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GRASPING OF 3-D SHEET METAL PARTS FOR ROBOTIC FIXTURELESS ASSEMBLY

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Abstract

A novel grasping strategy and gripper for fixturing 3-D sheet metal parts for the robotic fixtureless assembly application is presented. The grasping strategy combines a previously developed 2-D strategy with a unique hardware design for the fingers of the gripper. To fixture a sheet metal part, the fingers are placed within holes in the part and moved until the desired set of contact locations is achieved. The fingers are grooved at fixed angles such that the edge of the sheet metal part can be held within the grooves. The position of the sheet metal part is uniquely determined in 2-D by the geometry of the part while the non-planar dimension is controlled by the geometry of the fingers. Six frictionless point contacts are used. A computer algorithm is described that solves for suitable contact locations based on the part geometry. Four different grasps were tested on two sheet metal parts. Twenty five trials were performed for each grasp. The standard deviation of the part location prior to being grasped was 0.45 mm. After being grasped, this was reduced to 0.04 mm.

1 INTRODUCTION

Specially designed clamping devices known as fixtures are required for assembly of sheet metal parts in automotive and aircraft manufacturing. These fixtures are used to locate and immobilize the parts for spot welding and riveting. Since the number of sheet metal parts involved is large, between 300-500 per car for example, the number of fixtures required is substantial. When a new model is to be manufactured, new fixtures must be designed, built and installed in the plant. This retooling operation is very expensive. A recent potential solution to this problem is the use of two robots to assemble and join the parts without fixtures. When parts are changed for a new model, only the robot's software should have to be changed. This approach is known as Robotic Fixtureless Assembly (RFA) [4]. RFA is expected to reduce the retooling costs by 80% [5].

The issue in RFA addressed in this paper is fixturing of the parts using a robotic gripper equipped with several movable fingers. The fixturing will be performed in 3-D. Conventional robot grippers (i.e. parallel jaw and three jaw types) require frictional contacts for object immobilization. Since sheet metal parts often have very smooth oily surfaces, frictional contacts cannot be relied upon. In this work, the contacts between the fingers and the part are modelled as frictionless point contacts (FPCs). FPC's have the additional advantage of being able to slide to their desired locations.

As in conventional fixturing, the first goal is to locate the part accurately. Typically an accuracy of ±0.1 mm is required [5]. Initial errors due to robot and part positioning must be overcome to achieve this goal. The second goal is immobilization of the part at its desired location. To achieve these goals the number and location of the contacts, and a suitable finger location strategy must be determined.

With FPCs the number and location of the contacts required for immobilization may be determined by either force closure or form closure models [2] [1] [6]. For the case of FPCs, the locating strategy for force and form closure is equivalent. Nguyen shows that six contacts with independent spatial vectors are needed for grasping in 3-D [6]. Conventional fixturing designers rely on a pseudo form closure approach known as the "3-2-1" rule [3]. This rule states that a part with minimal features will be uniquely held and immobilized when it is rigidly contacting six points. Each contact point is termed a datum feature. The primary datum is a plane defined by three datum features on the most important locating surface as shown in Fig. 1. The secondary datum is a line defined by two datum features and the third is a point defined by one datum feature. The rule is not true form closure since motion is not restricted in all directions. Gravity, friction or other forces are assumed to maintain the po-