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PNEUMATIC PAINTING ROBOT

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ABSTRACT:
The article describes robots currently used for painting lacquered coatings onto various parts‘ surfaces. These robots are designed as classical electric robots with additional air-proof coating, which separates electric components from outer explosive environment. The article also describes the design concept of the painting robot based on different type of driving and design of robot arms based on thin-surface composite shell structure that contributes to decreasing of robot weight, energy consumption as well as manufacturing and operational costs.
KEY WORDS:
painting robot, robot drive, pneumatic artificial muscle, composite material

1. INTRODUCTION

Application of liquid or powdered paints, lacquers or glazers is the technology very often used as application of protective coating of parts and products. In case of mass production this technology is very important part of manufacturing procedure and it requires remarkable investments and man power requirements. Because of health protection, safety and productivity these devices are composed of machines (robots, conveyers, cabins, etc.) that in mutual cooperation form automatic production lines. The important part of such production lines is painting robots, which except health protection provide quality, productivity and effectiveness. This brings quick return of investment to robotized work place. Painting robots have to conform the work in hazardous environment and must have acceptable dynamic properties (speed of movement, speed of arm movement reversing). On the other hand, the requirements for positioning precision and repeatability are not so strict as it is for classic robots (e.g. for integrated circuits mounting in electronics industry).

The investments to robotized technologies during global crisis are inhibited by the relationship between relative man power redundancy and remarkable investment requirements of robot acquisition and installation. This problem does not involve automated painting because basic criterion for automation of such workplaces is not only investment costs but also legal issues concerning health protection and financial sanctions for breaking them. In this case the optimal solution is automation of paint work places, which brings higher production quality, effectiveness, safety, cost reduction and is more environments friendly. For all these reasons it is effective to contribute to painting robots further development and to find the new ways to improve their effectiveness.

2. TECHNOLOGY OF AUTOMATED COATING APPLICATION

Typical technology for the application of coating on the metallic and non-metallic parts and products is the technology of automated painting that is in mass production implemented by means of the automated production lines. The production lines contain conveyers, painting robots and miscellaneous support devices, including control unit, which controls the operation of the whole production line. Typical example of such solution is production line of POLYTEC Composites Slovakia s.r.o. company in Sládkovičovo, which produces composite bumpers for the world leaders in lorry producers [1]. Painting production line consists of ten zones that are mutually tied together and form complete technological process. Pressed bumper parts are put onto the stands which are joined with the conveyer driven by the electric motors. There are several bumpers on each stand. Each conveyer is equipped with portable memory device that contains the information about parts on the conveyer. This information is entered to the memory media at part loading stage, when production operator defines desired color of the parts.

The bumpers travel from loading ramp to the washing zone that consists of three sections. The first section serves to rinse the bumpers by supply water sprayed out of the nozzles under 6 bar pressure and with temperature of 45 ° C. In the second and third section the bumpers are rinsed by distilled water with the same pressure and temperature 20 ° C. After rinsing the composite pressed parts are led to drying zone. Bumpers travel on the spiral track (13 meters long) at the temperature of 100 ° C. After drying bumpers travel to cooling zone. The air with supply rate of 15 000 m^3/ hour flows against the bumpers on the 7 m long track. Cooling air is filtered from dust and dirt. The air is dried then in order to prevent its condensation on the production line.

After all those procedures the bumpers are ready to enter painting chamber, which is the most important part of the production line. The chamber is 8 m long and 4 m wide with inside temperature 25 ° C. The bumpers are painted by the two painting robots ABB-IRB 5400-12. The robots are placed on the both sides of the conveyer in the opposite corners of the chamber.

The stands with the parts coming into the painting chamber make a software link to the robots at precisely predefined place and from that moment robots start to watch their position. That place is determined by the part detection sensors placement and memory medium reader. The information from the conveyer are read and moved to the programmable logic controller (PLC) unit. PLC evaluates and processes the data and sends them to the robot controller unit. The robots initiate cleaning and filling sequences of painting system based on the desired color number comparison and current color in the painting tank. The sequences for the paint color change are always done while conveyer is stopped. The system is able to change color in a very short time, for example during the pause created by separation gap between two different types of products. After the color is changed the robots start to track the position of the loaded parts by means of position and movement direction sensors. The robot starts to perform pre-programmed trajectory with precisely defined painting parameters (movement speed, paint flow rate, color mixing ratio etc.). The trajectories are programmed by the sequence of separate points in space (point to point).

