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DESIGNING OF ROBOTIC DOUBLE-FUNCTION FINGERTIPS

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Abstract: This paper presents the design of robotic end-effector fingertips for precision assembly work. The fingertips are used to assemble four different elements of a battery package top cover. The workpieces have got complex shapes therefore double-function fingertips are essential in order to perform the four independent operation steps via an industrial robot. A Fanuc LRMate 200iC robot with a servo gripping mechanism are used to accomplish the assembling operations.

Keywords: *gripper, fingertips, robot, grasping*

1. INTRODUCTION

Robots can perform high repeatability and accuracy therefore it can be used to assemble workpieces [1], [2], [3]. Not only recently, robotic assembling [4] are a widely investigated area, especially for industrial purposes [1], [5]. Changing from manual assembly to robotic one may can rise serious difficulties because robots are controlled kinematically without force feedback. When workpieces are not matching due to their bad orientation the system cannot correct the motion of the end-effector.

There are a great number of commercially available grippers, which are actuated by, e.g., pneumatic air supply, electrical servo motors. However available fingertips usually have flat surface shapes [1], [6]. Using such fingertips to grasp a workpiece it will not be in a well determined orientation and position of the coordinate system of the end-effector. Therefore these fingertips cannot be used for a precision assembling. This drawback can be improved by applying three-finger gripper [7] but many cases this is not a perfect solution.

A better solution is the task specific fingertips, which have surfaces compatible with the geometries of gripped workpieces. However such fingertips may fit only to a specific type of workpieces. Since industrial robots usually have 6 DoF, the end-effector can be rotated to an arbitrary orientation. In many cases this gives the possibility to design the fingertips fitting to more than one workpiece. Naturally it depends on the geometry of the workpieces.

The purpose of this paper to design double-function gripper fingertips, which can be used for a battery package assembly process. There are four workpieces each of them having complex geometry. Well defined positions and orientations of the workpieces are required for the precision assembling. In order to satisfy this condition the surfaces of the fingertips and the corresponding workpieces must be compatible.

Further requirement is to apply as few robots as possible, which can be fulfilled by multipurpose fingertips. The present paper deals with double-function fingertips, which are applicable to assemble four workpieces.

The remainder of the paper is organized as follows. In section 2, the assembling strategy of the top cover workpieces are described and the scheme of the working area is also given. The 3D modelling of the fingertips are given in section 3. Autodesk Inventor 2016 software was used to create the model and the technical drawing of the fingertips. The summary and concluding remarks are presented in section 4.

2. WORKPIECES TO BE ASSEMBLED

The top cover of the battery package consists of four workpieces, i.e., steel spring, black plastic stick, red plastic button and top cover (see *Figure 1*). Four steps are needed to perform their assembling. Step I: the spring is attached into the hole ($\varnothing\ 1\ mm$) of the black plastic stick. Step II: the black stick is inserted into the plastic top cover element. Step III: the red pushbutton is snap-in to the top plastic cover. Step IV: the ready-made workpiece is placed to the next assembling stage.

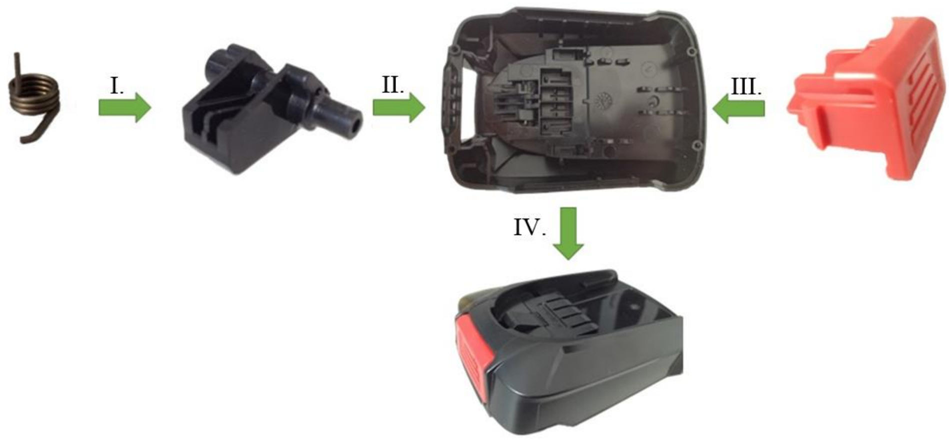

Figure 1. The assembling sequence of the top cover

In order to perform the assembling by robot the base positions and orientations of the workpieces must be well defined. Furthermore the working area of the robot must be considered, i.e., all of the workpieces and the assembling process must be placed within this area. A test bench was designed to perform the assembling of the four workpieces, the arrangement of the working area is shown in *Figure 2*. The sequence is denoted by arrows with numbers. A Fanuc LRMate 200iC industrial robot is applied to execute the assembling process.

