INCREASING THE INTELLIGENCE OF ROBOTISED ASSEMBLY

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Abstract: *The assembly automation help to increase the reliability of the operations and they help to reduce the costs in the small and medium size production. During automation the mechanical peripheries must be operated automatically without human help, collaboration and inspection. It means, these equipments have to have pneumatic or hydraulic or electric drives, PLC or other advanced control units and monitoring systems, which are the intelligent components of the assembly. During assembly we need a lot of intelligent mechanical peripheries, which are able to realise the operations. The authors give a short overview about their activity in the field of robotised assembly focused on the sensor based intelligence of mechanical robot peripheries.*
Keywords: *Assembly, Robots, Intelligence, Sensors, Monitoring*

1. INTRODUCTION

In the conventional assembly the mechanical peripheries can be handled, operated by the workers: manual (human collaboration) and they can be monitored by the workers, too (human inspection). During automation they must be operated automatically without human help and inspection. In the small and medium size production the assembly is the most complicated operation. The only way of increasing the reliability of operations is the development and application of intelligent mechanical robot peripheries such as grippers, tools, fixtures and special devices [2]; [4]; [6].

During automation the human inspection has to be replaced by using sensors. Sensor based monitoring, control and drive give the intelligence for the fixtures. Sensors and monitoring help to eliminate the disturbances and help to increase the reliability of operations. Using more sensors in the same time means the realisation of the sensor-fusion, the multi-sensor system [1].

2. INTELLIGENT MECHANICAL PERIPHERIES – TOOLS FOR REALISATION OF INTELLIGENT ASSEMBLY

The robotized assembly need a lot of tools, fixtures, tool changer, etc. They are mechanical peripheries of the assembly. They are mainly task-oriented fixtures. One part of them is the end-effectors, which can be mounted into the last robot wrist. The end-effectors must be changed before and after operations to continue the assembly. To realise the changing operations we need end-effector changers.

The most important assembly operations are the following [3]:

- Handling the parts to be assembled,
- Inserting the elements of the products into the fixtures,
- Peg in hole operations,
- Riveting, joining operations,

- Screwing operations,
- Gluing, welding operations,
- Function test of the assembled parts.

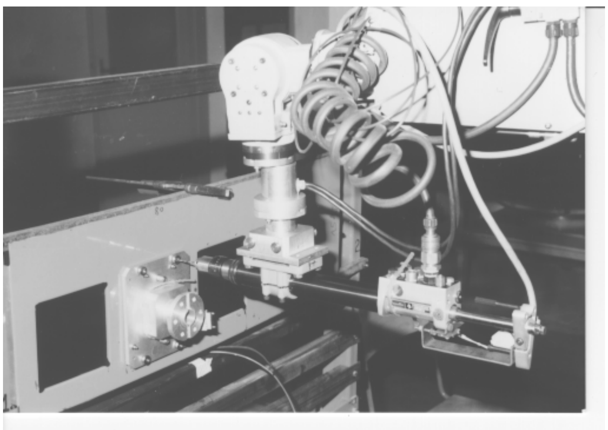
In the framework of increasing the intelligence of the robotised assembly the following main tasks have to solve:

- Control of the force, torque values to increase the reliability of clamping operations and to decrease the deformation, damage of thin wall parts work pieces with sensitive surfaces,
- Monitoring of the grasping/clamping force values,
- Monitoring of the forces and torque values during assembly operations, etc.

The authors will introduce some case studies about the intelligent assembly.

3. ROBOTIZED ASSEMBLY OF BUS REAR LAMPS

The whole assembly of rear lamps of the bus (Type IKARUS 255 made in Hungary) was the task. The first operation was the pre-positioning of the bus-body in the workspace of the robot. The final–positioning was realised by applying mobile CCD camera and 6 axes force/torque sensor built in the last robot wrist. After it the holes of the four fixing screws were drilled by the robot having a commercial pneumatic drilling unit (Desoutter) and an intelligent, pneumatic drilling fixtures (Fig. 1. and Fig. 2.). We applied 4 commercial tools, fixtures and four task-oriented, intelligent grippers, fixtures developed, built by us [8].
The drilling fixture has an optical proximity sensor, own pneumatic clamping cylinder with safety elements (a built-in two-way magnet valve, a non-return valve and a pressure switch) to avoid its dropping out of the rear wall, when drilling.



