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ENGINEERING DESIGN OF A MANIPULATOR FOR MOUNTING AN AIR SUSPENSION COMPRESSOR TO A CAR CHASSIS

Summary. This article is aimed at the engineering design of a manipulator, which is pneumatically controlled. It will serve for mounting the compressor of an air suspension system to the chassis of a sport utility vehicle (SUV) produced in the Slovak Republic. The manipulator will be used on an assembly line, on which SUVs are assembled. The designed device belongs to a group of dedicated devices, which are not produced within a serial production, however, it is the only functional prototype. Together with the manipulator structure, a pneumatic part of the assembly line including individual components, schemes and the pneumatic system will be proposed. Within the project process, all necessary customer demands, technical and safety standards have to be met. Moreover, ergonomic requirements for handling the device and other acts on the workplace have to be considered.

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1. INTRODUCTION

Pneumatically controlled mechanisms are mechanisms that use the pressure force change for the incurrence of a rectilinear or rotational movement. Pneumatic components are used in such fields, where very high pressures are not required in comparison with hydraulic systems. Due to clean operation, high speeds, automatization possibilities as well as fire safety, pneumatic systems are used in food processing, optics, production lines, building industry and also in the automotive industry. Further factors with which they are associated working conditions are not included in this project [1, 4-8].

The authors assume that the designed device will make human labour easier and make the car production process more effective. The main requirement consists in mounting the compressor of an air suspension system of a car [11-14] from beneath the chassis, specifically, from the right rear part of the car. For other requirements to be considered, we include [2, 3]:

- the manipulator structure has to respect the mechanical actuation of the device and the weight of the mounted component,
- the manipulator structure, type and location of control elements have to be chosen with respect to the device operating staff, that is, the device has to be controlled by just one operator,
- compactness, stiffness and the minimal weight of the manipulator,
- the air compressor has to be attached on the manipulator arm without clamps,
- guaranteed the possibility of the subassembly of the compressor on the manipulator arm,
- reliable fixation of the manipulator to the chassis without damage,
- a longitudinal rail system equipped with three sensors (optical, acoustic and shut),
- the manipulator has to be equipped with sensors of medium consumption (compressed air and electric energy),
- reliable mounting of the compressor to the chassis, that is, the guidance of the mounted component by the manipulator towards the chassis,
- guaranteed access to screw connections during the process of assembling,
- an adjustable frame of a compressor on the manipulator arm,
- the fastened arm of the manipulator, that is, braked in extreme positions,
- simple maintenance,
- any metal component of a compressor support must not be in a contact with a mounted component or the car.

2. THE ENGINEERING DESIGN OF THE DEVICE

The engineering design of the manipulator goes out from a scheme of the workplace with input geometrical parameters of the workplace (Fig. 1 left). Fig. 1 left shows the particular part of the car chassis (blue), which is placed in the position corresponding the real position of the car chassis on the given assembly line. The car chassis includes the compressor, which is located in the mounted position (Fig. 1 right, yellow). This part of Fig. 1 also contains the RPS (reference point system) point, which is the point of reference for individual parts of

the structure (Fig. 1 right, red). The chassis has to be located in this part of the assembly line in the particular tolerance limits. The compressor is attached in its setting without any clamps.

Dimensional definiteness was another important demand for the accurate position of the compressor. The compressor setting is made of PE 1000 polyethylene (Fig. 2, green). This material is suitable for the purpose due to its high wearing quality and resistance to abrasion. These properties are very important for the compressor setting because almost every 90 s the compressor is put into it.