The robotic assembling can be performed by the following sequence:

- The end-effector is moved from the base position to grasp the plastic stick.
- A steel spring is inserted into the hole of the stick and kept in this position by a magnet.
- This stick subassembly is put to a temporary place.
- Then the end-effector is moved to the top cover to grip it.
- The stick subassembly is taken away from the temporary position and snap-in to the top cover.
- Also a snap-in process is performed to fix the red pushbutton into the top cover temporarily.
- Then the red button is pushed to its final position.
- Finally the end-effector is moved to the end position where ready-made workpiece is stored.

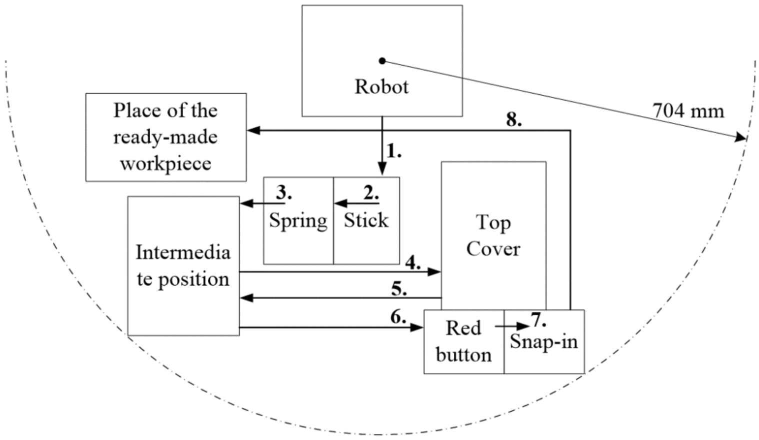

Figure 2. The block scheme of the robotic assembly

It is an economical solution if double-function fingertips are used for the above assembly process because one robot is enough to complete all of the operations. Due to the different shapes of the workpieces double-function fingertips are needed.

3. CAD MODEL OF THE FINGERTIPS

The model of the fingertips are created by the use of Inventor CAD software. The 3D models of the units are shown in *Figure 3* and *Figure 4*. The inside surfaces of the fingertips are shown in *Figure 3 (a)* and *(b)* the corresponding workpiece, which fits to it can be seen in *Figure 3 (c)*. The gripping surface of the stick and the corresponding tool surfaces are marked by blue circles [see *Figure 3 (a)–(c)*]. Red circle denotes the middle range of the stick, which fits to the fingertip [see *Figure 3 (a), (c)*]. A neodymium magnet is placed into the hole of the fingertip denoted by red circle shown in *Figure 3 (a)*. The function of the neodymium magnet is to keep the spring together with the stick.

In order to use also the same end-effector for grasping the battery cover, the outer sides of the fingertips are shaped to fit it. The outside surfaces of the fingertips and the battery cover are displayed in *Figure 4 (a)–(c)*. The orange ellipses show the fitting surfaces of the top cover and the fingertips.

The black stick can be grasped by closing the fingertips and by opening it will be released. Before grasping the top cover the fingertips are closed then at an appropriate position by activating the opening command the fingertips will grip the top cover.

There are two counter bores to mount the fingertips onto the end-effector of the robot [see *Figure 3 (a), (b)*].