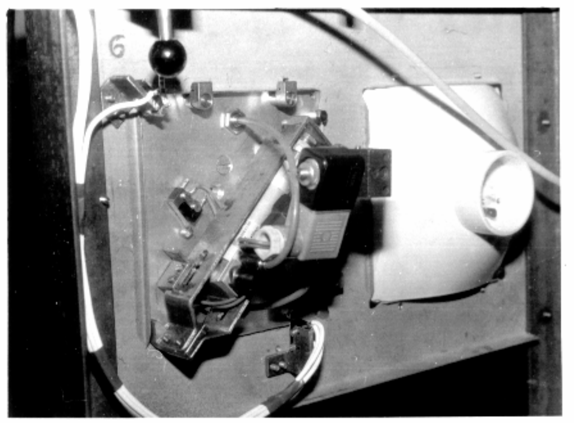


Fig.1.Robotised drilling using intelligent fixture   Fig. 2. Intelligent drilling fixture (rear view)

The Fig. 2. shows the drilling fixture in rear view. During drilling there is no transmission of pneumatic energy to the fixture, because it is a stand alone fixture during drilling.
To change the fixtures and tools we applied an end-effector changer developed by TU Budapest. Finally the fixing screws of the lamp-body were screwed using pneumatic screw unit (Desoutter) and a special task-oriented, pneumatic gripper for positioning and holding the lamp-body during screwing operations. The gripper consists of an optical proximity sensor, two vacuum clamping discs made of gum holding the fixture on the rear wall of the bus during screwing operation, a pressure switch monitoring the minimal pressure.
Using the intelligent mechanical peripheries the assembly was realised without disturbances, because the monitoring system eliminated them.

4. INTELLIGENT FIXTURES OF A ROBOTIZED ASSEMBLY CELL

TU Budapest has built an assembly cell to realise the robotised assembly of ball taps (1/2", 3/4" and 1") made by MOFEM Ltd. Hungary. The Fig. 3 shows the last assembly operation: the inserting the handling element of the ball tap and the assembly cell with robot [1].

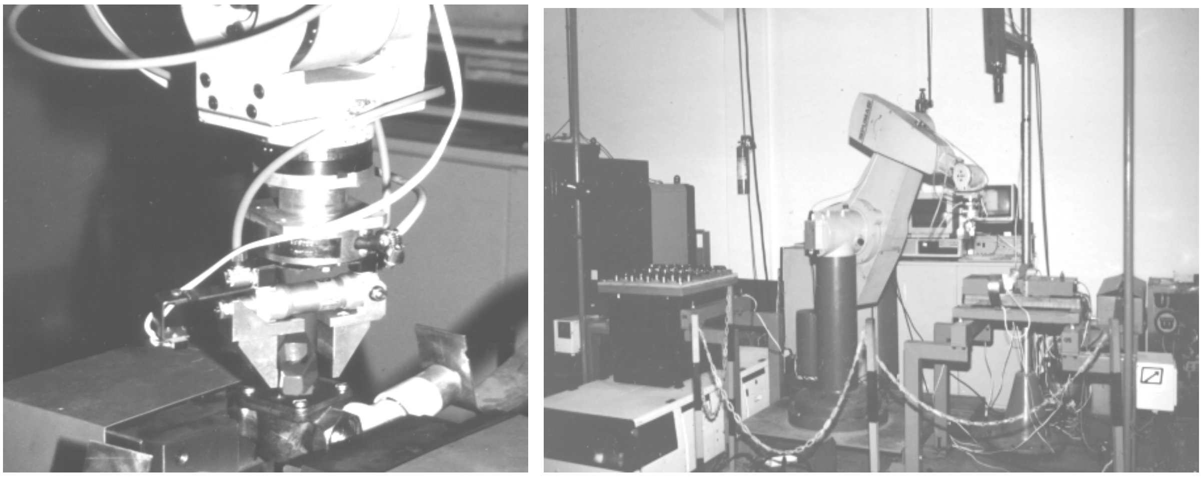


Fig. 3. Robotized assembly of ball tap and the assembly cell with PUMA 760 robot

All the steps were realised out automatically using robots and 5 intelligent mechanical robot peripheries. The steps of the final assembly of the valves are [1]:

- Moving the house of the valve into the fixture,
- Putting the closing unit (ball element) into the house,
- Putting the cover part onto the house,
- Screwing the 4 screws for fixing the cover,
- Inserting the handgrip onto the pin of the cover,
- Screwing the screw for fixing the handgrip,
- Function test of assembled valves.

We have developed, built and applied a special, intelligent pneumatic gripper (Fig. 3), a commercial pneumatic screwing unit (Type Desoutter AFT 40-500), an end-effector changer and a task-oriented pneumatic vice with clamping force control.