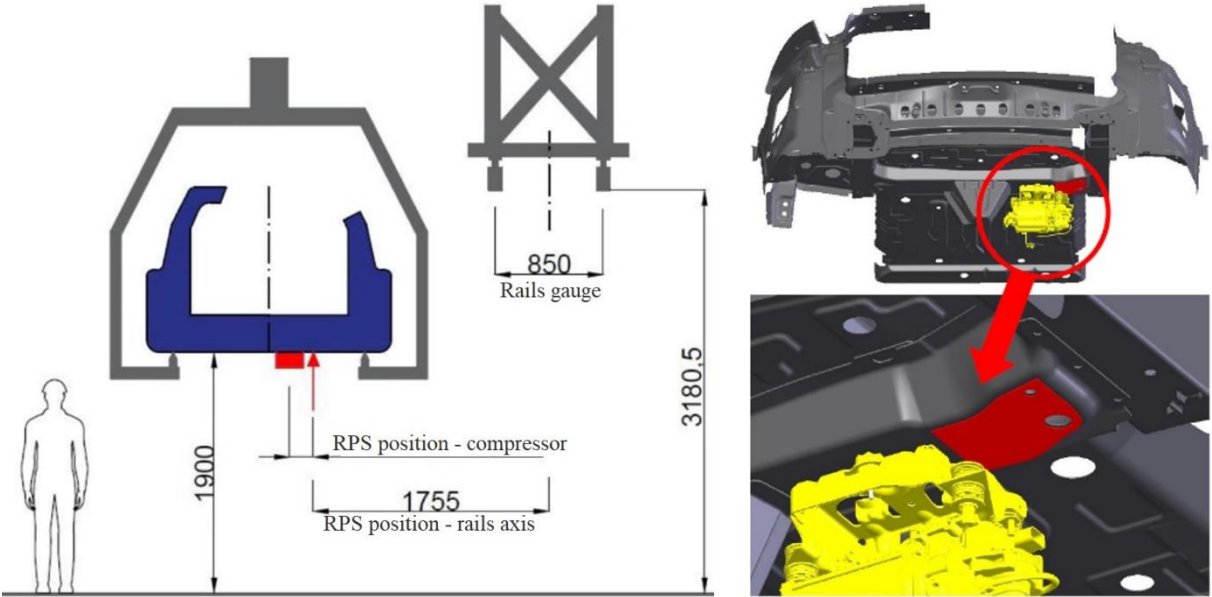


Fig. 1. Scheme of the workplace including input data (left), a three-dimensional model of the particular part of the car chassis (right), the specific position of the compressor (yellow), the specific position of the RPS point (red)

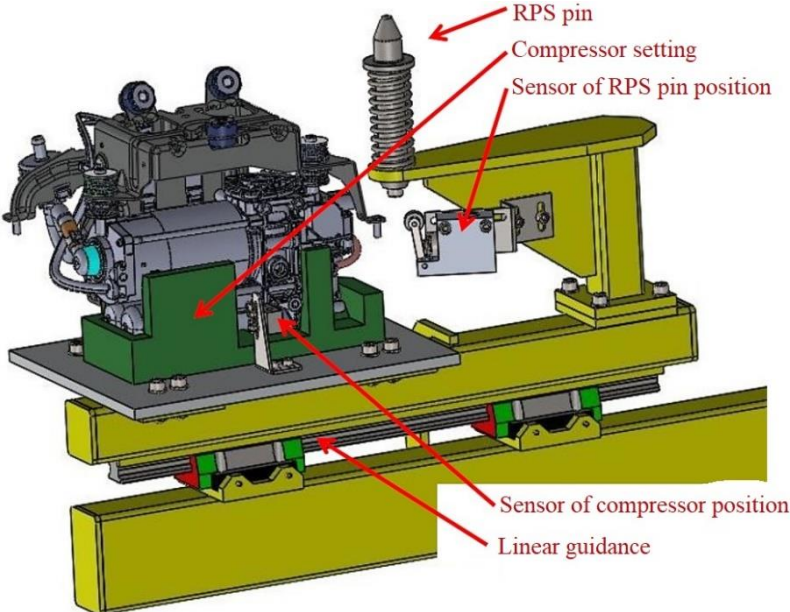


Fig. 2. The setting of the compressor (green), RPS pin

The polyethylene setting is placed on an aluminium plate, which is mounted on a moving beam (Fig. 2). The aluminium plate is connected with the manipulator by means of screw connection and slots. Slots serve for adjustment of the compressor setting to the accurate position towards the RPS pin in x and y directions. The aluminium plate includes also a sensor of the compressor position Festo R3-M5. On the beam, a console with a suspended RPS pin and a sensor of the position is placed.