After bumpers are painted the venting zone follows. The bumpers travel through 15 m long tunnel, while the temperature is gradually risen from 30 ° to 60 ° C in order to continuous vaporization of moisture.

The final procedure is baking zone 30 m long. Hot air with temperature of 90 ° C is spurred against the bumpers at flow rate of 50 000 m^3/hour.

Finished bumpers are checked after they get out of the painting line. The checked parameters are: the thickness of the paint, adhesiveness and glossiness. After the check they are wrapped and placed on the transport palettes and sent to the production plants.

3. CURRENT SOLUTIONS OF PAINTING ROBOTS

Painting robots used in current production plants are supplied by traditional well-known robot producers that have great experiences in robots development and production. Almost all contemporary robots are based on electric drives controlled by appropriate electronic control unit. Great advantage of such robots is their performance parameters, especially movement speed (1 – 2 m/s), positioning precision (max. +/- 0.5 mm).

Painting robots work in painting chambers that are places with explosion danger of the grade 3. The robots are adapted for working in explosive environments. They are air-pressurized and the pressure is constantly controlled. Pressurized air forms a protective atmosphere against possible discharge on electric components integrated in the robots.

4. DESIGN CONCEPT OF THE PNEUMATIC PAINTING ROBOT

Current painting robots posses acceptable operation parameters, which results in remarkable contribution to higher productivity as well as to health protection of the personnel. In spite of these advantages it is necessary to take into account the requirements level of such workplaces in relation to their work affectivity. That is the place where further analysis and reassessment is required.

The main disadvantages of the currently used painting robots can be characterized by the following properties:

- they have rather high weight. It results from the principle of their design and operation. The arrangement of robot arms causes that bottom arm moves middle arm together with its driving motor. This arrangement causes that power requirements and hence the weight raise exponentially in direction from the top arm to the bottom arm. In case of painting robots these requirements are multiplied by the fact that electric drives have to be mounted in the special protective casings, which causes further power and weight requirements.

- they are highly power consuming. They require high power supply in comparison to the load they transfer. For example, the painting robot MOTOMAN – EPX2050 requires maximal power supply of 5 kVA for the 15 kg load movement (robot APR-20 for 10 kg load – 3,5 kW).
- they require two different power sources – electric and pressurized air.

Based on the operational requirements of the painting robot and with regard to its current short-comings it is possible to form the painting robot requirements, which would carry the advantages of the current robots and eliminate their negative properties. These requirements could be summarized by the following parameters (painting robot – new generation):

- Number of degrees of freedom: 6 (3 degrees in wrist)
- Load: cca 15 kg +/- 10 kg (or according to needs)
- Vertical reach: cca 2 – 4 m
- Horizontal reach: cca 2 – 5 m
- Weight: up to 40% of the current robots
- Speed of movement of the arm end point: min. 1.5 m/s, max. 2 m/s
- Precision of positioning: +/- 0.5 mm
- Power supply: up to 35% of the current robots
- Mounting: floor, ceiling, wall

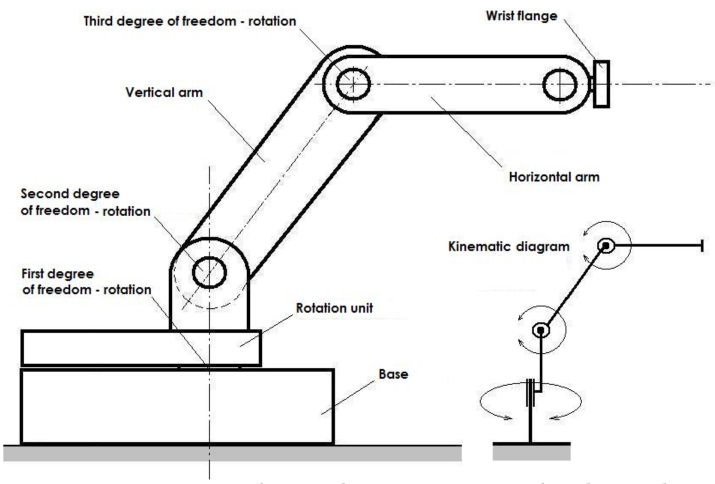

Figure 1. Painting robot with pneumatic artificial muscles and arms from composite materials – Design concept with 3 degrees of freedom (without wrist). Artificial muscles are inside the arms

The above mentioned requirements are feasible when assuming that the design of robot drives and arms would be different from current solutions. This difference can be achieved by using new construction materials and design methods. Nowadays the composite materials and their production became common, which enables us to design robot arms and other parts from these materials making them much lighter.

