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HYBRID FORCE/VELOCITY CONTROL OF A PNEUMATIC GANTRY ROBOT FOR CONTOUR TRACKING: TUNING AND MODEL VALIDATION

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ABSTRACT

The paper examines hybrid force/velocity control of a pneumatic gantry robot for contour tracking. Both experimental and simulation results are presented. The control system is structured to control the contact force and the tangential velocity simultaneously. Controller tuning and model validation results are given for a fixed gain PI-based hybrid force/velocity controller. A simple yet effective model is presented in sufficient detail such that other researchers can perform their own simulations to investigate the utility of their own controller designs. The model is used to demonstrate the negative effects of Coulomb friction. Future work will focus on friction compensation techniques to improve performance.

NOMENCLATURE

C	viscous friction coefficient
C_c	contact damping coefficient
e	controller error
f_a, f_c	Applied and contact forces
F_d, F_s	dynamic, static Coulomb friction forces
F_w	potentiometer wire force
K	EtoP valve gain
K_c	contact spring constant
K_P, K_I, K_D	PID controller gains
M	cylinder effective mass
u	control signal
τ	compressibility time constant
v	velocity
x, z	x-axis and z-axis cylinder end positions

Subscripts

t	tangential
x, z	x-axis and z-axis cylinders

INTRODUCTION

Control of the interaction between a robot manipulator and a workpiece is critical for successful execution of tasks where the robot's end effector must perform a contact operation on the surface of a workpiece. Representative tasks include polishing, grinding and deburring. In such applications the robot's end effector must track the contour of the workpiece while applying a constant force. Many of these operations are performed by human operators. In order to justify automation, a robot must be faster and cheaper. Considerable research has been conducted on force control with electric robots [1]. By contrast, little research has been conducted on force control with pneumatic robots. The latter has the potential to be considerably cheaper. However, the compressible nature of air as the working fluid means pneumatic robots are more difficult to control. This paper presents work with a pneumatic gantry robot that was originally constructed to grind the edges of steel blanks prior to being stamped as part of an automotive part manufacturing process [2]. The objective of the previous project was to control surface roughness. The objective of the current project is to control contact force.

HYBRID FORCE/VELOCITY CONTROL

It is appropriate to begin by drawing a distinction between hybrid force/position control and hybrid force/velocity control. Both can be applied to a contouring application. Raibert and Craig [3] are usually quoted as the seminal paper on position/force control. But as pointed out by Goddard et al [4], force/position control needs a global model of the workpiece, whereas force/velocity control needs only local information. Thus, it is argued that force/velocity provides a simpler and more robust structure. However, it is acknowledged that researchers continue to work with the former, for example the hybrid force/position control study of Ikeda and Minami [5].