APPLICATION OF HYBRID TECHNIQUE IN OPTIMISATION OF DELAMINATION EFFECT IN AWJ DRILLING OF CFRP MATERIAL: A Review

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ABSTRACT:

Composite laminates like CFRP and GFRP are used in many applications in industries like aerospace and aircraft due to their extremely high strength to weight ratio and corrosion resistance properties. Welding can't be done for fastening the composite laminates with other metallic component. It can be joined by using bolt. But drilling a hole in composite laminates is a big challenge, because drilling induces damage such as delamination, fiber pull out, fiber push out etc. which give rise to the failure of material. Literature review provided a solution for it, Abrasive Waterjet Technology suited best for the given problem. It is one of the most recently developed advance non-traditional method used in the industry for cutting, drilling, milling, peening etc. The best advantage of udsing AWJ method is that it provides, no-thermal distortion, high machining versatility, high flexibility and small cutting forces. Since every method is not a perfect method. AWJM also induces damage such as delamination, consequently a poor quality

oof hole is obtained at the entry and exit of the drilled CFRP. According to the research conducted by researchers, the reduction in the jet diameter or decreasing the water pressure can reduce delamination. The literature review provided the consequences among the various process parameters which affects the drilling quality and is solved with the help of various

technique. This work uses advance optimization techniques like ANN (Artificial Neural Network), ANFIS (Adaptive Neuro-Fuzzy Inference System)

Keywords: Abrasive Waterjet Machining, drilling on CFRP, Delamination, ANN and ANFIS..

INTRODUCTION:

A growing interest is observed in using of composite materials in place of conventional materials, due to its unique properties, such as extremely high strength to weight ratio, stiffness to weight ratio and corrosion resistance. As a result these materials are increasing being used in aerospace and aeronautical structural applications. Carbon fibers which are commonly used to reduce the weight of structural components on aircraft results in improved fuel economy, reduced emissions and increased load carrying capacity of aircraft. Fiber reinforced composite laminates commonly used in industries mainly includes CFRP (Carbon fiber Reinforced Polymer) composites GFRP (Glass fiber Reinforced Polymer) composites and fiber metal composite laminates (FMLs). Because of their considerable advantages they are being used to replace in conventional metallic materials in wide range of industries including sporting goods, defense , automobiles along with aerospace and aeronautical. In this study we are mainly concerned and focused on CFRP composite material.

APPLICATIONS:

CFRP is proved to be good for environment and energy related applications like wind power blades, tidal power blades , fuel cells tube trailer tank, battery charging flywheel and electric cable core. CFRP had also found its application in automobile parts like car body, frame, hood, roof, and body panel for bus, propeller shaft, compressed natural gas tank, radiator core support, and chassis. They are also used in sporting goods like

ski, bicycle, fishing rods, hockey sticks, badminton rackets, and golf shaft. Because of its key properties of high strength to weight ratio it has gained the attention of aerospace and aeronautical industries.

LITERATURE SURVEY:

On the basis on topic of Multi Objective Optimization Drilling of Composites, the Composite chosen to be further studied CFRP. Different papers published on Elsevier and certain journals involving the various experiments pertaining drilling of CFRP have been reviewed below. From these papers it is become easier to limit the parameters tested on various composites including CFRP and further study them. The papers have brought forward the various properties of CFRP under varying conditions. It has shown the applications of the FRP composites and enabled to perform optimization techniques which will be further informative. It has become easier to final on the tools to be used for the Conventional Drilling of CFRP.

