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MACHINABILITY ASSESSMENT OF 3D-PRINTED COCRMO PLATE: INFLUENCE OF MICRO-DRILL BIT DESIGNS

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ABSTRACT

Cobalt chromium molybdenum (CoCrMo) is a hard-to-cut material widely utilized in the fields of medical, biotechnology, and aerospace engineering due to its exceptional combination of properties, including high strength, toughness, wear resistance, and low thermal conductivity. However, these attributes often pose obstacles to its machinability, leading to rapid tool wear and a shortened tool life. In the context of micro drilling, tools tend to break rather than wear out, especially when subjected to high loads and forces. Therefore, this paper investigates the impact of different micro drill tool designs (denoted as S and EZ by the manufacturer) with consistent machining parameters on the forces and wear when micro drilling CoCrMo. Three-dimensional (3D) printed CoCrMo plates are fabricated using the Selective Laser Sintering (SLS) process, and custom-made tool bits with preferred geometries are also prepared. Output forces are measured using a dynamometer, while wear is assessed through optical microscopy.

KEYWORD

Selective Laser Sintering, Micro Drilling, Cobalt Chromium Molybdenum, Tool Wear.

INTRODUCTION

Cobalt Chromium Molybdenum (CoCrMo) alloy is widely employed in medical applications, particularly in the production of medical devices and surgical implants. This preference is due to its exceptional biocompatibility, high mechanical strength, and chemical resistance (Baron et al, 2015). Typically, this alloy is cast and, to a lesser extent, forged to achieve the desired component geometry. Subsequent machining operations are necessary to attain the required geometric tolerances and surface finish. However, similar to other hard-to-machine materials like nickel and titanium alloys, CoCrMo exhibits reduced machinability (Akbar et al, 2017). Poor machinability is manifested through an increased wear rate and compromised surface integrity of parts and components, directly affecting their performance over their service life.

Numerous studies have been conducted on conventionally manufactured CoCrMo (Baron et al, 2015; Akbar et al, 2017; Hamidon et al, 2021) but there is limited research on 3D printed variants, particularly within the micro drilling domain. Previous investigations have explored various aspects, including the influence of machining parameters, residual stress, and surface roughness, as well as the effects on surface integrity. However, to the best of the author's knowledge, there is a lack of references regarding the impact of tool types on micro drilling in 3D printed CoCrMo plates.

Therefore, the primary objective of this paper is to provide insight towards the machinability of 3D printed CoCrMo when employing different designs and geometry of micro drill bits using fixed machining parameters. To achieve this objective, a series of micro drilling experiments were conducted under flood cooling conditions until reaching the tool life criterion, defined by the critical value of flank wear or the maximum allowable number of holes drilled. The study closely examines and analyzes output thrust forces and tool wear to ascertain the influence of micro drill tool designs and geometries.

MATERIAL AND METHODOLOGY

The ASTM F1537 cobalt chromium molybdenum alloy was obtained through the selective laser sintering (SLS) additive manufacturing process. Custom plates measuring 60mm × 60mm × 4mm were fabricated by the 3D Gens Company in Malaysia, as depicted in Figure 1. This alloy possesses exceptional attributes, including high tensile strength, excellent biocompatibility, corrosion, and fatigue resistance, as well as good wear resistance. Two custom-designed drill bit variants were manufactured by HPMT, specifically the S-design and the EZ-design drill bits. Both drill bits share a common diameter of 2mm. These tools were subjected to identical machining parameters. Subsequently, the resulting thrust forces and wear patterns were meticulously observed and analyzed to determine the superior tool design for micro drilling 3D CoCrMo. Machining operations were carried out using a DMG Mori DMU50 CNC Machine, while force measurements were obtained through the Kistler Type 9554B dynamometer. Tool wear was assessed and observed utilizing the XOPTRON X80 microscope.

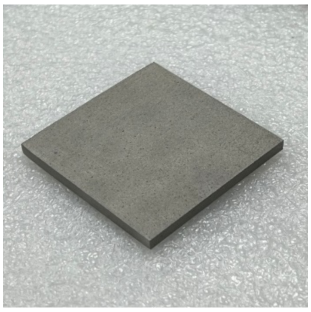

Figure 1: 3D Printed CoCrMo

RESULT AND DISCUSSION

The machinability of 3D printed CoCrMo using different drill tool designs was assessed based on the output thrust forces. From the tabulated tables (Table 1 and 2), it is evident that S-design tools exhibit a reduction in force when the point angle decreases from 140^o to 130^o, but there is a sharp increase when it further decreases to 118^o. On the other hand, EZ-design tools display a consistent trend of decreasing force values as the point angles of the tools decrease from 140^o to 118^o. These trends can be attributed to the specific geometries and designs of the drill bits. This phenomenon can be elucidated by referencing the work conducted by (Hassan et al, 2018) which explored drilling composite materials. According to their study, when the point angle of a drill bit is small, the cutting edge becomes longer, and the contact area between the cutting edge and the material becomes smaller. A smaller contact area between the tool and the material results in more dispersed force distribution and higher thrust forces.

However, this is not the case for EZ-design tools. The results indicate that as the point angles decrease, the thrust forces also gradually decrease. This outcome can be attributed to the unique design of EZ-design tools, which incorporate a chisel design that reduces thrust load and enhances biting performance (HPMT, 2021). Additionally, EZ-design drill bits feature effective clearance and gashing, which serves to reduce cutting forces.

Table 1: Tool Design S Average Thrust Force Output

Run	Hole No	Speed (m/min)	Tool (S)	Force Average	Run Force Average (N)
1	10	50	1 (140°)	261.69	273.68
	20			281.54	
	30			277.81	
2	10		2 (130°)	206.85	208.995
	20			206.29	
	30			213.84	
3	10		3 (118°)	497.65	508.72
	20			518.87	
	30			509.64	

Table 2: Tool Design EZ Average Thrust Force Output

Run	Hole No	Speed (m/min)	Tool (EZ)	Force Average	Run Force Average (N)
1	10	50	4 (140°)	180.255	178.33
	20			194.901	
	30			159.841	
2	10		5 (130°)	129.689	133.23
	20			132.588	
	30			137.410	
3	10		6 (118°)	133.166	131.86
	20			138.600	
	30			123.800	

CONCLUSION

This paper presents an experimental study aimed at investigating the impact of different micro drill tool designs on the machinability of selective laser sintered (SLS) advanced manufactured cobalt chromium molybdenum (CoCrMo) alloy plates, utilizing a flood cooling method. Notably, the trends in force and wear exhibit a proportional relationship; when the force increases, wear also increases, and vice versa. The primary objective of this experiment is to determine the more suitable tool design for micro drilling SLS CoCrMo plates. It is evident that the EZ design tool outperforms the S-design tool due to the significantly lower magnitude of thrust forces it generates. Lower forces are anticipated to result in a reduced wear rate for the tool, potentially extending its lifespan. For further exploration of micro drilling performance with both tool designs (S and EZ), future research should consider varying machining parameters such as cutting speed, feed rate, and cooling methods. These parameter variations may provide valuable insights for optimizing the micro drilling process of CoCrMo alloys.

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