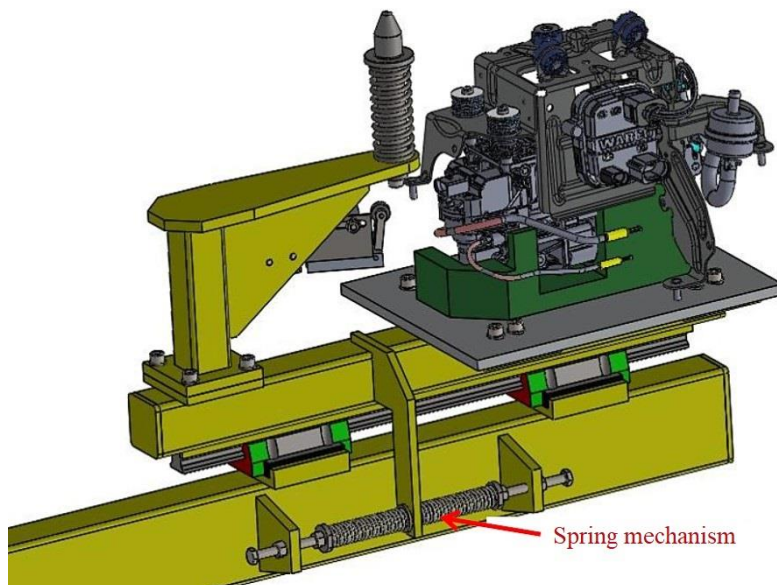


Fig. 3. A view of a spring mechanism for centring of the compressor setting

The whole compressor setting is movable so as to compensate of tolerances in the Y direction. It is ensured by means of a linear guidance Hiwin HGW25HC. Decisive parameters include the static carrying capacity. The manufacturer guarantees the static carrying capacity of 76000 N. Although, this loads will never be reached, because just the own weight of the compressor setting and the compressor is considered and it is of 14.8 kg.

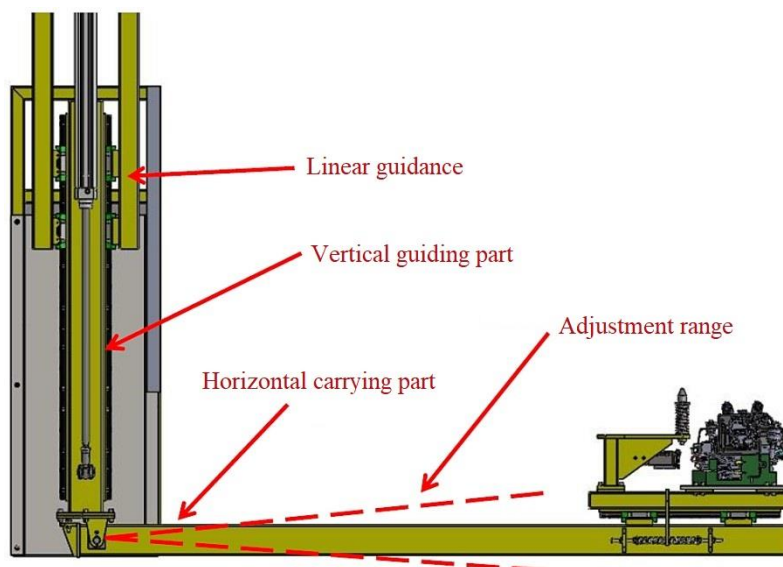


Fig. 4. A movable arm of the manipulator

A guiding rail is located on the compressor setting beam, other two trolleys are mounted on the manipulator arm. Setting centring is solved by means of an adjustable spring mechanism (Fig. 3), which keeps the setting of the tolerance zone of the RPS pin. Adjusting of the initial position of the compressor setting before the operation of the manipulator is ensured with screws and spring backstops.

