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**DESIGN OF A UNIVERSAL ASSEMBLY MACHINE CONCEPT USING THE INDUSTRY 4.0
CONCEPTION**

**NÁVRH KONCEPTU UNIVERZÁLNÍHO MONTÁŽNÍHO STROJE S VYUŽITÍM KONCEPCIE
INDUSTRY 4.0**

Abstract

The aim of the thesis is to present the concept of the assembly device, which is based on the equipment already implemented. The concept involves deploying collaborative robots to increase the efficiency of the assembly cycle. The primary goal is to use time that is used in conventional equipment only for handling device operations. Collaborative activity reduces worker downtime, and this timeframe is significant in terms of process.

Abstrakt

Smyslem práce je představení konceptu montážního zařízení, který vychází ze zařízení již implementovaného. Koncept počítá s nasazením kolaborativních robotů pro zvýšení efektivity montážního cyklu. Primárním cílem je využití času, který je v konvenčním zařízení využit pouze pro manipulační úkony zařízení. Kolaborativní činnost redukuje prostoje pracovníka, přičemž tento časový rámec je z hlediska procesu významný.

Keywords

Industry 4.0, assembling, collaborative work, efficiency, rationalization

1 INTRODUCTION

Deploying robots in any work environment to automate various work tasks is becoming more and more popular. The huge advantage of such automation is, above all, the elimination of the error that is brought into the process by a human factor. Equally important factors are, of course, the increased safety of the workplace and also the shortening of the work cycle of the automated operation. Collaborative robotics represents another important step in this revolution, which, after successful mastery, will bring countless opportunities for direct application. A major issue is security in this area, because collaborating with humans and technology in one work environment requires high security requirements.

Deploying automated mechanisms has been widely used for decades. The use of manipulators is widespread in the human service environment, however inappropriate, but also when required with higher precision. The ever-increasing pace of working robotic workstations does not allow the use of human staff for the reasons given above. The operating cost of a machine that is faultlessly working is also much lower than that of a worker. This is also one of the reasons why robots are, as a concept

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in recent years, hindering competition as jobs for human beings and its use in the general public rather negative responses. Robots based on collaborative concepts can help to change their perception. If they did not enter the competition as a competitor but as an assistant for dealing with dangerous, uncomfortable or highly accurate operations, they could be perceived rather in a more positive context. Such assistance necessitates, of course, the above-mentioned adaptation of security measures summarized in the technical specification ISO / TS 15066 (Robots and robotic devices - Collaborative robots, February 2016).

The concept of a universal semi-automatic assembly machine is to bring together the possibility of human and robot collaboration. The goal of this plan is not only to get into Industry 4.0 and gain a lot of experience that will undoubtedly make decisions about success in an ever-expanding competitive environment, but also contribute to significant financial rationalization by greatly reducing the machine's working cycle time. The concept is based on an already implemented mounting machine that works with conventional drives and linear guides. However, human-robot collaboration (HRC) concepts are limited by the definition of maximum permissible forces and the speed of movement of a collaborative member where standard documentation is the ISO / TS 15066 technical specification. By respecting the prescribed parameters, it will be possible to reduce the time using the Universal Robots robot assembly cycle. Due to the fact that such a conventional device is currently being used in the Mubea concern, and at least the same number is expected for the future in the shortest time, this savings could represent a remarkable reduction in the cost of one assembled unit.

2 ISO/TS 15066:2016

Thanks to this new technical specification issued by the International Organization for Standardization (ISO), human and robot collaboration can be realized. It contains all the safety features of the process, defines the conditions under which the process can be implemented, complements the requirements and instructions for co-operating with industrial robots, as set out in ISO 10218-1 and ISO 10218-2, issued in 2011. Requirements for other types of robots are not, so only industrial robots according to these standards can be used for such cooperation. [1,2] This platform opens up new opportunities to develop and secure both components of the work environment, both robotic and user-driven, leads them to practical use and provides answers to many factual questions. The standard specifies the following for a shared workplace:

- Definition,
- Important features of the security control system,
- Factors entering the workplace design with a collaborative robotic system,
- Embedded security systems and their efficient use,
- Guidelines for implementing the following collaborative technologies:
 - Safety dimensionally monitored stop,
 - Hand guide,
 - Speed and separation monitoring,
 - Active power and power limitations.