For function test of assembled valves we have built a test device. All the special, task-oriented pneumatic fixtures have proximity sensors, pressure switch. The clamping force values of the vice can be controlled by controlling the air pressure. The air pressure control can be made by using step motor, which is able to rotate the control wheel of the pneumatic regulator of air supply unit. The actual pressure values (and the grasping-clamping forces) can be monitored by a pressure sensor based on strain gauge technique [1].

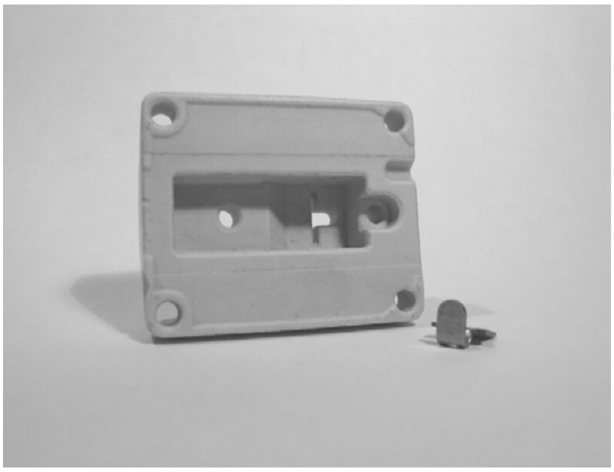
5. INTELLIGENT MECHANICAL PERIPHERIES OF AN ASSEMBLY CELL

The authors have developed and built an assembly cell, which is able to assembly a part of a temperature switch of a household wash machine. The element consists of a body make of ceramic and a contact element made of cooper plate (gauge 0,8 mm).

The main assembly operations are [3]:

- Handling the ceramic body from the bowl feeder into the pallet by the first manipulator,
- Inserting the copper contact element into the gap of the ceramic body from the other bowl feeder by the second manipulator,

- Upsetting (plastic deformation) of the copper plate,
- Unloading the assembled parts from the transport belt using a special mini-manipulator.



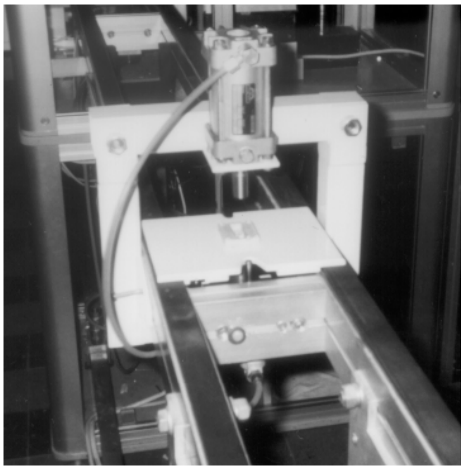


Fig. 4. The parts to be assembled (left) and the fixture for upsetting operation

Figure 4 shows the elements to be assembled and the fixture for upsetting operation.
We want to introduce the upsetting operation. After the inserting the contact element into the gap of the ceramic body from the other bowl feeder by the second manipulator the pallet will be moved by the transport belt to the next fixture belt.
The pallet will be positioned, stopped on the transport belt by one of the pneumatic cylinder as a buffer. This cylinder was placed under the belt. The upper pneumatic cylinder will support the body and contact element against the force during plastic deformation (upsetting). This fixture is able to realise the plastic deformation (upsetting operation) of the end of the contact element in the body. The fixtures consist of three cylinders, an optical proximity sensor, a pressure switch and one axis force sensor based on strain gauge technique. After supporting the elements the lower end of the contact element will be upset by the third hydro-pneumatic cylinder, which is built under the belt. The force is limited using a pressure ring spring. The maximal force value is about 3000 N. The actual force values can be measured and monitored by using one axis force sensor. The stroke of the third, special cylinder is only 6 mm. A special tool mounted on the end of piston rod of cylinder is able to make the upsetting operation [3].

6. GRASPING FORCE CONTROL AND MONITORING OF ROBOT GRIPPERS

Grasping force monitoring and control help to increase the reliability of the assembly operations. The grasping and clamping force monitoring is necessary in the following cases:

- in the case of deformable, thin-walled work pieces (precision grasp) [4],
- high surface quality of work pieces to be handled (precision grasp),
- for increasing the reliability of the handling and inserting operations (power grasp).

We often use pneumatic grippers, which are able to handle work pieces with maximum weight of 50-80 kg, too [7].
The grasping (clamping) forces are directly proportional to the air pressure of cylinders. It means: the grasping forces can be controlled and monitored by controlling and monitoring the air pressure values. For measurement of actual pressure value a pressure sensor based on strain gauge technique can be used among others. The direct measurement of grasping force values can be realised by force sensors built into the gripper or its fingers [5].