2.1 LITERATURE SURVEY ON MATERIAL SELECTION :

Khashaba, et al [9] observed that at minimum cutting variables the thrust force of continuous winding, woven/epoxy and chopped composites were suddenly dropped from the maximum value to zero at the drill exit with significant push-out delamination by variable feed technique. Santiusteetc, et al [10] observed the effect of bending moment (involving both cracking and crushing damage) for fiber orientations close to the cutting speed direction in CFRPs. The increment of angle orientation leaded to increased crushing damage beneath the machined surface. Krishnaraj, et al[17], while drilling CFRP/Al stacks, investigated that the magnitude of thrust force and torque during drilling of Al compared to CFRP is double at low feed rate (0.05 mm/rev) where as at 0.1 mm/rev and at 0.15 mm/rev it is approximately three times higher. Capello, et al [14] worked on Workpiece damping and its effect on delamination damage in 5 June 2003 using Damage free machining to analyze the differences in delamination mechanisms when drilling with and without a support placed under the work piece. R. Janssen, et al [20] presented concerning the realization of economical drilling processes of multi-layer materials. Phapale, et al [26] presented delamination characterization and comparative assessment of delamination control techniques in CNC machining of CFRP. There are also information about the cutting tools and the factors which have great effect on the drilling process. When this temperature is exceeded the mechanical properties are changed. Reduction of the strength and hardness of the composite can be expected. Haeger, et al [28] discussed a non-destructive detection of drilling-induced delamination in cfrp and its effect on mechanical properties. The point angle of the drill bit significantly affects the delamination behavior, since a lower point angle helps to avoid pushdown delamination on the exit side but promotes peel-up delamination on the entry side. Voßa, et al [29] worked on chip root analysis after machining carbon fiber reinforced plastics (CFRP) at different fiber orientations. Analysis shows that the height of the compressed particles is about the radius of the worn cutting edge. As a result the particles are unable to convey over the tool´s rake face and are instead forced under the tool´s clearance face and smear along the machined surface. Ellert, et al [31] worked on major factors influencing tensile strength of repaired CFRP samples. The art of material removal, geometry, surface pretreatment and different repair techniques were analyzed. Because of high accuracy and reproducibility, a mechanical material removal is preferred to manual removal. Rawata [19] analyzed the effect of speeds and feed rates on the damage mechanisms, namely, delamination, surface roughness, fiber pullout, thermal damage, hole circularity and hole diameter error were established using a newly introduced concept of Machinability Maps.

2.2 LITERATURE REVIEW ON ABRASIVE WATERJET DRILLING ON CFRP COMPOSITES :

Presently, there is no process which gives the complete solution for the delamination of CFRP material. It has been demonstrated that the performance of AWJM is superior compared to lazer machining and waterjet machining as far as delamination is concerned [1,2]. Also it has been reported that the waterjet cutters are efficient tools for the machining of the layered composites [3,1]. In AWJM high velocity jet of abrasive slurry is impacted on work pieces and it removes material based on the principle of erosionof the material. AWJM has advantages like high machining versatility, relatively small cutting forces, high flexibility and no thermal distortion [ ]. While comparing with other machining process like lazer and conventional machining no heat affected zone on workpiece is produced [4]. Although AWJM is associated with noisy pump and higher operating cost, it appears to show promise in machining of CFRP as compared to lazer and WJM [5,1,6]. Based on the literature it appeared that although many attempts have been made to study AWJM and AWJ of CFRP, most of the studies have been undertaken on drilling. Therefore it is necessary to investigate the profile cutting using AWJM. Besides, to the best of our knowledge, there are few studies on modeling of AWJM of these materials. Therefore the present study has been undertaken to investigate the combination of input process parameters such as jet pressure, standoff distance, feed rate on dimensional accuracy, surface quality, and material removal rate. In addition, empirical models have also been developed for kerf, surface roughness, and material removal rate using response surface methodology. The scope of this study is, therefore, limited to empirical study of machinability of CFRP using AWJM.

2.3 LITERATURE REVIEW ON HYBRID AI TECHNIQUES USED :

Chang and Kuo [15] analyzed the surface roughness and material removal rate of aluminum oxide in laser assisted turning using Taguchi method. They varied the rotation speed, feed, depth of cut and pulse frequency during experimentation identified that the rotational speed was the most significant parameter affecting both the surface roughness material removal rate.

R.Rinaldo et al [16] analyzed the natural variables of drilling tools in Finite element analysis and studied spindle speed frequency. They conclude that cutting mechanisms can be achieved by initiation propagation.

ANOVA GRA (GRT relational analysis) analysis of Si3Ni4-TiN conductive ceramic composite in EDM was done by C. Sathiya Narayanan et al [17] material removal rate, taper angle, circularity, runout, surface roughness were observed by varying current pulse on time, pulse off time, dielectric pressure and spark gap voltage. Increase in spark eroding process was experimentally observed.

