DESIGN OF COOLING CHANNEL IN HOT STAMPING TOOL BY HEURISTIC APPROACH

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SUPERVISOR’S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Engineering in Manufacturing.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Disebabkan permintaan untuk mengurangkan pelepasan gas, penjimatan tenaga, dan pengeluaran kenderaan yang lebih selamat, pembangunan bahan ultra kekuatan tinggi keluli (UHSS) adalah bukan perkara yang remeh. Untuk mengukuhkan bahan UHSS seperti keluli boron, ia diperlukan untuk menjalani beberapa proses iaitu pemanasan melalui cap panas pada suhu dan masa tertentu serta penyejukan melalui pelindapkejutan. Dalam proses cap panas, die yang sama digunakan seperti dalam proses cap sejuk, tetapi dengan saluran penyejukan tambahan. sistem saluran penyejukan disepadukan ke dalam reka bentuk die untuk mengawal kadar pemindahan haba untuk proses kosong panas pelindapkejutan. Semasa proses pelindapkejutan, reka bentuk mati berkesan menyumbang ke arah pencapaian kadar pemindahan haba yang optimum dan pengedaran suhu homogen pada kekosongan panas. Dalam kajian ini, parameter reka bentuk saluran penyejukan iaitu garis pusat saluran pendinginan (CA), padang antara saluran penyejukan (CB), jarak saluran penyejukan ke permukaan alat (CC), dan jarak saluran penyejuk ke alat dinding (CD) dioptimumkan untuk alat rata dan U-bentuk menggunakan kaedah heuristik. Kaedah heuristik digabungkan dengan analisis haba dan statik analisis unsur terhingga (FEA) melalui ANSYS untuk menentukan reka bentuk optimum penyejukan penyejukan panas. Analisis statik dilakukan untuk memastikan alat tersebut mampu menahan tekanan yang dikenakan, sementara analisis haba dilakukan untuk memastikan pengedaran suhu homogen. Setiap parameter saluran penyejukan dioptimumkan dan ditanda aras dengan kaedah tradisional Taguchi. Kemudian, percubaan proses cap panas dilakukan untuk mendapatkan pengedaran suhu produk dan alat kosong. Seterusnya, hasil simulasi dibandingkan dengan kerja eksperimen untuk tujuan pengesahan. Hasil pengedaran suhu antara FEA dan eksperimen adalah mendapatkan ralat kurang daripada 20 %. Reka bentuk optimum alat setem panas dengan pemindahan haba yang tinggi dan tegasan von Mises yang lebih rendah (VMS), parameter berikut (sebelum ini ditakrifkan sebagai CA, CB, CC, CD mm) diperlukan (8,8,10) mm untuk alat rata, (8,8,8,10) mm untuk alat U-bentuk atas dan (8,8,8,8) mm untuk alat U-bentuk yang lebih rendah. Juga jelas bahawa corak pengedaran suhu model FEA bersetuju dengan keputusan percubaan. Berdasarkan alat bentuk rata, ralat peratusan purata untuk taburan haba kosong ialah 1.83 % dan untuk alat itu ialah 2.67%. Bagi alat U-shape, ralat peratusan purata bagi alat atas, alat bawah dan pengagihan haba kosong masing-masing 16.65 % 17.95 % dan 7.92 %. Kekuatan tegangan dan nilai kekerasan produk kosong (sampel rata dan U berbentuk) diukur menjadi kira-kira 1200 MPa dan 600 HV, masing-masing. Kesimpulannya, berdasarkan parameter yang dioptimumkan dalam kajian ini, jelaslah kekuatan tegangan yang tinggi dengan nilai kekerasan yang tinggi dapat dihasilkan dari kaedah heuristik.

ABSTRACT

Owing to the demand for reducing gas emissions, energy savings, and the production of safer vehicles, the development of Ultra High Strength Steel (UHSS) materials is non-trivial. To strengthen a UHSS material such as boron steel, it is required to undergo a number of processes namely, heating it via hot stamping at a certain temperature and time as well as cooling it through quenching. In the hot stamping process, a similar die is used as in the cold stamping process, but with additional cooling channels. The cooling channel systems are integrated into the die design to control the heat transfer rate for quenching process of hot blanks. During quenching process, an effective die design contributes towards the achievement of the optimum heat transfer rate and homogeneous temperature distribution on hot blanks. In this study, the parameters of the cooling channel design i.e. the diameter of cooling channel (C_A), the pitch between cooling channel (C_B), the cooling channel distance to tool surface (C_C), and the cooling channel distance to wall tool (C_D) are optimised for a flat and U-shape tool using heuristic method. The heuristic method is coupled with the thermal and static analysis of finite element analysis (FEA) via ANSYS to determine the optimum design of hot stamping cooling channels. The static analysis are performed to ensure that the tool is able to withstand the applied pressure, whilst the thermal analysis was carried out to ensure homogeneous temperature distribution. Each parameter of the cooling channels optimised and benchmarked with traditional Taguchi method. Then, hot stamping process experiment is conducted to get the temperature distribution of the blank product and tool. Next, the simulation results were compared with experimental works for validation purpose. The result of the temperature distributation between FEA and experiment expected error less than 20 %. It is found that the optimum design of the hot stamping tool with a high heat transfer and lower von Mises stress (VMS), the following parameters (previously defined as C_A, C_B, C_C, C_D in mm) are required (8,8,10) mm for the flat tool, (8,8,8,10) mm for the upper U-shape tool and (8,8,8,8) mm for the lower U-shape tool, respectively. It is also evident that the pattern of the temperature distribution of the FEA model agrees the experimental results. Based on the flat shape tool, the average percentage error for the blank heat distribution is 1.83 % and for the tool is 2.67 %. As for the U-shape tool, the average percentage error for the upper tool, lower tool, and the blank heat distribution are 16.65 % 17.95 % and 7.92 %, respectively. The tensile strength and the hardness value of the blank products (flat and U-shaped samples) are measured to be approximately 1200 MPa and 600 HV, respectively. In conclusion, based on the aforementioned optimised parameters in the study, it is apparent that a high tensile strength with high value of hardness product could be produced from the heuristic method.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

MPa	Mega Pascal
°C/s	Degree Celsius per Second
min	Minutes
s	Second
W/m.K	Watt per Meter Kelvin
mm	Milimeter
°C	Celsius
E	Elastic of Modulus
k	Thermal Conductivity
Cp	Specific Heat
%	Percentage
t	Thickness
B	Bending Length
P	Force
L	Length
Re	Reynolds Number
p	Density
μ	Absolute viscosity
V	Velocity
D	Distance
q	heat transfer
h	Heat Transfer Coefficient
A	Heat Transfer Area
Tf	Surrounding fluid temperature
Ts	Surface temperature

LIST OF ABBREVIATIONS

UHSS	Ultra-High Strength Steel
HSS	High Strength Steel
AHSS	Advance High Strength Steel
FEA	Finite Element Analysis
C_A	Diameter of Cooling Channel
C_B	Pitch Between Cooling Channel
C_C	Distance Cooling Channel To Tool Surface
C_D	Distance Cooling Channel To Wall Tool
HTC	Heat Transfer Coefficient
FLD	Forming Limit Diagram
DOE	Design of Experiment
VMS	Von Mises Stress
OA	Orthogonal Array

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