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超声波振动辅助磁力研磨加工研究*

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摘要：根据研磨加工的材料去除模型，分析得到增加研磨压力是提高磁力研磨加工效率的可行手段。通过在单纯磁力研磨工艺中引入超声波振动，增加了研磨粒子的瞬时研磨压力。经实验证明，在超声振动辅助磁力研磨加工中，研磨粒子在水平切削和垂直冲击挤压运动的综合作用下，对工件材料的去除率高且表面质量均匀；加工效率较单纯磁力研磨工艺提高了约 50%；工件表面粗糙度 R_a 可降至 0.06 μm 左右；电子显微镜观察发现其加工后工件表面形貌较单纯磁力研磨细密均匀；采用 X 射线干涉仪检测得知，经超声振动辅助磁力研磨加工后的工件材料(SUS304)表层的应力状态已由原始的残余拉应力 +320 MPa 变为压应力 -40 MPa，有效提高了工件的疲劳强度。

关键词：磁力研磨　超声波振动　复合加工　表面形貌　应力状态
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Ultrasonic Vibration-assisted Magnetic Abrasive Finishing

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Abstract: Based on the material removal model, it was concluded that the increase of finishing pressure was a practicable method for improving the efficiency of the magnetic abrasive finishing. By adding ultrasonic vibration to the magnetic abrasive finishing process, the instantaneous pulsating finishing pressure of magnetic abrasive particles could be increased. Experiment results showed that, magnetic abrasive particles could efficiently remove the workpiece material and keep surface smooth with the combined force in rotational movement and vertical impact. The practical experiment proved that the finishing efficiency was improved by 50% or so. The surface roughness of workpiece decreased to 0.06 μm. Compared with only magnetic abrasive finishing, the ultrasonic vibration-assisted magnetic abrasive finishing made the surface morphology smoother and well-distributed in digital microscope. By using X-ray interferometer detection, the stress state of workpiece surface layer after ultrasonic vibration-assisted magnetic abrasive finishing changed from residual tensile stress (+320 MPa) to compressed stress (-40 MPa), which effectively improved fatigue strength of workpiece.

Key words: Magnetic abrasive finishing　Ultrasonic vibration　Combined machining　Surface morphology　Stress condition

引言

随着制造技术的进步，大量新材料、新结构的零件应运而生，同时也对零件的表面质量提出了越来越高的要求。复杂形状零件因结构复杂，传统的加工工艺和工具难以完成精密加工。磁力研磨法(Magnetic abrasive finishing，MAF)作为一种非传统的光整加工工艺，是利用磁性研磨粒子在磁场的作用下沿着磁力线分布排列并形成具有一定刚性的磁粒刷；通过磁粒刷与工件之间的相对运动实现对工件表面研磨的加工方法[1]。磁性研磨粒子作为磁力研磨的加工工具，通常由铁磁相和磨粒相组成，每

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