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WORKING ASPECTS OF CLEANING ROBOT SYSTEM TO EXTERNAL GLASS WALLS OF BUILDINGS

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Abstract— The paper is based on the previous author research with the aim of research and implementation in services fields of washing-cleaning of operational robots systems, used at exterior frontage of buildings that are realized from modular glass panels.

The climbing constructive variant of robot is more used in cleaning-washing services or periodical inspection of frontage buildings with glass walls can be realized and applied with success in these operations to smart buildings.

The system is composed from mechanical system with light structure, power system formed by pneumatic-vacuum system, and command-moving in conformity with predictable software. The flexible processing system proposed and presented by the authors, a system composed from a work device and a transfer device.

Keywords— Climbing vacuum robot system, Cleaning-washing services of external glass frontage of buildings

I. DESCRIPTION OF FUNCTIONAL PRINCIPAL OF CLIMBING VACUUM ROBOT SYSTEM

THE adhesion by climbing of robot on the vertical surface of glass wall's building to assure the cleaning from washing is realized progressive action of 6 suckers that interfere by flexible pipes of vacuum robot system.

The leading and control of robot at long distance is realized by a predictable program which assured the climbing, washing and cleaning operations of glass wall from superior level to inferior level with touching of ground floor of building [2].

The working program is realized by on specialist engineer of software and get into PC. The programming is made in function of glass windows sizes of building and its height. The functional principal robot system and its working phases of washing robotized operation is based on many frames and parts extracted from 2D drawing of robot.

The cleaning-washing of glass windows of walls' building that is realized by the vacuum robot is composed from a rough washing subsystem, formed by a brush and a vibrating rectangular sponge-*I*.

This system presented in Fig. 1 is connected at spaying and washing pump which assured the spraying with pressure of cleaning fluid in inferior cavities of subsystem.

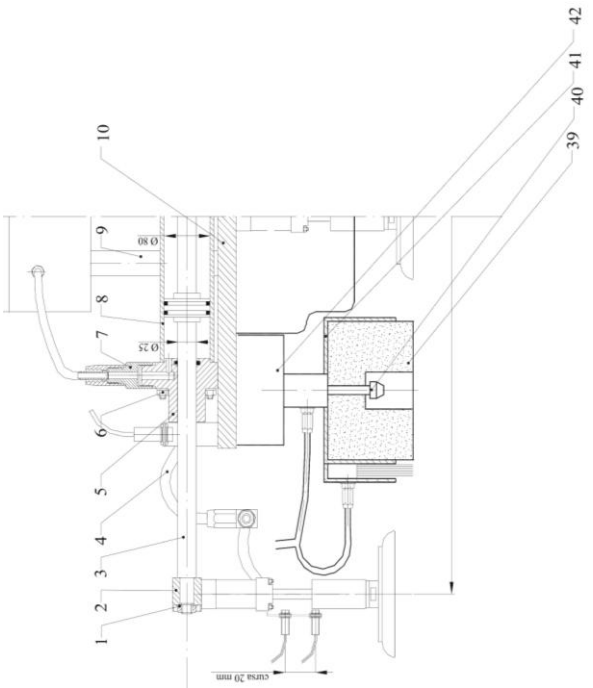

Fig. 1. 2D model of rough washing subsystem of vacuum robot

The cleaning-drying system of glass wall's building is realized by a climbing vacuum robot, which is composed by a drying-absorption subsystem that is formed from a rotated drum on which is wrapped the sponge-II to assure the finishing of cleaning-drying operation of window, finished by a cleanser system.

The finishing system of cleaning-drying of windows is presented in Fig. 2.