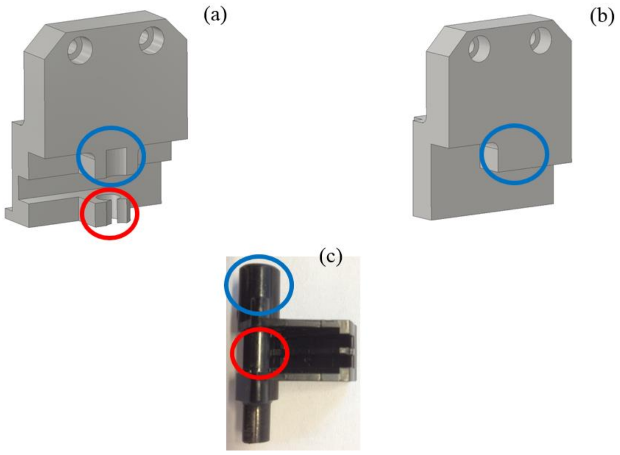

Figure 3. Inner shaped surfaces of the fingertips and the picture of the stick

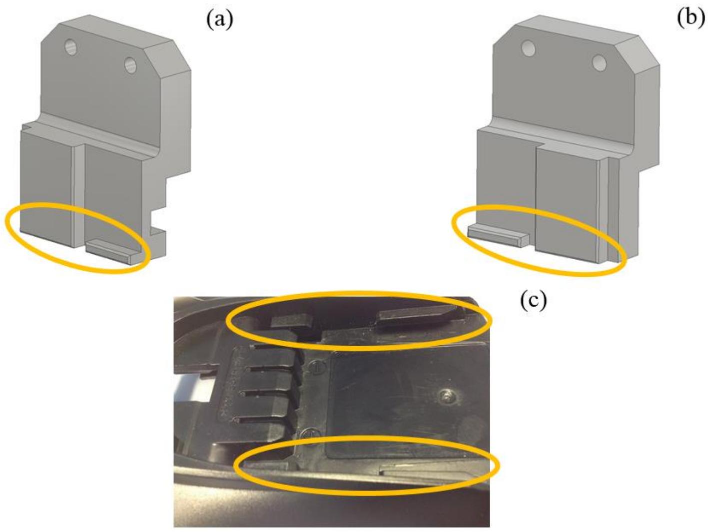

Figure 4. Outer shaped surfaces of the fingertips and the picture of the top cover

The technical drawings of the fingertips were created under Inventor CAD software and shown in *Figure 5* and *Figure 6*. The material of the gripper fingertips is aluminium alloy. The given geometry of the fingertips can be manufactured by milling machine. The general chamfers of the surfaces are 0,5 × 45°.

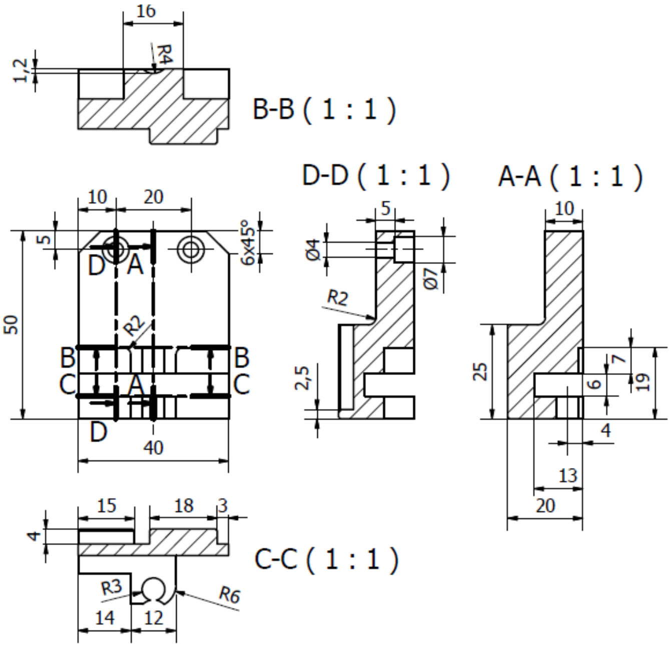

Figure 5. Technical drawing of the first fingertip

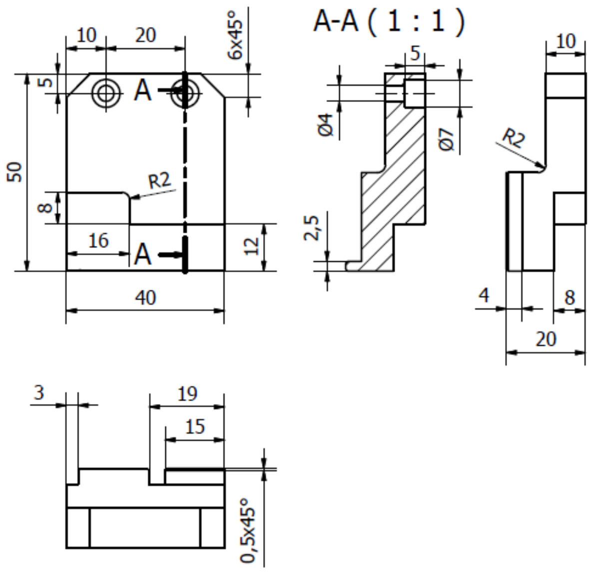

Figure 6. Technical drawing of the second fingertip

4. SUMMARY

Special purpose double-function fingertips have been designed to assemble four workpieces. The fingertips can grasp via inside surfaces a plastic stick together with a steel spring. The outer surfaces of the fingertips capable to grip a plastic top cover in order to perform three assembly steps. Though both the plastic stick and the plastic top cover are having complex geometry their positions and orientations in the coordinate system of the end-effector are precisely determined. This fact is essential to perform precision assembling via robot.

The assembly process was performed properly. This experiment validated the above proposed geometries of the fingertips. The robot can assemble the workpieces less than 1 minute. Thereafter the assembling process of the battery pack can be continued from the position of the ready-made top cover.

The presented case study is a good example that robotic assembly is applicable for such a complex assembly process, which was originally worked out manual assembly.

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