# EXPERIMENTAL ANALYSIS AND OPTIMIZATION OF COATED AND UNCOATED CARBIDE TOOL IN DRILLING AISI 316 L AUSTENITE STAINLESS STEEL USING MINIMUM QUANTITY LUBRICATION TECHNIQUE

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DOCTOR OF PHILOSOPHY

(MANUFACTURING ENGINEERING)

UNIVERSITI MALAYSIA PAHANG

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**SUPERVISOR 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 Doctor of Philosophy in Manufacturing Engineering

_______________________________

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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

Proses pemesinan moden menghadapi tekanan kos yang berterusan dan jangkaan kualiti yang tinggi. Bagi mengekalkan daya saing, syarikat harus terus mengenalpasti peluang pengurangan kos dalam pengeluaran, mengeksploitasi peluang-peluang ekonomi, dan terus meningkatkan proses pengeluaran. MQL menyingkirkan air dan cecair penyejuk berasaskan minyak dan menggantikan mereka dengan pelincir berkuantiti kecil bercampur dengan udara .Aliran udara-minyak ini secara tepat telah disukat dan dihantar ke sisi alat pemotong itu. Dalam kajian ini, analisis prestasi penggerudian karbida bersalut TiAIN dan karbida padu pada bahan AISI 316L Austenite Stainless Steel menggunakan Pelincir Berkuantiti Minimum (MQL ) telah dinilai dari segi kekasaran permukaan, jangka hayat mata alat dan ketepatan saiz lubang gerudi. Projek ini memberi tumpuan kepada penggerudian lubang kecil pada keluli tahan karat austenit dengan menggunakan mesin kisar kelajuan tinggi. Kajian ini telah dijalankan untuk menentukan keadaan optimum kelajuan memotong, kadar suapan dan titik sudut mata alat ketika penggerudian keluli tahan karat austenit menggunakan mata alat karbida dan karbida bersalut. Reka bentuk experiment digunakan untuk mengenal pasti 12 exsperimen yang ditetapkan berdasarkan 3 tahap untuk setiap parameter input. Main effect analysis dan ANOVA(Analysis of Variance) merupakan kaedah analisis untuk membandingkan prestasi antara matalat solid dan bersalut TiAIN. First order dan second order analisa regression akan digunakan untuk mendapatkan jangkaan tepat untuk proses optimisasi. Kaedah optimisasi single dan pelbagai akan digunakan untuk mendapatkan kelajuan memotong, kadar suapan dan titik sudut mata alat yang optimum.. Sudut pemotong merupakan parameter yang paling berpengaruh untuk matalat bersalut, manakala kadar suapan merupakan parameter paling berpengaruh untuk solid karbida.. Mata gerudi karbida bersalut digunakan untuk optimisasi menunjukan halaju pemotongan 110m/min, kadar uluran 0.15 mm/rev dan 110 darjah sudut pemotongan menghasilkan 35.5 minit jangka hayat, 1.062 um kekasaran permukaan dan 6.051 ketepatan geometri lubang. Ujilari pengesahan menunjukan kadar kesilapan yang rendah diantara pemesinan sebenar berbanding yang dianggarkan dengan sudut pemotongan, kadar suapan dan halaju pemotongan boleh menghasilkan pemotongan yang optimum. Secara amnya mata gerudi karbida bersalut boleh dioptimun dalam proses penggerudian keluli tahan karat AISI 316L menggunakan kaedah MQL untuk mendapatkan kualiti dan produktiviti yang kehendaki.

# ABSTRACT

Modern machining processes face continuous cost pressures and high quality expectations. To remain competitive a company must continually identify cost reduction opportunities in production, exploit economic opportunities, and continuously improve production processes. Minimum Quantity Lubricants (MQL) eliminates large quantities of water and oil-based coolants and replaces them with a small quantity of lubricant mixed with air delivered to the cutting tool's edge. In this study, performance analysis of solid and TiAIN coated carbide tool in drilling AISI 316L Austenite Stainless Steel using MQL based on surface roughness, tool life and dimensional error as the responses. This project focuses on the drilling small hole on the austenite stainless steel by using high speed milling machine. This research was carried out to analyse and optimize machining parameters of cutting speed, feed rate and tool geometry of point of angle using coated and uncoated tools. Design of Experiment was applied to identify 12 number experiment settings based on three levels for each input parameters. Two analyses of Main Effect Analysis and then verified by Analysis of Variance (ANOVA) were employed to compare the performance between coated and uncoated tools. Before optimize the 3 input parameters, first order and second order regression were applied to determine the highest accuracy prediction can be used for optimization stage. Both single and multiple optimization were conducted to search the optimal cutting speed, feed rate and tool geometry of point based on based on surface roughness, tool wear and dimensional error. According to Main Effect Analysis and ANOVA results, it is showed that point angle is the most influence input parameters for TiAIN coated tool, however, feed rate is the most influence input parameters for uncoated tool. Second order regression was used for high accuracy prediction compared to first order. Coated tools was used for optimization showed that multi optimum cutting parameters are 110 m/min of cutting velocity, 0.150 mm/rev of feed rate and 110° to achieve 35.5 tool life, 1.062 um surface roughness and 6.051 hole accuracy. Confirmation showed that less error from prediction and actual experimental to confirm coated tool with certain point, feed rate and cutting speed can produce the optimal machining performance. Under MQL condition, coated carbide tool can be optimized for drilling AISI 316L Austenite Stainless Steels to satisfy the product quality and productivity.

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| | |
|---|---|
| A | Factor of cutting speed |
| B | Factor of feed rate |
| C | Factor of point angle |
| $D_A$ | Average hole diameter |
| $D_T$ | Tool diameter |
| Fz | Cutting force/thrust force (N) |
| *fr* | feed rate (mm/rev) |
| Ra | Surface roughness (µm) |
| T | Tool life (minute) |
| $x_1, x_2, x_3,..,x_k$ | Input variables |
| Ө | Point angle (degree) |
| V | Cutting speed (m/min) |
| y | Response |
| ε | Error |
| % | percent |
| °C | Degree celsius |
| mm | Millimetre |
| µm | Micrometre |
| Å | Angstrom |
| MPa | Mega Pascal |
| W | Watt |
| N | Newton |
| wt | Weight |
| K | Degree Kelvin |
| Ni | Nickel |
| Cu | Copper |
| Fe | Iron |
| Mo | Molybdenum |
| Al | Aluminium |
| Ti | Titanium |
| Mn | Manganese |
| Si | Silicon |

| | |
|---|---|
| C | Carbon |
| Cr | Chromium |
| Nb | Niobium |
| N | Nitrogen |
| WC | Tungsten carbide |

## LIST OF ABBREVIATIONS

| | |
|---|---|
| CCD | Central composite design |
| CMM | Coordinate measuring machine |
| DE | Diameter error (mm) |
| HV | Hardness Vickers |
| HK | Hardness Knoop |
| FCC | Face-centered cubic |
| HCL | Hydrochloric acid |
| PA | Point angle |
| BUE | Built-up edge |
| MRR | Material removal rate |
| H.S.S | High speed steel |
| ANSI | American National Standards Institute |
| CBN | Cubic boron nitride |
| PCD | Polycrystalline diamond |
| PVD | Physical vapor deposition |
| CVD | Chemical vapor deposition |
| DOE | Design of Experiment |
| SEM | Scanning electron microscopy |
| HRC | Hardness Rockwell unit |
| RSM | Response surface methodology |
| ANOVA | Analysis of variance |

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