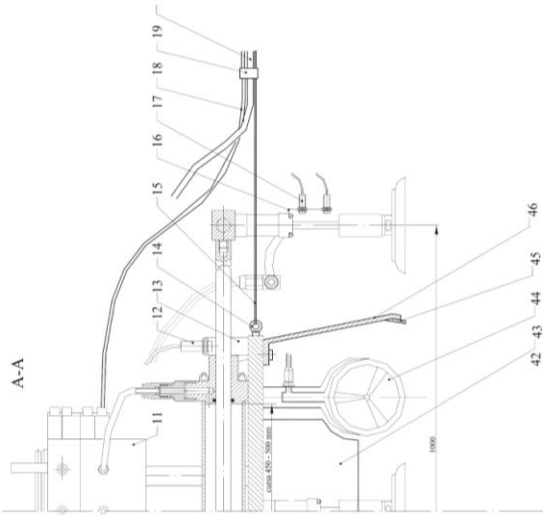

Fig. 2. 2D model of drying-aspiration finishing subsystem of vacuum robot

The pneumatic feeding, vacuum electrical and informational system is located on the terrace of last flour of building. Also, the leading software of vacuum robot is getting in and recorded in the command system of PC.

The interfaces between mechanical system of robot and its acting, informational and leading system is realized by a mixed interface that assure predictable conditions of robot in fast moving on long distance, and allowed a simultaneous connection of vacuum robot at energetic and informational system.

In Fig.3.a) and Fig.3.b) are presented two views, 3D and 2D respectively, of constructive type of fast interface used at construction of vacuum robot, which is located in a superior place of robot [4]-[5].

The required commands of vacuum robot moving on vertical way to assure the washing-cleaning of frontages' glass walls are transmitted by an electric cable of acting and command, where a flexible steel hose assured a supplementary safety protection for a possible detachment of suckers. These three elements have considerable lengths, and their useful length is calculated in function of height buildings cleaned.

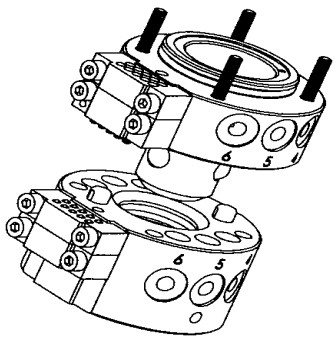

Fig. 3.a) 3D Model of fast interference of vacuum robot with its command system

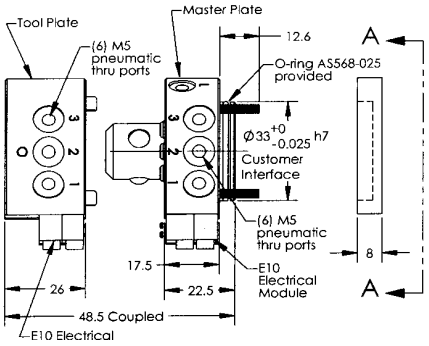

Fig. 3.b) 2D Model of fast interference of vacuum robot with its command system

In Fig. 4 is presented 3D model of vacuum robot in vertical position from where can be observed its functional mode. In addition, it can be mentioned that on the platform building is mounted a rolling way which allowing the horizontal moving of robot to realize a successive cleaning of all windows surfaces of building [4]-[5].

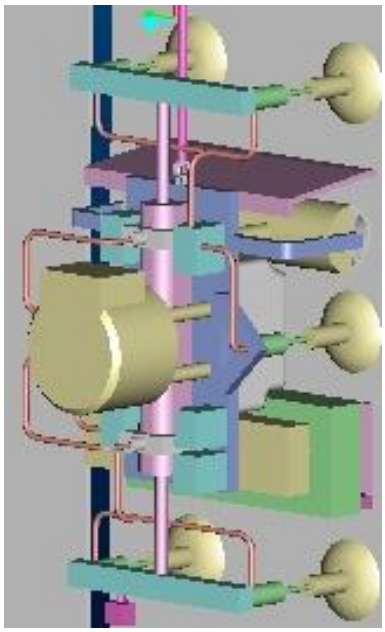

Fig. 4. 3D model of vacuum robot for positioning and vertical moving in up and down side

II. DESCRIPTION OF SECVENTIAL FUNCTIONAL STAGES OF CLEANING VACUUM ROBOT

The cleaning vacuum robot of frontages of glass buildings are working in conformity with its program that realized automated successive phases the descent and washing of windows surfaces of building on vertical way, where the its work stroke is realized in cleaning direction from up to down side.

On entirely working time of robot, it is watching by a human operator, located to the last platform of building near installation. After an analyzing of frontage architecture of building, the operator can selected the position of staring cleaning operation of robot. The

location of robot on vertical glass wall is realized by vacuumed of two central suckers that is following in next phase to going on the cleaning program from PC, which means execution of commands for washing-cleaning and moving of vacuum robot.