The above-mentioned characteristics represent only the first step for industrial applications. The ISO / TS 15066 specification provides the basis for full-scale work in this area, giving scope for application and development practices for this new technology. Using these regulations, it is not necessary at certain workplaces to install protective devices for some power and power reduction applications using ISO 10218-1 and ISO 10218-2. The technical specification includes data from studies of threshold pain from different parts of the human body. At the University of Mainz, they selected 100 subjects to develop a study that helped to specify strength and pressure limits for 29

areas of the human body. These data can be very useful in the development and implementation of collaborative robotic workplaces with limited power and power.

ISO 10218 specifies requirements in very general terms, whereas ISO / TS 15066 provides more detailed instructions. The original standard provides only a few pages of requirements for all types of collaborative workplaces. Many questions, especially with regard to human collaboration and robotic workplace, from the resulting standard, are answered in the new provision. Without practical deployment, however, it is sometimes difficult to find answers to many such questions, so this directive is rather a guideline for practical applications. Every real situation requires a specific view and a unique approach. More practical applications will provide answers to ISO / TS 15066 development and specification. If ISO 10218 recommendations are implemented, it is also suitable for ISO / TS 15066.

It is important to note that this is not a standard but a technical specification. This difference is significant because, for the creation of a full ISO standard, it is first necessary to issue a partial, rather working, part of the standard prior to its approval, which is precisely the technical specification. This helps define process parameters for practical deployment. From it, a complete and formal ISO standardization document is derived after the addition. The format of the technical specifications is marked with a slash with the letters "TS", its purpose is to collect and record the entries of states and parameters from the practical process in the state in which it is. This information is available across the community, so the standardization process is available to everyone to complete, to control changes over time. These changes can then be used in the future to define additions to the standard itself. The specifications are also used to perform and record test results that serve as a feedback to the Organization for Standardization. This is the way to specify the right parameters and process requirements, some layouts.

The technical specification ISO / TS 15066 is primarily intended for:

- Vendor robot assemblies,
- Technical integrators,
- Tool manufacturer,
- Product managers,
- Application engineers.

For industry, this innovation can have a significant impact. The current safety standards require complete shutdown of the machine when the safety circuit breaks down (safety lock, light curtain ...). The ISO / TS 15066 specification works without the need to shut down the entire machine in the event of no injury, while the situation will be fully and safely controlled. The safety gap created by this step should be removed by the standard that is just the ISO / TS 15066 specification. The production hall area is an expensive commodity, the use of collaborative robots opens up opportunities to substantially reduce the obstructed area by manufacturing machines and equipment. Their secure implementation will undoubtedly result in significant savings in the cost of reducing the captured area. The Czech Republic has the equivalent of UNMZ, which is administered by the Czech Standardization Institute. This organization was founded after the split of Czechoslovakia, 1. 1. 1993, the original organization was the Czechoslovak Electrotechnical Association established in 1919.

3 CONVENTIONAL MOUNTING EQUIPMENT

The device from which the concept is based is fully implemented in the production process. It is a versatile assembly machine that is ready to be easily converted to another type of mounting element. The purpose of the machine is to mount the sleeves on the stabilizer rod fitted with a rubber bed. The rubber bed is attached to the stabilizing rod by a fixed joint using the vulcanization technology. The mounting brackets come into the take-off position on the conveyor belt.