The manipulator arm lifts the compressor in the z-direction and it consists of two parts, specifically, a vertical guiding part and a horizontal carrier part (Fig. 4). These parts are connected by a connecting pin. Such a connection allows adjusting the horizontal carrier part to the proper position by rotating around the x-axis. Adjustment is allowed by two adjusting screws SGTPP8-40 (Fig. 5).

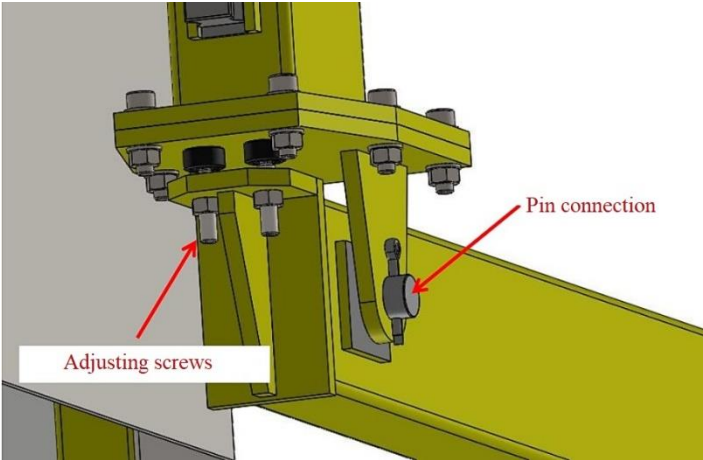


Fig. 5. An adjusting mechanism with a pin connection

Trolleys of the linear guidance of the compressor setting and the RPS pin are mounted on the horizontal arm by means of shaped surfaces with defined geometry and tolerances.

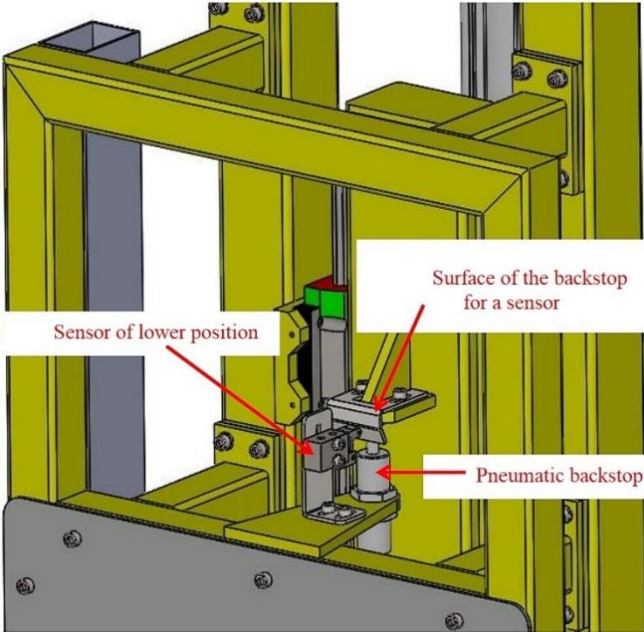


Fig. 6. A backstop of the lower position

The vertical guiding part of the arm consists of a rectangular profile, on which rails of the linear guidance Hiwin HGW25HC by precision machined surfaces are placed. Two other components are placed in the lower part: a weldment of the pin connection and a surface for adjusting screws heads and a hole for a piston rod eye of a pneumatic cylinder, which serves for lifting the component.