The working cycle of vertical moving of robot to realize the window cleaning is unwind by successive of following work stages: The spraying pump (49) is sprayed with pressure and continuous the washing fluid into internal cavity of surface, and the brush and vibrator sponge-I (39) execute a constant vibrating moving of them on the glass wall surface of building that is realized by the vibrator (42) and with the frame (41). The moving of robot in up and down side of frontage building is realized by 4 sidewise suckers and 2 central suckers, with details presented in Fig.5 and Fig.6.

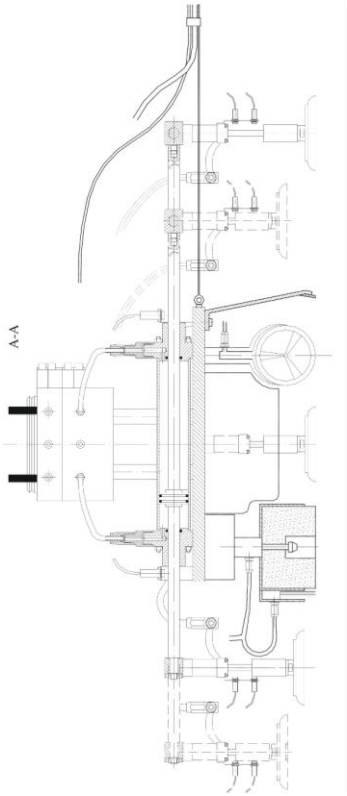

Fig. 5. 2D model of vacuum robot with detail about its functional mode.

In first stage, these two central suckers are vacuumed due to a fixing of robot on glass frontage, and their central position are located between two cleaning subsystems, composed by a vibrating sponge-I and a brush, while the drying subsystem is composed by a rotated drum-II and cleansed that assured an balanced position during of vacuumed on the surface of window building. Once the safety stability of robot is realized the sidewise suckers are un-vacuumed due to un-detaching of them from glass wall, and gone back on internal way with a stroke of 20 mm. The simultaneous returning of these four sidewise suckers is realized by a command of rods moving from four pneumatic cylinders with double acting, which phase of going back is presented in Fig.6.

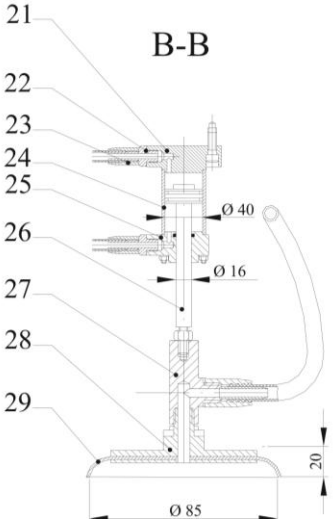

Fig.6. 2D model of sidewise port-suckers of vacuum robot

In Fig. 7 can be observed the fixing positions of sensors on rods of pneumatic cylinders which the role is to transmit the information with correct position of suckers, which is realized by a command system that determine exactly the stroke foot of sucker in conformity with required conditions of robot working. The sidewise suckers are climbed together with their support, fixed at the ends of pistons rods (3 and3'') of pneumatic pump with double acting and bilateral rods (8), which are simultaneous moving in downside, in conformity with advanced way, step by step.

The linear size of stroke for advances the robot is determined by its program and function of constructive parameters of robot. This size is adjusted by the operator from fixing of side covers of moving sensors, and on bilateral rods of pneumatic piston of motor is fixed a sliding ring which position is reading by the moving sensors. So, the moving of suckers' supports is limited at exact step determined from the command system, with stroke of side suckers between 450 to 500 mm (Fig.7.).

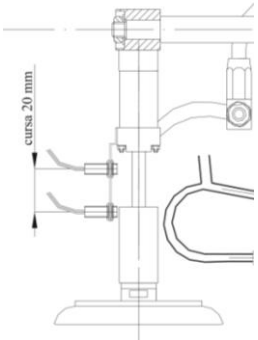

Fig. 7. 2D model of pneumatic cylinders with details about sensors system of vacuum robot

The assembles of suckers supports arrived in a new position due to transmitting the signal by sensors when

the leading system realized the command of pistons moving (2 and 26'') and the moving of suckers supports (28) and suckers (29) with 20 mm, returned in contact with plane surface of glass wall.