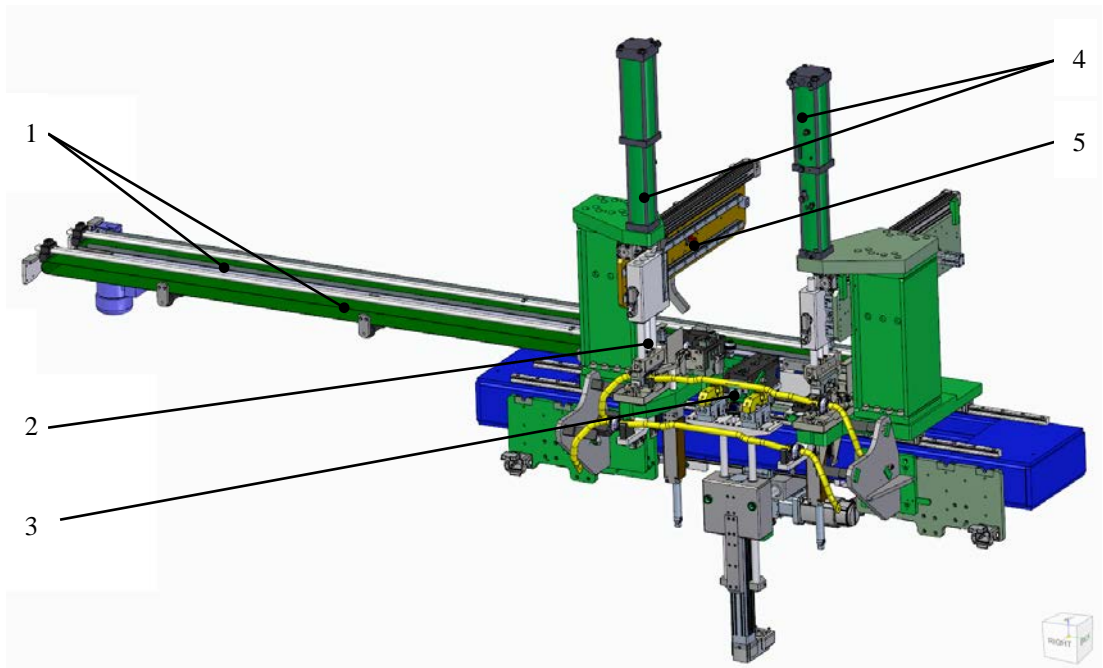


Fig. 1 Conventional equipment

where:

- 1 – Conveyor of metal clamps,
- 2 – Tool guide for mounting operation,
- 3 – Space for stabilizer bar with rubber bushing,
- 4 – Mounting pneu - hydra TOX paket,
- 5 – Two axis manipulator.

After the sleeve has reached the end position, the sleeve is removed using a two-axis loader, whereby the movement of the individual axes is mediated by the Festo pneumatic drives, guided by the THK line. The sleeve is then locked in its position by a multiple pushing motion of the tire. - a hydraulic TOX packet.

The principle of conventional mounting of the metal clamp

A problem in the pressing process is caused by the rubber bushing material, whereby the pressing of the pressing head results in the leakage of the rubber when the other vertical force no longer results in a better fitting of the sleeve.

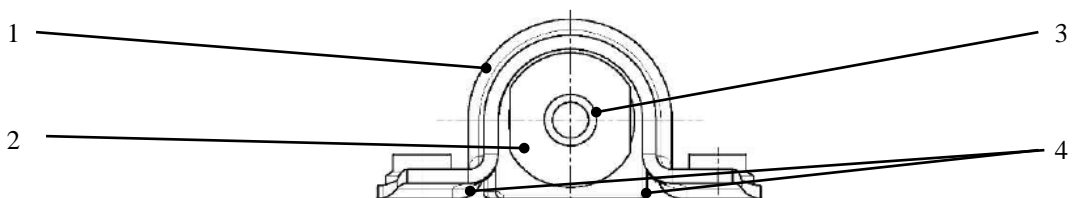


Fig. 2 Description of assembly process

where:

- 1 – Metal clamp,
- 2 – Rubber bushing,
- 3 – Stabiliser bar,
- 4 – the rubber flowing initiator.

This problem was resolved in real terms by:

- The assembly process of the socket has been divided into 3 sections:
- The assembly of the sleeve has been divided into 3 sections:
 - Initial load, to release the pressure while maintaining the position (the rubber runs to the original position);
 - Pushing the rubber to the desired position (possible after the previous pressure release);
 - The metal sleeve and rubber sleeve are moistened while the sleeve is being transported.

These steps helped stabilize the assembly process, the wet rubber nozzles and the sleeve on both sides, making the slide surface more resistant to unwanted rubber leakage at the bottom of the sleeve. Above all, however, relieving rubber is an important factor for a successful assembly process. However, these corrections had, of course, a negative impact on machine stroke. There has been a 100% increase in the time required to fit the socket itself.

4 CONCEPTION INDUSTRY 4.0

The main argument for the use of the Industry 4.0 concept is mainly the possibility of shortening the cycle time of the machine and faster conversion of the machine to another mounting type. The I4.0 concept allows for the co-worker and robot to work in one workspace, one does not have to relinquish this space, resulting in a higher number of assembled pieces per unit of time, and also reduces the workload of the employee. [3]

