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基于廓形识别的弯管内表面精密磨削试验研究

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摘 要：目的 针对弯管内表面磁粒研磨工艺中手动采点所产生的随机误差大、研磨间隙无法保证以及位姿不准确等问题。**方法** 结合工业机器人与工业相机，设计并实现了弯管廓形中线的快速获取及研磨位姿计算的工艺方法。首先，对弯管内表面磁粒研磨工艺的基本原理进行了分析，根据研磨过程中单颗磨粒受力状态以及研磨区域磁场模拟，得出影响研磨压力的主要工艺参数；其次，利用工业相机获取弯管图像，通过图像处理算法得到弯管的廓形中线；最后将中线上的坐标点进行坐标转换、拟合、离散，并结合磁粒研磨工艺特点计算出研磨过程中机器人的运动位姿，同时与手动采点法的试验结果进行对比分析，以检验该方法的可行性。**结果** 经廓形识别方法提取出的研磨轨迹较为平滑，用时少，能够保持稳定的研磨间隙且更贴近实际弯管中线。在相同试验条件下对具有180°转角的铜弯管进行研磨，经廓形识别方法研磨60 min后，表面粗糙度Ra由原始的0.854 μm降至0.236 μm，达到最佳。表面划痕细致且均匀，无过磨、深度划痕等缺陷，平均速率比手动采点法提高约35.8%，粗糙度下降率提高约3.8%。**结论** 廓形识别法在弯管内表面磁粒研磨工艺中的应用，能快速准确的获取弯管廓形中线并计算机器人研磨位姿，在保持正确研磨位姿的同时能够维持稳定的研磨间隙，可有效提高弯管内表面磁粒研磨效率及表面质量。

关键词：磁粒研磨；弯管；廓形中线；研磨轨迹；受力状态；研磨效率

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Experimental Research on Precision Grinding of Inner Surface of Elbow Based on Profile Recognition

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ABSTRACT: The work aims to solve the problems of large random errors caused by manual point sampling in the magnetic abrasive finishing process of the inner surface of the elbow, the grinding gap cannot be guaranteed, and the inaccurate pose. Combined with an industrial robot and an industrial camera, a process method for quickly obtaining the centerline of the curved pipe profile and calculating the grinding pose was designed and realized. First, the basic principle of the magnetic abrasive finishing process on the inner surface of the elbow is analyzed. According to the force state of a single abrasive particle during the grinding process and the magnetic field simulation of the grinding area, the main process parameters that affect the grinding pressure are obtained. Secondly, use the industrial camera to obtain the image of the bent pipe, and obtain the profile centerline of the bent pipe through the image processing algorithm. Finally, the coordinate points on the center line are converted, fitted, and discrete, and combined with the characteristics of the magnetic abrasive finishing process to calculate the movement poses of the robot during the grinding process. At the same time, the test results of this method and the manual point collection method are compared and analyzed, to test the feasibility of this method. The finishing trajectory extracted by the profile recognition method is smoother, takes less time, can maintain a stable finishing gap and is closer to the actual center line of the bend. Under the same test conditions, copper elbow with 180° corner was ground. After 60 minutes of grinding by the profile recognition method, the surface roughness Ra decreased from the original 0.854 μm to 0.236 μm, reaching the best effect. The scratches on the surface are dense and uniform, without defects such as over-grinding and deep scratches. The average speed is about 35.8% higher than the manual point-taking method, and the roughness reduction rate is enhanced by about 3.8%. The application of the profile recognition method in the magnetic abrasive finishing process of the inner surface of the elbow can quickly and accurately obtain the profile centerline of the elbow and calculate the grinding pose of the robot. It can maintain a stable grinding gap while maintaining the correct grinding position, which can effectively improve the grinding efficiency and surface quality of the magnetic abrasive on the inner surface of the elbow.

Key words: magnetic abrasive finishing, elbow, profile centerline, grinding track, force state, grinding efficiency

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