The upper part includes the surface of the backstop for the pneumatic sensor of the upper position Festo R3-M5. This surface comes in contact with the pneumatic backstop Festo YSR-16-20-C. This backstop has mainly a safety function because it is the only one mechanical element, which prevents the whole arm from sliding out of the guidance, for example, in case of mounting or changing of the pneumatic cylinder.

A rotating part (Fig. 7) of the manipulator consists of two vertical profiles between which the arm moves in the z-axis. Linear guiding trolleys are mounted on these profile same as on the horizontal part of the arm. Both profiles are attached to the plate, which is connected with one part of the radial-axial bearing. It is Hiwin CRBE0925C bearing. The static carrying capacity of the bearing in the radial direction of 80.2 kN and in the axial direction of 182 kN. The estimated weight of the manipulator is 200 kg, it means, the proposed bearing meets the safety criteria. The proposed bearing has to allow convenient maintenance access.

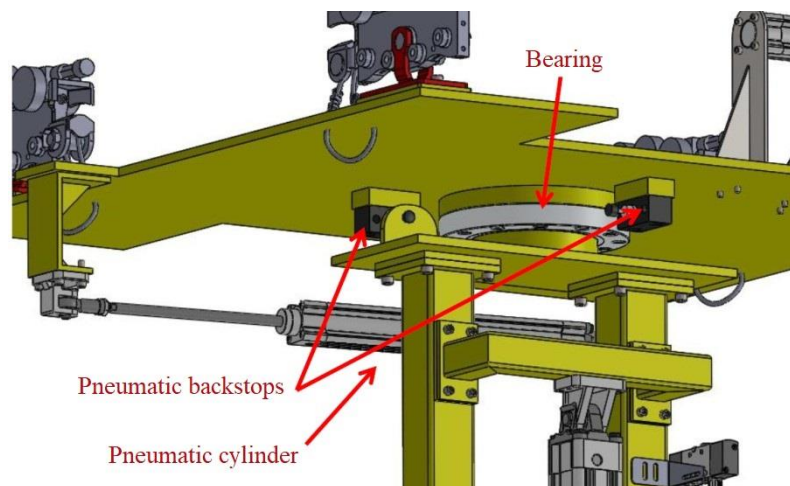


Fig. 7. A rotating mechanism

The original customer requirement has defined manual rotating of the mechanism around the y-axis. However, the arm must be in extreme positions fixed and manual control would require another additional mechanism. Therefore, the rotating motion of the mechanism is controlled by means of a pneumatic cylinder. Such a solution allows to set the extreme positions of the rotation as well as insures the arm in these positions. Last but not least, the operation of the operator is facilitated. Implementation of the hydraulic arm requires to weld two surfaces for pneumatic backstops Festo SCK-00-003. Screw character of backstops adjustment enables precisely to determine the extreme positions of the manipulator. Furthermore, pneumatic cylinders of lifting and rotating, an air treatment unit, a pneumatic valve, pneumatic flexible tubes, electric cable and well as a control panel are placed on the rotating part of the manipulator.

The control panel has to meet technical, safety and ergonomic demands [9, 10]. As the panel is located close to the moving part of the manipulator, any contact with this part should be avoided (Fig. 8). A steel covering is used for this. Two-handed operation is the other safety element. It excludes any contact of an upper limb with the rotating part. Two-handed operation

of the manipulator is solved by means of two handles, which at the same time serve for manipulation in the x -direction and from which buttons are operated in according to ergonomic principles.

