Faculty of Manufacturing Engineering

OPTIMIZATION OF CUSTOMIZED DRILL REAMER GEOMETRICAL FEATURES FOR AEROSPACE COMPOSITE PANEL

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OPTIMIZATION OF CUSTOMIZED DRILL REAMER GEOMETRICAL FEATURES FOR AEROSPACE COMPOSITE PANEL

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DECLARATION

I declare that this thesis entitled "Optimization of Customized Drill Reamer Geometrical Features for Aerospace Composite Panel" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……

Name : Ts. Mohd Fairuz Bin Jaafar

Date : 7 JUN 2021

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy in Manufacturing Engineering.

Signature : ……

Supervisor Name : Associate Professor Ir. Ts. Dr. Mohd Shukor Salleh

Date : 30 JUN 2021

DEDICATION

My beloved father, mother, family, supervisor, and supportive friends accompany me along the problematic pathway in my university life.

ABSTRACT

Recently, carbon fibre reinforced plastic (CFRP) materials are used widely to manufacture lightweight structures. It is tailored to material properties such as high specific strength, high specific stiffness, high modulus, low weight, and high corrosion resistance and a primary option for aerospace structures. Drilling CFRP is very challenging compared to metal due to its inherent homogenous and anisotropic mechanical properties. During drilling, the typical damages that occur during drilling are delamination, pull-out fibres, fuzzing, and burrs, affecting the CFRP structure's load-carrying capacity, reducing assemblies' lifespan. Currently, multistep drilling is implemented in aircraft manufacturing to reduce delamination, which is regarded as the most critical damage that reduces mechanical parts' stiffness. However, multistep drilling required many drill types and a large number of holes in aircraft manufacturing and increased the total drilling cost per hole. The tremendous amount of holes required in aircraft manufacturing may lead to hole perpendicularity error due to lethargy and loss of concentration drilling operators. Therefore, this research aims to determine and optimize cutting tool geometrical features for drill reamer, for one-shot drilling of CFRP in various penetration angles. The machining and geometry feature performances are investigated and fabricated with a new design to obtain desired quality specifications, namely, delamination, hole wall surface roughness, hole size, and drilling thrust force in a one-shot drilling process. The multistep drilling process needs to repudiate for economical production. The parameter optimization consideration begins with parameter screening. The parameters inclusive of machining parameters and drill reamer geometrical features are investigated in various penetration angle drilling. Taguchi orthogonal array is applied for the screening phase. From eight parameters consisting of drilling angle conditions, machining parameters, and tool geometry features, only three parameters have been selected to perform optimization by response surface methodology (RSM): drilling penetration angle, second primary clearance, and helix angle. The other parameters are fixed at the best level to produce the best hole quality identified by radar chart analysis towards quality responses through the statistical analysis. In RSM, the relationship for each mentioned response was successfully developed using mathematical regression model analysis. The optimum tool geometrical features (helix angle; 4.405°, and second primary clearance; 10°) considering the maximum drilling penetration angle (5°) assigned are chosen based on the highest desirability score. The new customized drill reamer was fabricated and followed by validating experimental works that obtained less than 10% relative error compared to the prediction, which confirmed its validity. The customized tool is further investigated to reduce the drilling penetration inclination, which affirms that the quality of the hole is improved and fulfills aircraft manufacturer specifications. The hole quality in terms of delamination, hole surface roughness, hole size, and thrust force improves by about 10% from the validation trial conducted with drilling angles decreased. Undeniably, the perfect perpendicular drilling to the CFRP panel is feasible and highly recommended.

