Technology 167:251–264.

[6] Hocheng,H., C.C. Tsao , C.S. Liu , H.A. Chen,2014," Reducing drilling-induced delamination in composite tube by magnetic colloid back-up", CIRP Annals - Manufacturing Technology xxx: xxx–xxx.

[7] Lachaud, F., R. Piquet, F. Collombet, L. Surcin, 2001," drilling of composite structures",Composite structures 52, 511-516.

[8] Takabi,B.,Bruce L. Tai,2017,"A review of cutting mechanics and modeling techniques for biological materials", Medical Engineering and Physics 0 0 0: 1–14.

[9] M.R. Wisnom, 2010,"Modelling discrete failures in composites with interface elements", Composites: Part A 41: 795–805.

[10] Tsao, C.C., H. Hocheng, 2007," Parametric study on thrust force of core drill", Journal of Materials Processing Technology 192–193, 37–40.

[11] Tsao, C.C., H. Hocheng, 2008,"Evaluation of thrust force and surface roughness in drilling composite material using Taguchi analysis and neural network", journal of materials processing technology 2 0 3: 342–348.

[12] Durao, L.M.P., M.F.S.F. de Moura, A.T. Marques, 2006," Numerical simulation of the drilling process on carbon/epoxy composite laminates", Composites: Part A 37: 1325–1333.

[13] Durão, Luís Miguel P.,Daniel J.S. Gonçalves, João Manuel R.S. Tavares, Victor Hugo C. de Albuquerque,2010," Drilling tool geometry evaluation for reinforced composite laminates", Composite Structures 92 , 1545–1550.

[14] Singh,A.P., Dr. M. Sharma,2013,"modelling of thrust force during drilling of fibre reinforced plastic composites", Procedia Engineering 51: 630 – 636.

[15] Zitoune, R., V. Krishnaraj, F. Collombet, S. L.Roux, 2016," Experimental and numerical analysis on drilling of carbon fibre reinforced plastic and aluminium stacks", Composite Structures S0263-8223(16)30140-4.

[16] Giasin,K.,S.A. Soberanis,T. French,V.Phadnis,2016," 3D Finite Element Modelling of Cutting Forces in Drilling Fibre Metal Laminates and Experimental Hole Quality Analysis", Appl Compos Mater 24:113–137.

[17] Teja, P.V.S., S. Prakash, B. Narasimha Prasad, G. Elijah, 2015," Finite Element Analysis in Drilling GFRP Composites", Indian Journal of Science and Technology, Vol 8(15), DOI: 10.17485.

[18] Durão, Luís Miguel P,João Manuel R.S. Tavares, Victor Hugo C. de Albuquerque, Daniel J.S. Gonçalves, 2013," Damage evaluation of drilled carbon/epoxy laminates based on area assessment methods", Composite Structures 96: 576–583.

[19] Bangoli, F., M. Bernabei, D.F. Gordon, P.E. Irving, 2009,"The response of aluminium/GLARE hybrid materials to impact andto in-plane fatigue",Materials Science and Engineering A 523,118-124.

[20] Leevers , P.S., I. Horsfall , A. Rager , Z. Major, D.R. Moore, A. Pavand,J.G. Williams ,2014," High rate fracture toughness testing of thermoplastics", Polymer Testing 33:79–87.