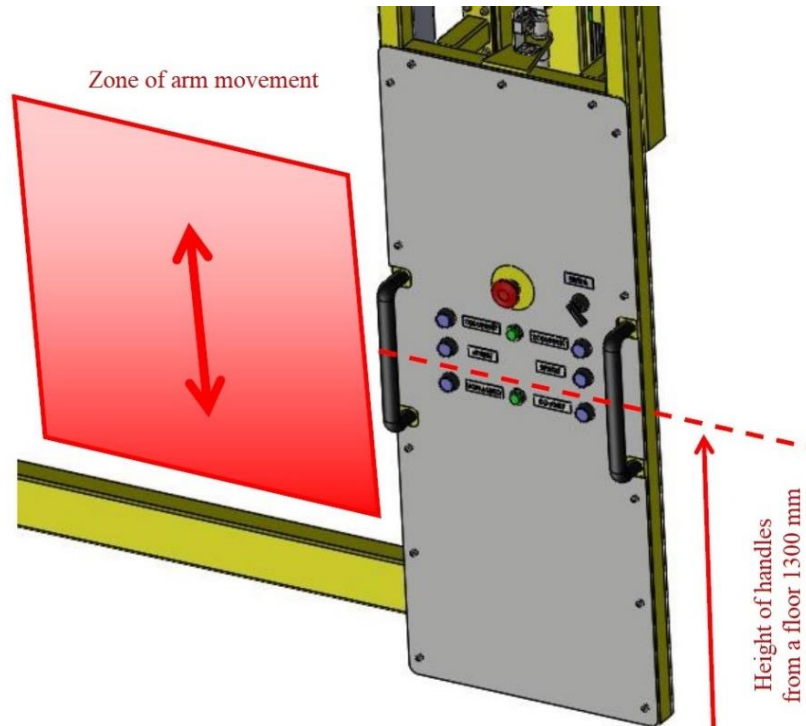


Fig. 8. The control panel with the arm movement zone



Fig. 9. The control panel

The steel covering serves for mounting all control and display elements. It meets requirements for simple access and manipulation within maintenance interventions. The control panel (Fig. 9) includes seven pneumatic buttons, two pneumatic pilot light and electric button for an emergency stop.

Pneumatic buttons are doubled due to two-handed control, two separate buttons serve for rotating the manipulator around z-axis and a pneumatic switch button ensures the manipulator against movement. Moreover, pneumatic pilot lights of placement accuracy of the compressor and the lower position of the manipulator are also located in the operator's field of vision. The emergency stop button is placed in the middle of the control panel. It should be noted, that the emergency stop button is the only one electric element on the whole manipulator structure and is powered by voltage of 12 V.

The rear covering protects all pneumatic and electric elements of the manipulator from contact with the moving arm. Pneumatic flexible tubes are routed through plastic canals.

The weight of the entire manipulator has to be carried and moved in the x -axis direction. This is ensured by means of the trolley (Fig. 10), which consists of a steel plate. On this plate, four trolleys carrying and guiding the whole manipulator are mounted.

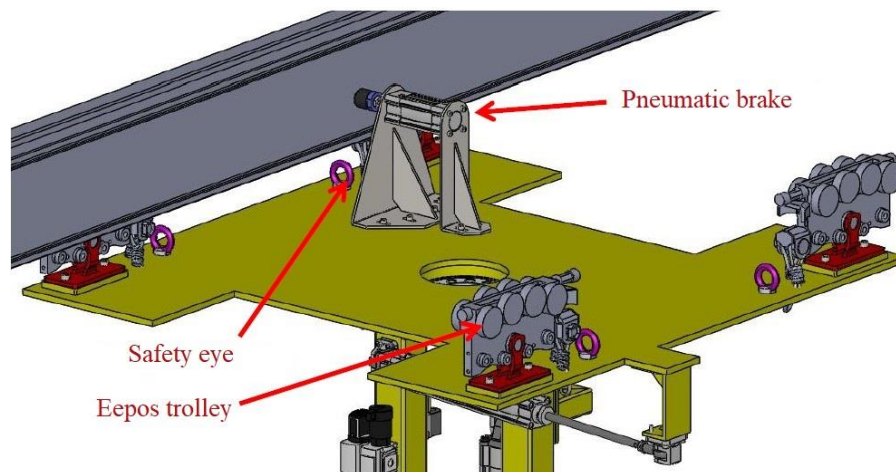


Fig. 10. The manipulator trolley with a pneumatic brake

Trolleys are placed on aluminium profiles Eepos L. Two profiles are able to transmit the weight of 1200 kg. These profiles are added by trolleys AL300/300. They can be loaded in vertical direction bi-directionally by the load of 3000 N. Trolleys are fixed to the steel plate by means of an eye, type 0° Standard. It can be also loaded bi-directionally by the load of 600 N. In terms of safety, it is necessary to consider eventual damage of the trolley and resulting potential fall of the manipulator. For this reason, every trolley includes safety cables, which one end is located on the aluminium profile and the other end is fixed on the manipulator.