There are two solutions controlling the air pressure values:

- The air pressure can be controlled in discrete steps (0.5 bar) by using special pneumatic blocks. They consist of a regulator, a four-way magnet valve, a non-return valve and a pressure switch. The pneumatic blocks can be switched on by robot control through its Output channels. They can be monitored by using pressure sensors based on strain gauges. The sensors provide the robot control with information about the actual pressure (the grasping force).
- The air pressure control can be made by using step motor, which is able to rotate the control wheel of the pneumatic regulator of air supply unit. The actual pressure values (and the grasping forces) can be monitored by a pressure sensor based on strain gauge technique. The resolution of the pressure measurement is ± 0,1 bar at this method.

The first solution was realised earlier, the realisation of the second one is in progress. Both methods can be used at the other clamping devices, too.

6.1. Grasping force monitoring using measuring finger

To measure the grasping forces in the robot gripper, a strain gauge force sensor was integrated into one of the two angle type fingers, which was developed by TU Budapest in co-operation with KALIBER Ltd./Budapest [7].To build a gripper with measuring finger based on strain gauge technique we made several stress-optic tests to find the size, the location and the distribution of the stresses. The Fig. 5. Is shown the measuring finger, its plastic model(left). The scale is 4:1

We have tested and used our grasping force sensor with measuring finger for monitoring of the handling operations during assembly. Unfortunately the force/voltage function of this gripper was not linear (linearity <± 2 %) and it had hysteresis: <± 6 %. The force-stroke function of the gripper was not constant and the cross sensitivity of the sensor was more than 5%. The grasping force–air pressure function was measured, too.

This special gripper was used in our assembly cell during handling the rotating parts of the ball taps assembly and during the assembly of the temperature-switch of a wash machine. We have applied a 6-axis force/torque sensor (based on strain gauge technique) mounted in the last robot wrist in the same time [5].

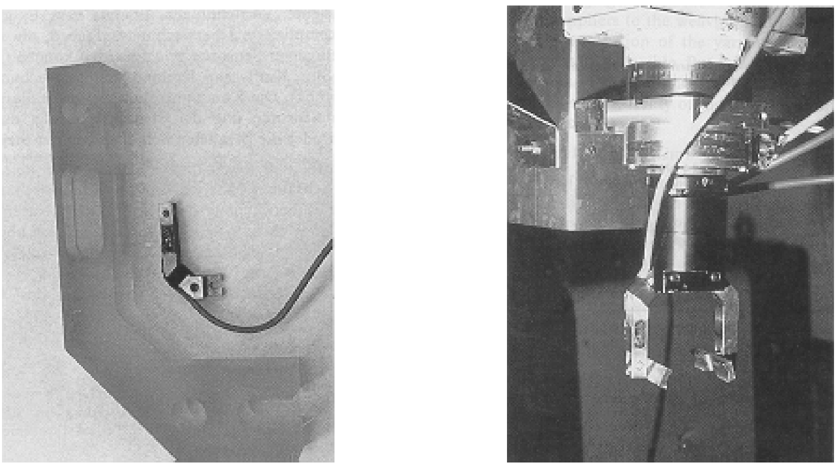


Fig. 5. Measuring finger, its plastic model(left) and the gripper with measuring finger and 6-axis f/t sensor mounted into the last robot wrist

7. CONCLUSIONS

Assembly is the last, but the most complicated operation in the production. During assembly automation the operations must be realised automatically without human help and inspection. The only way of increasing the reliability of operations is the development and application of intelligent mechanical robot peripheries such as grippers, tools, fixtures and special devices.
Intelligent fixturing, intelligent mechanical peripheries helps to avoid the disturbances, to improve the quality of the products and to reduce the costs of the products. It makes the production more flexible. These fixtures, tools are more expensive and complicated, than the conventional fixtures, because they have own automatic clamping, grasping, control and monitoring units, too. They are tasks-oriented tools, which have to be developed by the users.
During automation the human inspection has to be replaced by using sensors. Sensor based monitoring, control and drive give the intelligence for the fixtures. Sensors and monitoring help to eliminate the disturbances and help to increase the reliability of operations.
Applying force/torque sensors and monitoring the robot control will receive information about the mechanical data of the operations to eliminate the disturbances. The whole monitoring of the robotized operations can be realised only by using multi-sensor technique [1].

8. ACKNOWLEDGEMENT

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