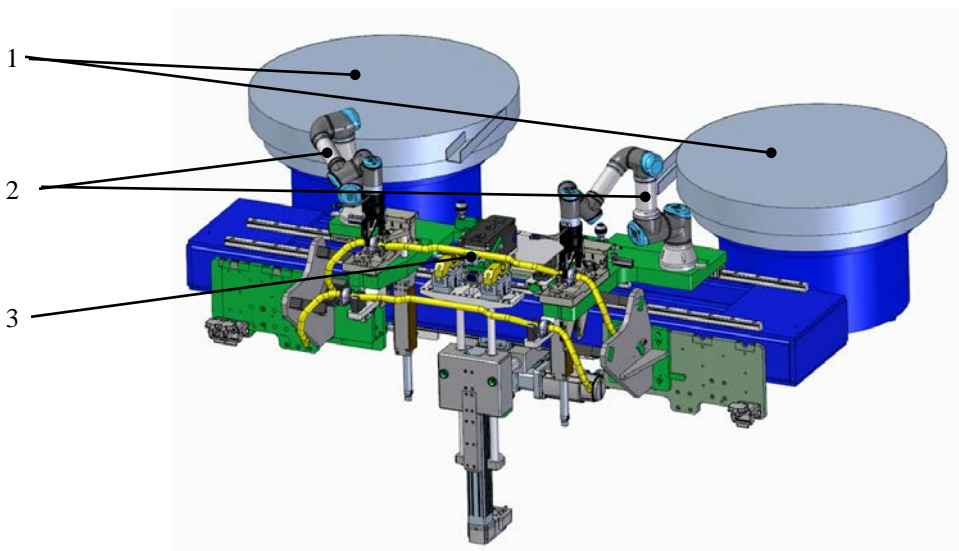


Fig. 3 Equipment using the concept of Industry 4.0

where:

- 1 – Vibration conveyor,
- 2 – Collaborative robot UR3,
- 3 – Space for stabilizer bar with rubber bushing.

A vibration conveyor equipped with a set of interchangeable runners for correct orientation of the desired type of metal sleeve delivers the sleeve to the desired position with the desired orientation. The vibration conveyor can be set to the correct frequency for the desired type of socket according to its weight. The collaborative robot picks up the sleeve from the output position of the vibrating conveyor, while the machine operator performs a stabilizer with a vulcanized rubber. After the robot mounts the socket on the stabilizer rubber, it moves to take another socket to the vibrating conveyor. This eliminates the transport time of the sleeve and the complex double process of its assembly.

4.1 The principle of mounting of the metal clamp with conception Industry 4.0

The metal sleeve is made of "Steel EN 10149-2-S420MC", which is resistant to plastic deformations. Therefore, it is possible to pick up the sleeve using a special tool and a collaborative robot from the output of the vibratory conveyor by stretching it slightly with two pins. Expansion must be designed to avoid plastic deformations but to return to its original shape and dimensional tolerances after the force applied to the socket. [4]

The problem may be legislation that only tolerates the relatively small force of the effector in the field of collaborative robotics, which is the grip of the robot that operates with the workpiece. To overcome the overlap between the rubber and the sleeve, it is necessary to develop a relatively high force that depends on the geometry of the two components. These values are very different, so dynamic calculations will be applied over a longer timeframe. These will be followed by further steps in defining the effector itself, its components, and any safety features of the assembly process.

In principle, it is assumed to use the concept even in workplaces without human service, when the assembly stations will be implemented into larger machine units. In this case, concurrent activity should rather place emphasis on saving time than on process characteristics that restrict the human-robot collaborative activity, otherwise known as HRC (Human Robot Collaboration).

