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Development of Industrial Autonomous Mobile Robot for Part Handling in Machine Tool industry

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Abstract: The purpose of this paper is to introduce an autonomous robot for part handling in machine tool industry. It is developed for practical industrial application. Based on task analysis of part handling application, specifications and features of the robot are determined. Major features of the robot are omni-directional platform and dual arms. Omni-directional platform has three omni-wheels and arms are parallel and antagonist mechanism. These features are explained in detail.

1. INTRODUCTION

Recently, machine tool industry is confronted with many difficulties such as 3D (difficult, dangerous and dirty) avoidance, deficiency of skilful labor by increased age, increased labor cost and decreased material cost. To cope with these problems, many companies have moved plants abroad or increased investments for automation using robot system.

There are many researches about robots for automation in machine tool industry. Usually gentury type robot or fixed manipulator(Park et al., 2006) is used in this applications. But, these systems are specified to each product line consisted of several machine tools. When products are changed, systems also have to modified or reconstructed. This needs many time and large investments.

Mobile manipulator can solve these problems. It moves among machine tools and handle various parts. Tasks of the robot can be changed easily by teaching or reprogramming such as SmartPal(Dai, K. et al., 2005). But research results about mobile manipulator conducted in laboratory level can not be applied to industrial application.

In this paper, mobile dual arm robot which is able to load and unload various parts is introduced. In section 2, tasks for part handling robot are analyzed. Structure of developed autonomous robot is described in section 3. Finally, section 4 concludes this research.

2. TASK ANALYSIS OF PART HANDLING ROBOT

In machine tool industry, most of tasks of human operators are loading material to machine tool and unloading material from machine tool. And also human operators carries the material and finished goods to another machine tool or stack. Therefore, the industrial autonomous mobile robot for machine tool is developed to load and unload material instead of human operators. Fig. 1 shows the developed robot how to work with machine tool.

The tasks of the developed robot are as follows:

(1) Grab work-piece with various shapes and size below 10kg.
(2) Transfer a work-piece to machine tool
(3) loading and unloading in Machine tool

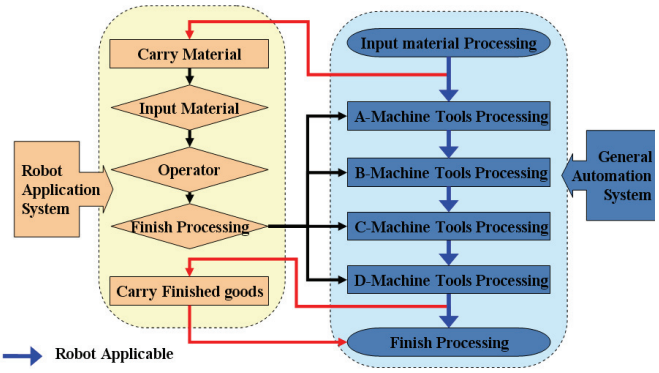

Fig. 1. The task flowchart of autonomous mobile robot

To accomplish the required task, the developed mobile robot would have mobile platform and dual arms. The mobile platform is necessary to transfer a work-piece to machine tool. A dual arm is necessary to load and unload a work-piece in machine tool.

3. STRUCTURE OF AUTONOMOUS ROBOT

Developed robot adopts omnidirectional mobile robot as mobile platform and dual arm with parallel and antagonist mechanism as manipulator as showed in Fig. 2.

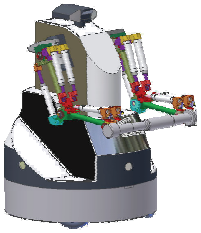

Fig. 2. Industrial autonomous mobile robot for machine tool

3.1 omni-directional mobile platform

The most popular wheeled mobile robot is equipped with two independent driving wheels. This robot can rotate about any point, but does not allow sideways motion. This limitation of mobile platform may restrict tasks of mobile manipulator.

To cope with these problems, omnidirectional mobile robots have been proposed. They are capable of arbitrary motion in an arbitrary direction without changing the direction of wheels, because they can achieve 3 DOF motion on a two-dimensional plane. (Carlisle, B., 1983)

The robot of this paper adopt omnidirectional mobile platform which can improve mobility and generate optimal trajectory to machining tools for given tasks. Equation (1) shows relation between wheel traction forces and robot motion forces.

$$\begin{Bmatrix} f_x \\ f_y \\ M \end{Bmatrix} = \begin{bmatrix} -1/2 & -1/2 & 1 \\ \sqrt{3}/2 & -\sqrt{3}/2 & 0 \\ L & L & L \end{bmatrix} \begin{Bmatrix} D_1 \\ D_2 \\ D_3 \end{Bmatrix} \quad (1)$$

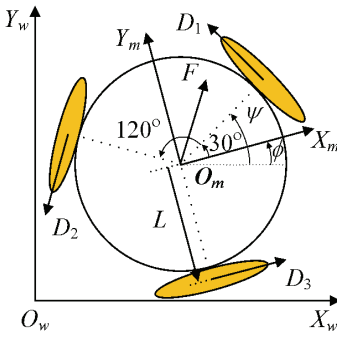

Fig. 3 Omnidirectional mobile platform

3.2 dual arms with parallel and antagonist mechanism

Most robot used in machine tool industry is serial type robot. Compared to a serial mechanism, a parallel mechanism has many advantages. It has a high stiffness, a high accuracy and high power because of its closed structure. Therefore, in this paper, the developed dual arm is designed using parallel mechanism and antagonist mechanism. Fig. 4 shows the example of the antagonist mechanism.

Muscato and Spampinato developed five degrees of freedom anthropometric robotic leg (Muscato et al., 2006, 2007). The mechanical structure of the robotic leg is made up of 4 links, corresponding to the pelvis, thighbone, shinbone, and foot. The leg of human is similar to the arm of those. Therefore, the mechanical structure of the anthropometric robotic leg is used by adding the one revolute joint at the pelvis. The degree-of-freedom of each arm is 6 except gripper and the overall d-o-f of the developed dual arm is 12. For each arm, the shoulder joint is moved by three rotational degrees of freedom through one rotational joint and one universal joint. The elbow joint is moved by one rotational degree of freedom. The wrist joint is implemented by two rotational degrees of freedom through one universal joint. Fig. 5 shows the prototype realized.

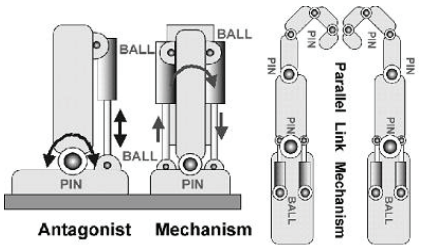

Fig. 4 The antagonist mechanism

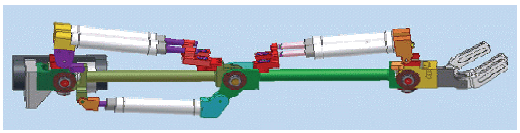

Fig. 5. The prototype drawing of left arm of the dual arms.

4. CONCLUSIONS

In this paper, an autonomous robot for part handling used in machine tool is introduced. It is developed for practical industrial application. Based on task analysis for part handling application, specifications and features of the robot are determined. Major features of the robot are omnidirectional platform and dual arms with parallel and antagonist mechanism.

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