Pengembangan metode micro milling untuk produk dinding tipis dengan bentuk kompleks = Development of micro milling method for thin wall complex shape products

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Abstrak

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Proses micro-milling merupakan salah satu pilihan proses mikro-manufaktur 3D, yang mampu menghasilkan produk dengan bentuk kompleks. Bentuk kompleks umumnya ditemui pada mold dan dies atau produk kompleks lainnya seperti impeller dan turbin.

Tahapan penelitian diawali dengan pengembangan mesin micro-milling Hadia Micromill-5X, yang meliputi pengembangan konstruksi, pengembangan sistem kontrol gerak dan pengembangan metode perencanaan lintasan pahat yang memanfaatkan sistem CAD/CAM terintegrasi. Tahap berikutnya adalah karakterisasi perfoma proses micro-milling dalam menghasilkan produk mikro, yang dilakukan melalui studi literatur dan pengujian eksperimental. Analisis karakterisasi meliputi kekasaran permukaan, burr yang terbentuk, serta analisis kondisi pahat pada rentang waktu tertentu. Hasil karakterisasi menunjukkan kekasaran permukaan pada sisi proses end-milling dapat dicapai lebih baik bila dibandingkan pada sisi proses peripheral dengan nilai kekasaran permukaan minimum 20 nm. Terdapat empat jenis burr yang terbentuk pada suatu micro-channel yaitu yaitu enterance burr, top burr, exit side burr dan bottom burr. Bottom burr merupakan salah satu jenis burr baru yang diidentifikasi pada penelitian ini. Hasil utama dari tahap ini adalah rekomendasi parameter pemesinan optimum untuk aplikasi produk mikro dengan bentuk dinding tipis.

Dari hasil pengujian performa, mesin Hadia Micromill-5X dan metode yang dikembangkan terbukti mampu menghasilkan produk dinding tipis datar dengan ketebalan minimum 11,71 μm dengan aspek rasio 23,48. Perbedaan antara tebal desain dan tebal aktual (∆Tda) adalah berkisar antara 3,51 μm hingga 25,48 μm. Salah satu penyebabnya perbedaan ini adalah ketidaksesuaian diameter pahat aktual (Da) dengan diameter yang ditetapkan. Ketika ketidaksesuaian pahat turut diperhitungakan terhadap diameter aktual, maka deviasi atau perbedaan ukuran yang terjadi (∆Tae) adalah berkisar antara -4,69 μm hingga 3,48 μm. Nilai ∆Tae masih berada dalam rentang keakurasian motor stage, yaitu ± 5 μm maupun run-out aktual, yaitu 8,33 μm.

Metode micro-milling untuk produk dinding tipis dengan bentuk kompleks yang dikembangkan pada penelitian ini, diaplikasikan untuk pembuatan 2 micro-impeller yang masing-masing memiliki jumlah blade dan ketebalan yang berbeda. Micro-impeller yang memiliki 8 blade dengan diameter aktual 3.098 μm, tinggi 600 μm, ketebalan rata-rata blade 33,7 μm dan jarak terluar antara blade 1.207 μm, deviasi ukuran maksimum yang terjadi hingga 13,3 μm dapat dihasilkan dengan baik. Namun, pada micro-impeller yang memiliki 16 blade dengan diameter 3.190 μm dan ketebalan rata-rata blade 11,96 μm terdapat beberapa blade yang terbelah dan terdefleksi. Secara umum, metode micro-milling yang

dikembangkan telah dapat diaplikasikan dengan baik. Keterbatasan dalam menghasilkan bentuk dinding tipis lebih dikarenakan sifat dan karakteristik material dari produk, yang mengalami defleksi sebagai akibat dimensi dinding yang sangat tipis.;
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ABSTRACT
Micro-milling process is one of choices to manufacture 3D product, which has the ability to produce complex shape. Complex shapes are commonly found in mold and dies or other complex product such as impeller and turbine.

The research was started by developing the micro-milling machine, Hadia Micromill-5X, which covers the development of machine construction, control system and tool-path generation method by using integrated CAD/CAM system. The next part of the research is to characterize the micro-milling performance to produce micro product, through literature study and experimental test. Characterizations analysis covers surface roughness, burrs and tool condition in a certain range of time. The result shows that the surface roughness on end-milling process side is better than peripheral process side, with minimum surface roughness of 20 nm. There are four types of burr that formed on micro-channel, which are entrances burr, top burr, exit side burr and bottom burr. Bottom burr is the first identify in this research. The main result of characterization phase is a recommendation of optimum cutting parameter for thin-wall micro-product application.

Based on performance testing, the micro-milling machine Hadia Micromill-5X and developed method is proved to have the capability to produce thin-wall product with minimum thickness of 11.71 μm, with an aspect ratio of 23.48. The difference between design and actual thickness (∆Tda) is around 3.51 μm to 25.48 μm. One of the causes of the difference is the incompatibility of actual tool diameter (Da) with desired diameter. If the tool diameter incompatibility is considered, than the size differences (∆Tae) are around -4.69 μm to 3.48 μm. ∆Tae value is still in the range of motor stage accuracy and actual run-out, which ± 5 μm are and 8.33 μm respectively.

Micro-milling method for thin-wall complex shape product developed in this research was applied to produce 2 micro-impellers with different amount of blades and thickness. 8?s blade micro-impeller with actual diameter of 3,098 μm, 600 μm heights, average thickness of 33.7 μm, with 13.3 μm of maximum deviation size, was produced properly. However, there are several torn and cloven blades on 16?blade micro-impeller with a diameter of 3,190 μm and average actual thickness of 11.96 μm. In general, the micro-milling method developed in this research is properly applied. The limitation to produce a thinner wall is caused by the material properties and characteristic of the product, which experiences deflection due to the flimsiness of a thin wall.
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