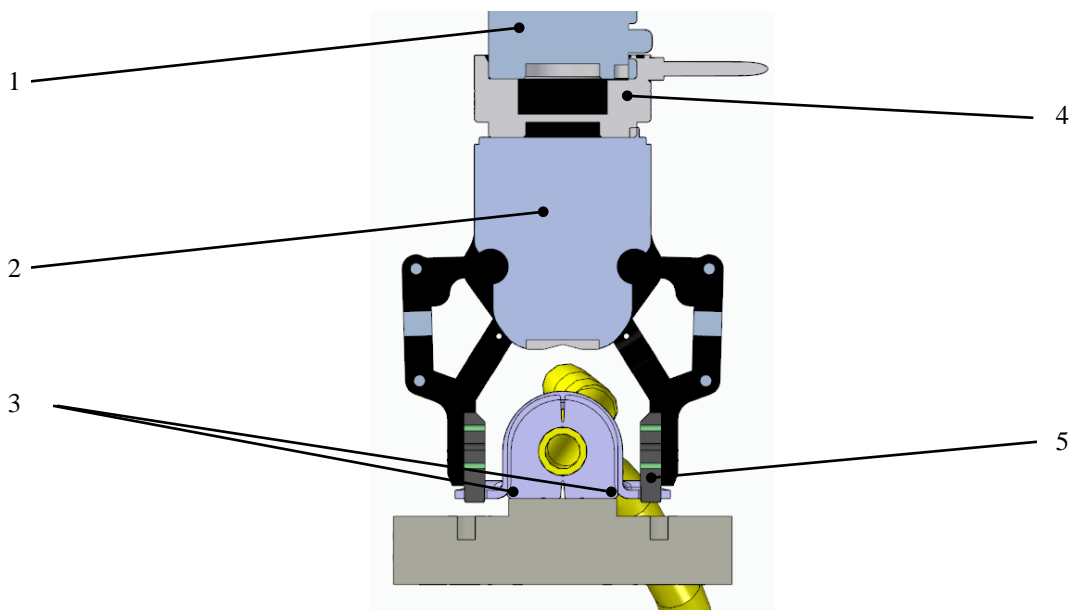


Fig. 4 Robotic arm with Robotique effector

where:

- 1 – End arm of cobot UR3,
- 2 – Two finger adaptive gripper Robotiq 2-finger 85 (with UR collaborative work certification),
- 3 – Critical location to overcome the mounting overhangs of rubber / sleeve,
- 4 – Force and moment sensor Robotiq FT 300 (with UR collaborative work certification),
- 5 – Shaped gripping tool of the clamp (chargeable according to clamp shape).

A special shape tool is designed to fit the idea of collaborative robotics. The FT300 force and torque sensor stops the movement of the UR3 robot at the moment when the set parameters are exceeded. The UR robot itself is built to suit Industry 4.0, each robot joint is equipped with force and torque sensors. The use of the FT300 accessories contributes to safety by capturing the parameters even at the end effector site, which is the Robotiq 2-finger 85 adaptive gripper in this case.

4.2 Vibrating conveyor

These devices, as outlined in the text above, have an important amplitude of vibration. This is adjusted according to the weight of the material transported. In this regard, it is possible to construct the container itself in such a way as to be able to convey more types of sleeves. In particular, the helix that moves the parts must be wide enough to carry any wider sockets. It is then only necessary to set the right amplitude with the special software supplied by the vibrating conveyor supplier. Equally important is the surface of the conveyor helix. To reduce the noise of the conveyor system, the helix is provided with a rubber coating that also protects the parts from unnecessary scalding. Transport of more prone parts is not recommended, as the vibrations cause the parts to be torn in particular by the other parts in the magazine.



Fig. 5 Vibrating conveyor

where:

- 1 – Conveyor output position,
- 2 – Drive of the conveyor,
- 3 – rubber-coated helix.

The great advantage of vibration conveyors is that the parts are always in the same position and orientation in the output position. The construction of the conveyor is such that once a part which is oriented poorly enters the control point, the part passes through the mechanical separator back into the container. The vibration conveyor output position is provided with a sensor that senses the

presence of the part. Once the part is removed, the vibratory conveyor motor is activated and another part is transported to the monitored area. There is no need to add parts to the conveyor belt, as is the case with conventional mounting equipment. Only if the number of pieces in the conveyor is dropped, for example by a laser sensor from above, the control system prompts the machine operator to unload the part directly from the transport box without having to compare the parts or for a lengthy stowage behind the conveyor.

5 CONCLUSIONS

Collaborative Robotics is a growing industry that deserves the right attention. Once properly applied, it can help to change the attitude to the robots as such. This new trend makes it possible to realize the idea of a modern factory working on the innovative Industry 4.0 platform. By collaborating with humans and robots, there is an open way for new ideas of automation to contribute to a better environment for factory workers. Severe monotonous work goes away for a human worker who can engage in more specialized activities.

Thanks to the technical specification ISO/TS 15066, which is the basis for the working standard, it is possible to remove safety barriers between the robot and the person using special sensors and special materials. This will create better conditions for the operator who does not need to be burdened by non-professional work.

The implementation of collaborative robotics is meaningful in areas where human service is needed, but at the same time it is possible to assign a monotonous work to the robotic arm, while co-operation takes place simultaneously. This results in a time saving, which is largely reflected in the financial rationalization of the machine and the increase in overall labor productivity.

Next steps will be dynamic calculation of force necessary to open the clamp to the smooth mounting to the rubber bushing. Then define the best effector to optimal work with the metal clamp. Next step will be certification of collaborative work for the new mounting equipment concept.

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