Another way how to improve weight, and thus dynamic parameters of robots, is the application of pneumatic artificial muscles as robot actuators, which is specifically advantageous in painting robots.

Pneumatic artificial muscles do not require special protective casings in explosive environments. It is possible to lighten the robot and decrease its power consumption, while improving its dynamic properties by joining together these two solutions. Even power supply would limit to one type, which is pressurized air.

5. ROBOT ARM DESIGN

The light painting robot pictured on Fig 1 is designed as assembly of standardized modules – robot arms (there are 3 on Fig 1) that are joined together. The modules have standardized design, they differ only by their dimensions and by pneumatic artificial muscles‘ sizes. In case of robot on Fig 1 it is assumed the two different arm sizes would be used. The upper arm is smaller and lighter, lower arm and rotation unit would be created by a bigger module. It is assumed that the design of the modules would be identical, the only difference would be their size and the size of the artificial muscles used in them. It is also assumed that pneumatic artificial muscles (PAM) would be Festo type (currently the only PAM type that is in mass production and is with acceptable quality and reliability).

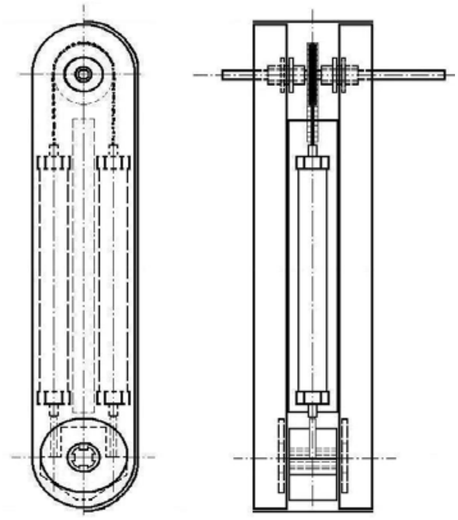

Figure 2. Unified module (actuator) – the arm of the painting robot with artificial pneumatic muscles and composite arms – design concept. Artificial muscles are places inside the arm without outer covering

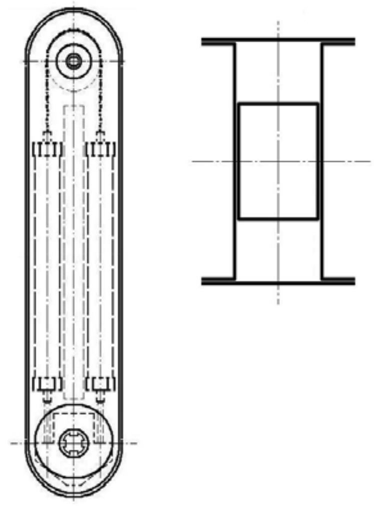

Figure 3. Unified module (actuator) – the arm of the painting robot with artificial pneumatic muscles and composite arms – design concept. Artificial muscles are places inside the arm, the arm is with outer covering

Basic assumption of the future solution of light painting robot assembly is top quality design of the unified robotic arm – a unified module (actuator) that can be used individually or can be used for creation of more complex controlled kinematical structures by joining them together. Figures 2 and 3 depict the design of the above mentioned module with possible placement and link of PAMs.

Figure 2 depicts unified module (actuator) – the arm of the painting robot with artificial pneumatic muscles and composite arms. The design concept considers forming an ultra light self-supporting monolith that is bending and torsion resistant. This can be created by joining together two thin wall composite shells of a tray shape and a square tube. The cross section of such assembly is depicted in figure 3 (on the right), including outer cover plates that increase load capacity and stiffness (torsion resistance) when mounted on the arm body. Pneumatic artificial muscles are placed inside the arm along the inner square beam.

5. CONCLUSIONS

Current robots used for application of painting covering on parts (painting robots) have classical design with electric drives and additional air proof casing that separates electric components from outer explosive environment. The inner space of these robots are pressurized with air to prevent the explosive vapors penetrate robot spaces with possible electric discharges. The article covers the design concept of painting robot with different philosophy of driving and robot bodies. The application of pneumatic artificial muscles and robot arms design based on ultra light self-supporting monolith structure is the way to decrease robot weight, power supply consumption as well as production and operation costs.

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