Saha et al. [18] using ANN for WEDM of tungsten carbide-cobalt composite found that peak current and capacitance significantly increases cutting speed and surface roughness. Pulse-on time ,pulse-off time, peak current and capacitance were varied during experimentation.

Somashekhar et al. [19] analyzed the material removal rate of aluminum in micro-EDM by varying gap voltage, capacitance and feed rate. They concluded that more variation in MRR was observed due to capacitance compared to others. They used ANN and SA as optimization techniques.

Amini et al. [20] used combination of Taguchi method, ANN and GA methods to optimize the material removal rate and surface roughness of TiB2 nano-composite ceramic in WEDM by varying power, time off, voltage, servo and wire feed rate. Shown that the achieved optimization results were in good agreement with the experimental result.

Shrivastava and Dubey [21] optimized the material removal rate by 76% and wheel wear rate by 31% in electric discharge diamond grinding of copper-iron-graphite MMC by using ANN,GA and grey relational analysis as optimization techniques.

Parikh and Lam [22] used orifice diameter, depth of cut and work piece-abrasive material combination factor to find Abrasive mass flow rate, focus diameter, traverse rate and pump pressure in AWJM. They found that results of neural network showed better than other techniques.

Singh and Grill [23] used adaptive Neuro-fuzzy inference system to calculate MRR by varying depth of penetration, time of penetration and penetration rate in porcelain ceramic, Alumina ceramic and sillimanite ceramic.Fuzzy logic-based models were designed to simulate MRR.

Rao and Kalyankar [24] used TLBO for cutting speed of WEDM of oil hardened and nitride steel. Surface roughness was considered as constraint.

Pawar and Rao [25] studies TLBO application for Titanium in AWJM. Power generation was considered as constraint.

CONCLUSION:

The work carried out by various researchers using abrasive Water Jet technique is reported for wide variety of metals, non-metals,ceramics and composites. But still AWJM has many limitations regarding to layered composites. Grit embedment, delamination,and fiber pull out are most important issues. These issues are not totally omitted it need to choose the parameters wisely. It is observed that the reduction of jet diameter or decreasing the waterpressure can reduce delamination effect.

REFERENCE:

[1] Vaibhav A. phadnis , Farrukh Makhdsum, Anish Roy, Vadimsilbrschmidtzs, “Experimental and numerical investigations in conventional and ultrasonically assisted drilling of CFRP laminate”, *Procedia CIRP*, vol. no-1, pp.455 – 459 ,2012.

[2] Sanjay Rawat, HelmiAttia. Characterization of the dry high speed drilling process of woven composites using Machinability Maps approach, *CIRP*(2009)105-108.

[3] J.P. Davim , Pedro Reis. Study of delamination in drilling carbon fiber reinforced plastics (CFRP) using design experiments), *Composite Structures* (2003)481-487.

[4] DeFuLiu,Yongjun,W.L.Cong a review for mechanical drilling of composite laminates, Elsevier(2011)987-996, *v.94, no.4, March, p.1265(15) (ISSN: 0263-8223)*, 2012.

[5] A.M. Abraoa,, P.E. Fariaa, J.C. Campos Rubio a, P. Reis b, J. Paulo Davimb, Drilling of fiber reinforced plastics: A review, *Journal of Materials Processing Technology* 186 (2007) 17.

[6] Islam Shyhaa, Sein Leung Sooa, David Aspinwalla,, Sam Bradleyb, Effect of laminate configuration and feed rate on cutting performance when drilling holes in carbon fibre reinforced plastic composites, *Journal of Materials Processing Technology* 210 (2010) 1023–1034.

[7] E.Kilickap, Optimization of cutting parameters on delamination based on Taguchi method during drilling of CFRP composite, *Expert Systems with Applications* 37 (2010) 6116–6122.

[8] K. Palanikumar, Experimental investigation and optimisation in drilling of CFRP composites, *Measurement* 44 (2011) 2138–2148.

[9] U.A. Khashaba, Delamination in drilling GFR-thermoset composites, *Composite Structures 63* (2004) 313–327.

[10] Carlos Santiuste a, Xavier Soldani b, Maria HenarMiguélez b, Machining FEM model of long fiber composites for aeronautical components, *Composite Structures 92* (2010) 691–698.