In next stage, it commands the simultaneous vacuumed of these four suckers, followed that a range of 10 s after vacuumed of central suckers to deviate the cambers of others two suckers. The brush and sponge (1), sponge drum (2), cleansed and central suckers are low downed with control on guide support. So, the brush and sponge (1) washed rough the glass surface by vibrating with cleaning fluid, while the central suckers returned into interior are free slipping and sponge drum-2 (44) realized the cleaning of windows. The extra cleaning fluid on drum after drying is aspirated and recycled into cleaning system of robot by the aspiration pomp of robot (49), following that in final stage the cleansed with lamella of rubber to assure a perfect cleaning of glass window surface. The fluid aspirated by the rotated sponge (2) is filtered from impurities and then get in the circuit. This working cycle described on stages are continuous repeated until the cleaning robot arrived at building ground, position located by the proximity sensors of robots or video cam (50) fixed on inferior arm of robot.

On each step realized by the robot the mini-winch of drum on which are wrapped the assembly of the electrical cable-hose, safety cable is rotated in wrapped wise to avoid stresses in this assemble.

The position of building ground is indicated to human operation by the proximity sensors with a sound signal or light signal. This command going on to un-vacuumed of all suckers, moved off of robot on glass wall with a telescopic arm attached on drum, followed by a slow moving on next working sector (sector equal with sponge thickness), and then the robot is rising on the terrace of building. This operation is realized by wrapping of cable assemble on winch drum, endowed with a wrap device and leading of assemble, due to its position on one range and formed homogeny layers, avoid blocking and struggled of hose.

Periodically, at these rising operations of robot on terrace of building the cleaning sponge (1) and sponge drum (2) are altering for cleaning, washing and rejected of impurities and watching the level of fluid, each added if it's necessary. An important particularity of robot consists of special fast jointing between robot and command system, which assured the electrical, energetically and informational connection with robot. The robot can be used by only one operator.

It is required to avoid cool temperatures for working and bad meteorological conditions.

This vacuum robot assures a high cleaning as handling work.

III CALCULUS OF ACTING FORCE INTO VACUUM OF CLIMBING ROBOT

For a safety working of robot is required some calculus for precise determination of fixed forces of suckers in contact with vertical position on wall building. The relations of calculus used have the goal to determine the minimal diameter of sucker robot (D), known the mass of handling part, in this case the robot mass, or calculus of catching forces (F_i) by known the sucker size [1]-[2].

$$F_i = A_s \cdot \Delta_p \text{ (N)} \tag{1}$$

, where: F_i-Force developed of the sucker; A_s-Sucker surface, and Δ_p- Depressurize. For a number of sucker is:

$$F = \frac{\pi \cdot D^2}{4} n \cdot c \cdot \mu \cdot \Delta_p = m \cdot g \text{ (N)} \tag{2}$$

, where: D – Sucker diameter, n– Number of suckers (n=4), c – Safety coefficient (c=0.4-0.6), μ- Friction coefficient (μ= 0.14), m – Robot mass; (m = 50 Kg), and g – Gravitational acceleration.

$$D = \sqrt{\frac{4mg \cdot}{\pi \cdot \Delta_p \cdot n \cdot c \cdot \mu}} \text{ (mm)} \tag{3}$$

By using (3) is determined the minim diameter of sucker results D=56.71mm. It will be chose a constructive diameter of sucker D=85 mm. From (1) it will be determined the force developped by a sucker Fi=39,94 N, respectively the catching force of these four suckers F=111.67 N. The vacuum robot designed weights approx. of 30Kg and the calculus were made for a robot mass of 50Kg.

IV CONCLUSION

The implementation of new architecture in frontages buildings with glass walls leads to use periodically cleaning-washing services of them. The handling cleaning of these frontages implies high costs because the work conditions are harder and dangerous that imposed the using of climbing vacuum robot.

This robot is able to introduce the robotized cleaning, washing and verification in services field with multiple extensions and needs.

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