G. M. Bone
Graduate Student.

M. A. Elbestawi
Professor.

R. Lingarkar
Graduate Student.

L. Liu
Research Associate.

Mechanical Engineering Department,
McMaster University,
Hamilton, Ontario, Canada L8S 4L7

Force Control for Robotic Deburring

An active end effector based force control system for robotic deburring is successfully implemented using a PUMA-560 robot. The system goal of a controlled chamfer depth with minimum surface roughness is achieved by minimizing the normal chamfering force variance online. Several force control algorithms are evaluated based on this objective. The control laws are designed based on models combining a deterministic plant with a stochastic disturbance which are identified from experimental data. Simulation results are verified by real-time force control experiments. Performance comparisons are made based on the force variance and surface roughness achieved by each controller. The 6 step extended horizon controller is shown to achieve the best overall performance.

1 Introduction

Automated robotic deburring systems have been investigated for a number of years as a replacement for the unpleasant and inefficient manual deburring operation. The high cost of deburring, for some parts as high as 35 percent of the total cost, continues to be the main incentive for this research.

In manual deburring the burrs are often removed from part edges by chamfering. It is often required that the chamfer depth be within specific tolerances; a consistency which is difficult to achieve manually. Correspondingly, much of robotic deburring research has been concerned with controlling the depth of cut when chamfering using non-compliant cutting tools [1-9]. Kazerooni, Bausch, and Kramer [1] concluded that the chamfering force is proportional to the tool feedrate times the combined cross sectional areas of the chamfer and burr. If the control strategy is to maintain constant force, the burr variations will be followed and the control of the chamfer depth will be poor. When projected in the direction normal to the part edge however, burr size variations have little effect on the total area. A consistent chamfer depth can therefore be obtained by controlling the normal force. This has become the prominent control strategy in robotic deburring research [2-7].

Ideally the force control would be performed using the robot arm alone. However, studies have found for most industrial robots the arm's low bandwidth limits its ability to control the chamfer depth at higher feedrates [3, 4]. Improved performance has been obtained using special end effectors to control the tool more directly [5-9].

With this approach the robot is used for the coarse motion of the tool around the part, while the fine motion control is performed by the end effector. While a 6 degree-of-freedom (DOF) robot may be required to follow the part edge, the chamfer depth may be controlled by a single DOF end effector normal to the chamfer surface as shown in Fig. 1. The end effector DOF must be rotated to keep it normal to the edge. The speed of this rotation becomes critical when sharp corners are negotiated. Hollowell [7] has shown that electronic rotation

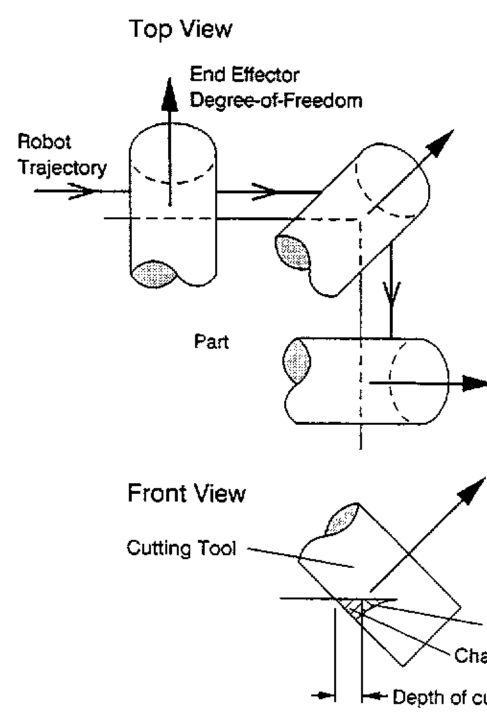

Fig. 1 Control of the chamfer depth of cut using a single degree-of-freedom end effector

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