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学位論文名	Ultraprecision Micromachining of Hard Material with Cutting Point Swivel Machining by Using a Non-rotational Tool with Special Chamfer （特殊チャンファ付き非回転工具を用いた刃先移動加工法による高硬度材料の超精密マイクロ加工）
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論文内容の要旨

Recently, in accordance with the technical development and miniaturization of information equipments, the demand of optical elements with high precision and miniaturization has been increasing. The optical elements including lenses are manufactured by the mold, so it is requested to fabricate the mold with high precision, miniaturization and complex shape. In the machining of the mold, the tool is pushed into the material, and the unnecessary part is removed by moving the tool, so the shape of tool is transferred into the surface. To obtain the surface with high shape accuracy and roughness, there is a proposition that of how to suppress the tool wear in the machining. There are a large number of investigations to solve this proposition, from the view-point like tool materials, the shape of tool, surface treatment, machining conditions and so on. However, in the machining of hard material, to keep the high precision machining as long as possible, the serious issue is the shortage of tool life.

This study focuses on the 『Machining method』 to suppress the tool wear and to increase the tool life in the machining of hard material. This study aims to create a new machining method which has the ability to suppress the tool wear, and to realize high precision machining at the same time. Then, by investigating the mechanism of the proposed machining method and applying it to the machining of complex shape, it is confirmed that a new machining method which has the ability to suppress tool wear and to realize ultraprecision machining is constructed.

In Chapter 1, the machining technology of the hard material, especially the investigations of the tool wear are summarized, and the background of this research work is introduced.

In Chapter 2, the mechanism of the brittle fracture in the machining of hard material and the effect of the tool with negative rake angle is introduced. Then, a method which is called『cutting point swivel machining』, by using the tool with special chamfer, which has the same negative rake angle along the rake face and the circle cross section of tool shape, is proposed. By compensating the setting error, it is confirmed that ultraprecision machining can be realized by using this cutting point swivel machining. The effect of the tool wear suppression is verified by the cutting experiment of SiC. It is found that good surface can be obtained by suppressing the tool wear at the same time.

In Chapter 3, it aims at investigating the mechanism of the cutting point swivel machining. It is found that the cutting point swivel machining has the ability to change the actual cutting direction in the machining. At this time, the moving distance of the cutting edge becomes longer than the conventional machining to remove the same volume of workpiece. Thus, the actual cutting width can be reduced and the cutting force can be reduced at the same time. In addition, by using the broad part of the cutting edge, the tool wear can be reduced substantially. Then, the relationship between cutting force and the speed ratio is investigated. It is found that the cutting force can be reduced by increasing the speed ratio. After that, it is found that the tool wear can be suppressed by increasing the speed ratio. However, when the speed ratio is increased furthermore, the tool wear becomes severe. As a result, it is shown that there is an appropriate speed ratio which has the ability to suppress the tool wear to the least.

In Chapter 4, to machine the complex shape, the cutting point swivel machining is applied to the creation of curved microgrooves. It is confirmed that microgroove with arbitrary curvature can be machined with good accuracy by using cutting point swivel machining. Then, to compare with ball end milling, which is mostly used in the machining of curved surface, it is found that although the efficiency of cutting point swivel machining is worse, the tool wear is less than that of ball end milling, and high precision machining can be obtained for a longer time. At last, the cutting point swivel machining is applied to the machining of curved surface. It is confirmed that both good shape accuracy and surface roughness can be obtained by using cutting point swivel machining.

In Chapter 5, this study is summarized.

As above, a new machining method which is called cutting point swivel machining is proposed in this study. The cutting point swivel machining is applied to curved microgrooving and the machining of curved surface. As a result, it is confirmed that the machining of complex shape with tool wear suppression can be realized. The use of this new machining technology can contribute significantly to the machining technology with high precision and complex shape, which is requested in the machining of mold.

論文審査の結果の要旨

本論文は，高硬度材料からなる金型を高精度に切削加工することを目的に，工具摩耗を大幅に抑制できる加工法として，新たな刃先移動加工法の提案を行っている．さらに，提案した加工法のメカニズムを解明するとともに，その応用としてマイクロ曲線溝加工と自由曲面加工に適用している．

第 1 章「緒論」においては，高硬度材料の加工技術，特に工具摩耗に関する従来の研究の概要をまとめ，本研究の着想に至った背景を述べている．

第 2 章「刃先移動加工法の提案」においては，まず工具すくい角を負にすることで，硬脆材料を加工する際に発生する脆性破壊を抑制できる加工現象について述べている．刃先周方向で均一な負のすくい角と円弧形状の断面を持つ特殊チャンファ付き工具を使用し，工具摩耗の抑制を期待できる「刃先移動加工法」についての提案を行い，あわせて加工機械に対する工具セッティング誤差の補正による高精度加工実現について検討を行っている．さらに，代表的な高硬度材料である SiC を被削材とした切削実験を実施し，従来の加工法と比較し提案加工法では工具寿命を 2 倍以上に伸ばすことができ，また工具摩耗の抑制にともない良好な表面性状を得られることを明らかにしている．

第 3 章「刃先移動加工法のメカニズム」においては，刃先移動加工法の摩耗抑制メカニズムについての検討を行っている．加工後の切削表面の観察から，刃先移動加工法は実質的な切削方向が変化していることを明らかにするとともに，刃先移動方向の速度比と切削力の関係を評価することによって，速度比を増加させると切削力を低減できることを示している．また，速度比を徐々に増加させるにともない工具摩耗が低減するが，一定の速度比をこえると逆に工具摩耗が激しくなることから，速度比にはある最適値が存在することを示唆している．

第 4 章「刃先移動加工法の応用」においては，刃先移動加工法を曲線状の溝加工と曲面加工に適用した結果を述べている．その結果，任意の曲率を持つ溝加工において本提案手法により良好な加工特性を得られることを示している．特に，従来の自由曲面加工法にはボールエンドミリングが多用されてきたが，高硬度材料の加工においては著しい工具摩耗が生じてしまうことが問題となっていた現状に対し，刃先移動加工法を適用することで工具摩耗を抑制しながら高精度な自由曲面の創成が可能であることを明らかにしている．

第 5 章「結論」においては，以上の章の要約を行うとともに，今後の展望について述べている．

以上のように，本論文は金型として使用される高硬度・硬脆材料の新しい切削方法，すなわち刃先移動加工法を提案し，そのメカニズムの解明，実用化検証を行うという極めて独創的かつ有用性の高い加工法技術研究についてまとめあげたものである．

よって本論文は博士論文として価値あるものと認める．