The upper part of the trolley contains the parking brake formed by a small pneumatic cylinder with a rubber ending at the end of the piston rod. This rod comes in contact with the Eepos aluminium profile in case of the parking brake activation and it prevents the manipulator movement.

Based on technical demands, only the lift of the arm in the z -direction has to be pneumatically controlled. The technical assignment, as well as the principle of function of the manipulator, requires that the arm has to be fixed in extreme positions during rotating around the z -axis. In addition, the manipulator has to be prevented against the movement as a whole as well as its components, for example, in case of leaving the workplace, maintenance, etc. In an

effort to avoid unnecessarily complicated solutions, for example, using cable, pins or others mechanisms, which would be potential sources of failures, the pneumatic control system of rotating and braking the mechanism was chosen.

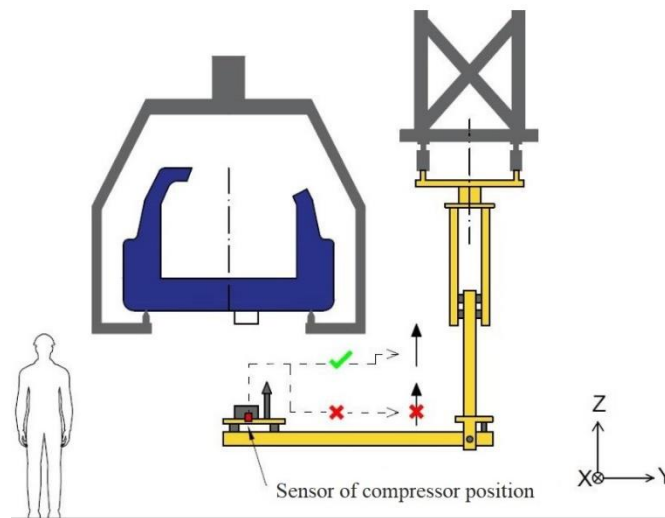


Fig. 11. A scheme of the function of the compressor position pneumatic sensor

The pneumatic system of the manipulator includes three pneumatic cylinders as follows:

- the cylinder for arm lifting - DSBC-50-800-PA-N3,
- the cylinder for rotating around the z-axis - DSBC-32-250-PA-N3,
- the cylinder for braking in the x-axis - DSBC-32-25-PA-N3.

Pneumatic cylinders for lifting and rotating are connected with corresponding parts of the manipulator by means of components of Festo producer. For the pneumatic cylinder used for braking steel, consoles are designed. To limit the manipulator's movements to the necessary operations, it was needed to place additional pneumatic components as follows:

- a sensor of a compressor position, Festo R3-M5. This sensor serves for evaluation of the proper placing of the compressor to the setting. If the compressor is in the proper position, the control panel shows by means of the green pneumatic pilot light Festo OH-22-BL, the correctness of placing. The sensor also serves as a lift condition of the arm lifting from the lower position to the upper position and thus, it prevents to lift the arm either when no compressor is placed on it or the compressor is placed improperly (Fig. 11).
- a sensor in an RPS pin position, Festo RO-3-1/4-B. This sensor serves for evaluation of proper and sufficient insertion of the RPS pin into the car chassis. When the proper mounting position is reached, it prevents further lifting of the arm, which could cause the lifting of the car chassis or some other damage (Fig. 12).
- a sensor of an arm lower position, Festo R3-M5. The main task of this sensor is to limit the manipulator rotating with the lifted arm because in case of such manipulation, the risk of contact of the arm with any parts of the chassis arises. Therefore, rotating around the z-axis is possible, when the arm is in the lower position. Similarly, reaching of this position is indicated on the control panel by the green colour of the pneumatic indicator Festo OH-22-BL. Another very important task of this sensor is the prevention of activation of the brake in lifted or even mounting position, when the manipulator, the chassis or other part could be damaged (Fig. 13).

