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CONTROL OF ROBOTIC FIXTURELESS ASSEMBLY

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ABSTRACT

Robotic Fixtureless Assembly (RFA) refers to the performance of assembly tasks by robots without the aid of jigs and fixtures. Two control problems encountered in RFA of three dimensional (3-D) sheet metal parts 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 novel Strain Gauge Equipped Fingers (SFGs) (developed previously in [13]) for vibration feedback, the orientation of the part in 3-D space relative to its path is controlled to reduce vibration. For the second problem, SGFs and a Force/Moment Sensor (FMS) are used respectively to provide feedback about the contact condition between a 3-D and a flat sheet metal part. 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 36%. The ICC reduced the angular error from 0.5° to 0.05° within 2.4 and 3.6 seconds using the FMS and SGFs, respectively.

1. INTRODUCTION

Currently in many industries, including automotive and aircraft manufacturing, specially designed clamping devices known as fixtures are required for sheet metal assembly. These fixtures are used to hold and position the workpieces for joining by welding or riveting. Since the number of sheet metal workpieces involved is large, between 300-500 per car for example [1], the number of fixtures required is substantial. Since it is common in the automotive industry that each year new variations of the previous years' models are introduced, new fixtures must be designed, fabricated and installed in the plant. This retooling operation is very costly due to the long lead time associated with the design and manufacture of the fixtures, and the loss of production during their installation. Additionally, most fixture design is performed before production parts and real production processes become available, and only after these are available can the fixtures be adequately tested. This can be problematic since most fixtures are not easily modified [2].

A possible solution to the problems associated with fixtures is the use of two robots to assemble and join the workpieces without fixtures. When workpieces are changed for a new model, only the robot's software should have to be modified, with little or no retooling. This approach is referred to as Robotic Fixtureless Assembly (RFA). It is expected that the use of RFA in the automotive industry can reduce retooling costs by 80% [3].

In this paper, two of the control problems encountered in RFA of 3-D automotive sheet metal parts 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, the small generic 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 RFA of 3-D sheet metal parts 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 and an inaccurate final assembly 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