[11] RedouaneZitoune *, VijayanKrishnaraj, Francis Collombet, Study of drilling of composite material and aluminium stack, *Composites* (2005) 253-261.

[12]C.C. Tsao n, Y.C. Chiu D., Evaluation of drilling parameters on thrust force in drilling carbon fiber reinforced plastic (CFRP) composite laminates using compound core-special drills, *CIRP*,(2011) 1116-1169.

[13] Hocheng H, Tsao CC. The path towards delamination-free drilling of composite materials. J Mater Process ,*Technol*(2005) 891-912.

[14]EdoardoCapello, Workpiece damping and its effect on delamination damage Incfrp,Elseviar,*Composite Structures* (2003) 226-239.

[15]V.N. Gaitondea,, S.R. Karnikb, J. Campos Rubioc, A. EstevesCorreiad, A.M. Abraoc, J. Paulo Davime, high-speed drilling of carbon fiber reinforced plastic composites to get details of model development and model adequacy test by analysis of variance (ANOVA),*Composite Structures* (2007) 549-558

[16]Yi˘gitKarpata,,BurakDe˘gerb,OnurBahtiyarb,Drilling thick fabric woven CFRP laminates with double point angle drills,*CIRP*.,(2012) 657-668

[17]VijayanKrishnaraja, A. Prabukarthi a, ArunRamanathana, N. Elanghovan a, M.Senthil Kumara, RedouaneZitouneb, J.P. Davimc, Optimization of machining parameters at high speed drilling of CFRP laminates , *Composite Structures* (2012) 957-962

[18]T.J. Grilo⇑, R.M.F. Paulo, C.R.M. Silva, J.P. Davim, delamination analyses of CFRPs using different drill geometries,*composite Structures* (2012)668-675

[19]Sanjay Rawata, HelmiAttia. Characterization of the dry high speed drilling process of woven composites using Machinability Maps approach ,) *CIRP* (2009 1164-1175

[20]E. Brinksmeier , R. Janssen’ University of Bremen. Drilling of Multi-Layer Composite Materials consisting of Carboni Fiber Reinforced Plastics (CFRP), *Titanium and Aluminum Alloys*(2008) 564-578

[21] C.C. Tsaoa, H. Hocheng. Effect of tool wear on delamination in drilling composite materials, *International Journal of Mechanical Sciences* 49 (2007) 664-679

[22] M.Ramulu ,T.Branson, D.Kim The study on the drilling of composites and titanium stacks. *Composite structures 54*(2007)226-236

[23] J.P. Davim, Pedro Reis. Study of delamination in drilling carbon fiber reinforced plastics (CFRP) using design experiments.Composite Structures 59 (2003) 481–487.

[24] Kyung-Hee Parka, Aaron Bealb, Dave (Dae-Wook) Kimb. Tool wear in drilling of composite/titanium stacks using carbide and polycrystalline diamond tools. *CIRP*(2004) 1112-1126.

[25] Chinmaya R .Dandekar, YungC.Shin Modeling of machining of composite material. *Composite Structures* (2012) 245-254.

[26] KamleshPhapale, Ramesh Singh, SandipPatil RKP Singh,Delamination Characterization And Comparative Assessment Of Delamination Control Techniques In CNC Machining Of CFRP (2016) 521–535.

[27]VáclavSchorník,vanaZetkováVáclavSchorník,IvanaZetková,The Influence of the Cutting Conditions on the Machined Surface Quality When the CFRP is Machined (2015) 1270 – 1276.

[28] Andreas Haeger, Georgeta Schoen, Fabian Lissek ,Non-Destructive Detection of Drilling-induced Delamination in CFRP and its Effect on Mechanical Properties (2016) 130 – 142.

[29] Robert Voßa, Marcel Henerichs, Friedrich Kuster, Konrad Wegener,Chip Root Analysis after Machining Carbon Fiber Reinforced Plastics (CFRP) at Different Fiber Orientations (2014) 217 – 222.

[30] HariVasudevan, Naresh C. Deshpande, Ramesh R. Rajguru Grey Fuzzy Multi-objective Optimization of Process Parameters for CNC. *Turning of CFRP/Epoxy Composites* (2014) 85-94.