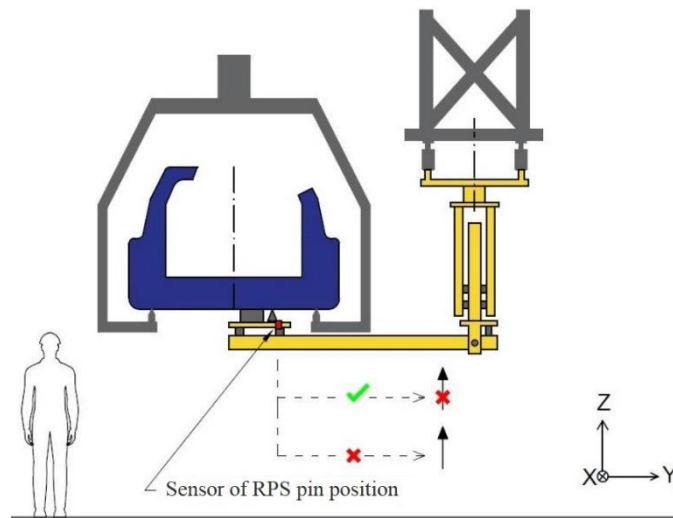


Fig. 12. Scheme of the functionality of the RPS pin position sensor

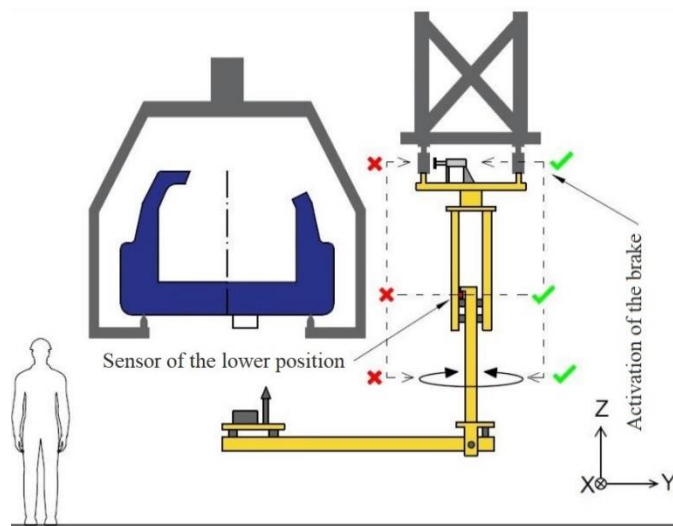


Fig. 13. Scheme of the functionality of the lower position sensor

3. CONCLUSION

The solution of the presented problem has consisted of obtaining input data from a customer. Based on these data, the engineering design and functional solution of the manipulator were created. The important task was the design of the compressor setting, which had to meet all requirements in term of its dimensions and the possibility of compensation of all inaccuracies. Safety of the device, protection of health and operator and ergonomic parameters was other important aspects of the design. Compliance with the relevant standards and internal regulations of the customer was a matter of course. Designs of the rotating part of the manipulator, the control panel, the travel and the pneumatic parts of the manipulator were realised together with the compliance of the customer-required components from precisely specified manufacturers. The next step in solving this problem will be the design of the pneumatic brake, the selection

of air treatment equipment, the creation of the pneumatic circuit diagram, the FEM simulation of the steel plate, the adjustment mechanism and the RPS pin console.

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