静電気力と超音波振動を用いたナノブラスト研磨用砥粒粒径均一化

Abrasive grain size normalization by coupled electrostatic force and ultrasonic vibration for application to nano-blasting

Ra 1 nm 程度の仕上げ面粗さと加工装置の単純化を両立させた研磨手法が求められている．超精密研磨の手法である高速流体噴射研磨とイオンビーム加工で用いる粒子の，中間の粒径ないし速度の研磨粒子を使用する方法を開発することで，仕上げ面粗さを小さくし，かつ装置を単純化できると考えられる．よって砥粒にナノ粒子を選択し，噴射する速度を向上させるためにナノ粒子を混合させる流体に空気を用いる．

仕上げ面粗さを小さくするためには，要求される範囲内に砥粒の粒径が分布する必要がある．しかしながら，自然状態にあるナノ粒子は凝集することが知られている．凝集粒子の粒径のばらつきが大きいため，凝集粒子を砥粒として用いることは現状では困難である．本研究では超音波振動と静電気力を用い，ナノ粒子の凝集粒子の粒径を小さくしかつ均一化する方法を提案する．

この方法では，先ず粒子に最も大きく作用する付着力である液架橋力を粒子を乾燥させることで減少させる．そして，超音波振動による音響放射力と平行平板電極により生じる静電気力を外力とし，凝集粒子中の粒子間の付着力を上回る外力を与えて粒子を分離させる．提案した方法を実現する装置を設計・製作し，装置内部に超音波振動と静電気力が作用するかを有限要素解析により検証した．

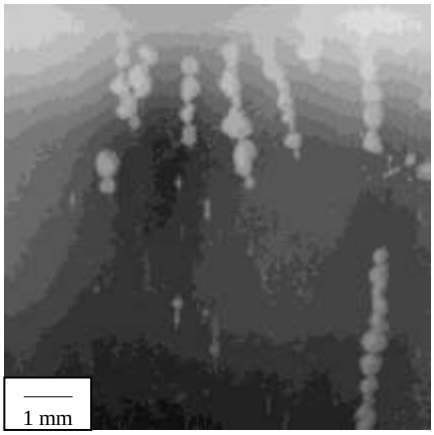
粒径分布の変化を装置を用いて実験により調査した結果，粒子に超音波振動のみを与えたとき，凝集粒子の解砕は確認されなかった．粒子に静電気力のみを与えたとき，粒径の平均は大きくなったが標準偏差は小さくなった．粒子に超音波振動と静電気力の両方を与えたとき，粒径の平均と標準偏差はともに小さくなった．よって，超音波振動と静電気力の両方を作用させる場合に，提案した方法が有効であり，凝集粒子の粒径の均一化の可能性を示すことができた．

There is a need for a polishing method that achieves both a surface roughness of about Ra 1 nm and simplification of processing equipment. By developing a method that uses abrasive particles of an intermediate size or speed between particles used in high-speed fluid injection polishing and ion beam processing, which are ultra-precision polishing methods, the finished surface roughness can be reduced and the equipment can be used. It can be simplified. Therefore, nanoparticles are selected as abrasive grains, and air is used as a fluid for mixing the nanoparticles in order to improve the injection speed.

To reduce the finished surface roughness, the grain size of the abrasive grains must be distributed within the required range. However, nanoparticles in their natural state are known to aggregate. At present, it is difficult to use agglomerated particles as abrasive grains because of the large variation in the particle size of the agglomerated particles. In this study, we propose a method to reduce the size and uniformity of the aggregated nanoparticles by using ultrasonic vibration and electrostatic force.

In this method, first, the liquid cross-linking force, which is the adhesive force that has the greatest effect on the particles, is reduced by drying the particles. The acoustic radiation force generated by the ultrasonic vibration and the electrostatic force generated by the parallel plate electrodes are used as the external force, and the external force exceeding the adhesive force between the particles in the aggregated particles is applied to separate the particles. We designed and fabricated a device to realize the proposed method, and verified whether ultrasonic vibration and electrostatic force act inside the device by finite element analysis.

The change in the particle size distribution was experimentally investigated using an apparatus. As a result, when only the ultrasonic vibration was applied to the particles, the disintegration of the aggregated particles was not confirmed. When only electrostatic force was applied to the particles, the average of the particle diameters increased, but the standard deviation decreased. When both ultrasonic vibration and electrostatic force were applied to the particles, both the average and the standard deviation of the particle size became smaller. Therefore, when both ultrasonic vibration and electrostatic force were applied, the proposed method was effective, and the possibility of uniformizing the particle size of aggregated particles was shown.



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