PENGOPTIMUMAN CIRI-CIRI GEOMETRI GERUDI PELULAS TERSUAI UNTUK PANEL KOMPOSIT AERO ANGKASA

ABSTRAK

Kebelakangan ini, bahan polimer yang diperkuat dengan serat karbon (CFRP) digunakan secara meluas untuk menghasilkan struktur ringan. Ia disesuaikan dengan sifat bahan seperti kekuatan, kekerasan dan nilai modulus yang tinggi disamping ketahanan kepada karat yang tinggi menjadikannya sebagai pilihan utama untuk struktur aeroangkasa. Penggerudian CFRP amat mencabar jika dibandingkan dengan logam kerana sifat mekaniknya yang homogen dan anisotrop. Kerosakan yang lazim terjadi semasa proses penggerudian adalah pelekangan, serat tertarik keluar, kekaburan, dan pepusar yang mempengaruhi keupayaan struktur untuk membawa beban seterusnya mengurangkan jangka hayat pemasangan. Pada masa ini, penggerudian pelbagai langkah digunakan dalam pembuatan pesawat untuk mengurangkan pelekangan daripada berlaku, dianggap sebagai kerosakan paling kritikal yang dapat mengurangkan kekakuan bahagian mekanikal pesawat. Walaubagaimanapun, pengerudian pelbagai langkah memerlukan pelbagai jenis gerudi dan jumlah lubang yang terlalu banyak dalam pembuatan pesawat akan meningkatkan kos pengerudian untuk setiap lubang yang dihasilkan. Jumlah lubang yang tinggi untuk penghasilan sesebuah pesawat menjadikan pengendali penggerudian lesu dan hilang tumpuan seterusnya mengakibatkan pengerudian condong. Oleh itu, penyelidikan ini bertujuan untuk menentu dan mengoptimumkan ciri-ciri geometri gerudi pelulas untuk satu syot penggerudian dalam pelbagai sudut penembusan. Parameter pemesinan dan ciri-ciri geometri mata alat dikaji dan difabrikasi dengan rekabentuk yang baru demi mendapatkan spesifikasi kualiti lubang yang diinginkan iaitu pelekangan, kekasaran permukaan dinding lubang, ukuran lubang dan daya tujah penggerudian. Pengoptimuman parameter dimulakan dengan penyaringan parameter yang ditetapkan. Parameter pemesinan dan ciri-ciri geometri mata alat dikaji dalam pelbagai sudut tembus penggerudian. Teknik Taguchi diaplikasikan untuk proses penyaringan. Daripada lapan parameter yang dikaji, hanya tiga parameter yang dipilih untuk dioptimumkan menggunakan kaedah gerak balas permukaan (RSM) iaitu sudut kelegaan utama yang kedua dan sudut heliks. Menerusi kaedah analisis statistik, parameter lain ditetapkan pada tahap terbaik untuk menghasilkan kualiti lubang yang diperlukan yang dikenalpasti menerusi analisis carta radar. Menerusi RSM, perkaitan antara setiap tindak balas berjaya dibangunkan menerusi analisis model regresi matematik. Ciri-ciri geometri mata alat yang optimum (sudut heliks; 4.405°, dan sudut kelegaan utama yang kedua; 10°) dengan penetapan sudut penembusan penggerudian maksimum (5°) dipilih berdasarkan skor kebolehinginan tertinggi. Fabrikasi gerudi pelulas tersuai dilaksanakan seterusnya dijalankan ekperimen pengesahan dan disahkan setelah memperoleh ralat relatif kurang daripada 10% berbanding ramalan. Mata alat tersuai seterusnya diselidiki dengan mengurangkan sudut kecondongan penembusan penggerudian dan didapati kualiti lubang yang dihasilkan bertambah baik dan memenuhi piawaian spesifikasi pengeluar pesawat. Daripada eksperimen pengesahan dengan pengurangan sudut penggerudian, penggerudian sudut tegak dapat meningkatkan 10% kualiti penggerudian dalam aspek perlekangan, kekasaran permukaan lubang, saiz lubang dan daya tujah penggerudian. Tidak dinafikan, pengerudian sudut tegak tepat boleh dilaksanakan dan amat digalakkan.

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Mohd Fairuz Bin Jaafar

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