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Robotic Assembly of Flexible Sheet Metal Parts

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ABSTRACT

Two control problems encountered in robotic sheet metal assembly are addressed in this paper. They are the control of vibration when handling the sheet metal parts and the control of the contact state between the parts during assembly. For the first problem, a Learning Extremum Controller (LEC) is proposed. Using a strain gauge based sensing device mounted on the robot gripper for vibration feedback, the orientation of the part relative to its path is controlled to reduce vibration. For the second problem, a sensor fusion system developed previously [10] is used to provide feedback about the contact condition between two sheet metal parts. An Integral Contact Controller (ICC) is used to correct any angular error between the parts to ensure full contact along the joint for subsequent welding. Experimental results confirmed the effectiveness of both control algorithms. The LEC reduced the vibration amplitude by up to 45%. The ICC reduced the angular error from 0.5° to 0.025° in 1.7 seconds.

1. INTRODUCTION

In this paper two of the control problems encountered in robotic sheet metal assembly will be addressed. The first is the vibration of the sheet metal parts when they are being handled. Large car body panels, because of their flexibility, require specially designed grippers to control vibration during handling. These are typically large devices which use several, widely spaced vacuum pickups to support the part in order to reduce vibration. Each gripper must be designed and manufactured for a particular part's size and shape, and to avoid interference with the subsequent welding operation. A much more flexible and cost effective alternative is the use of a small generic gripper. Such a gripper would not require redesign to handle different parts, and would naturally avoid the interference problem. However, this gripper would not provide overall support of the sheet metal part. Therefore, vibration control during part handling is a problem which must be tackled.

The second problem addressed in robotic sheet metal assembly is the monitoring and control of the contact state of the parts for proper assembly. Under ideal conditions, when two robots are used to assemble two sheet metal parts, full contact along the joint to be welded will be achieved. However, in reality, the parts may not be aligned properly. This misalignment could be due to the parts own dimensional error or the handling robots' positioning error. If the two parts are misaligned, a poor weld joint may result. Thus, the monitoring and control of the contact state of the part is very important.

The control of vibration and the positioning of flexible structures are two very related topics. They have been studied by many researchers. Some have applied Feedforward Input Command Shaping control [1-2] while others have employed active damping control [3-4], and passive damping control [5-6]. In the area of control of contact, several methods have been developed by researchers to detect contact states using force/moment sensing [7-8]. Nevertheless, these methods were all developed for rigid object assembly, and the flexibility of the parts was not considered. Mills [9] proposed a discontinuous control approach for robotic sheet metal assembly to handle the transition from noncontact to contact motion. However, the problem of monitoring and controlling of the contact state was not addressed. A multisensor based system was developed by the authors to detect the contact of a lap joint between two sheet metal workpieces [10]. Detection methods were developed based on the use of a Force/Moment Sensor (FMS), Strain Gauge equipped Fingers (SGFs) and sensor fusion of the FMS and SGF information. It was found that the sensor fusion method surpassed the best individual performance of the other methods.

The two problems in robotic sheet metal assembly mentioned above will be addressed in this paper. For the first problem, a Learning Extremum Controller (LEC) is proposed to control the vibration generated in a sheet metal part held by a small generic gripper when it is being handled by a robot. Using a strain gauge based sensing device mounted on the robot gripper, the sheet metal part's vibration can be monitored and fed back to the robot controller. Thus, the part's orientation relative to its path can be controlled to reduce vibration.

For the second problem, a sensor fusion system developed previously [10] is used to provide feedback about the contact state between two sheet metal parts to be assembled. An Integral Contact Controller (ICC) is used to correct any angular error between the parts to ensure full contact along the joint for welding.

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