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VACUUM ROBOT FOR CLEANING THE GLASS FRONTAGE OF THE BUILDINGS

Lecturer .dr. eng. Dănuț- Pavel TOCUȚ, lecturer. eng. Călin TRIPE-VIDICAN,
univ. prof. dr. eng. Aron TRIPE-VIDICAN.

University of Oradea, Faculty of Managerial and Technological Engineering.

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Summary.

This paperwork is based on a scientific research, made by the authors, with the scope of implementing the service robots in washing/cleaning operations, of building windows with glass walls.

The constructive type of the vacuum robot intended for cleaning operations of buildings frontage with glass walls, presented in this paperwork can be realized and applied in the robotized checking/cleaning services area.

1. Introduction

The economical development and growth recorded in the last years in our country allowed the construction, modernization and extension of numerous modern buildings, their destination being usually company headquarters and offices. The frontage of this office buildings with more levels are realized from glass panels and the periodical cleaning brought to the implementation of new robotized technologies in scope of accomplishing these operations.

This paperwork authors proposed themselves to conceive and project a new constructive type of climbing vacuum robot, destined to this service area. It has been realized like a necessity, in scope of periodically cleaning and washing operations of the glass windows situated at high altitude, with the human operator on the building roof, in safe conditions.

This kind of modern buildings usual destined to company headquarters, shopping complexes, libraries, business centers have been built in all the major cities in the country in the last few years.

In figure 1 is presented such a building recently finalized, in the town of Oradea.

In projecting the vacuum climbing robot the authors took in consideration the following particularities:

- the robot must have a very good adherence to the surface on which it moves.
- to exert a low pressure on the surface which will be cleaned to avoid braking the glass.

- to realize a quick and uniform vacuum and un-vacuum of the fixing suckers according to a well established program, accomplishing the move – clean cycle.
- to have access on all the building cleaning surface.

The projected robot is provided with a safety system (sustaining cable) and the constructive structure adopted is simple. When the cleaning liquid flows in a closed circuit there have been provided filtering elements for economy by recycling, reflowing of the fluid.

Figure .1. Raiffeisen bank headquarters in the Lotus Market complex.

Also the used sponges used for the cycle washing – cleaning have a constructive particularity which doesn't allow the washing liquid to splash beyond the work space.

It has been adopted a optimal trajectory for the movement on the building surface from up to down.

On base of these peculiarities we have conceived a constructive type of a robot for windows cleaning, the 2D drawing being presented in figure 2.

2. Presentation of the robot ensemble and the component elements

The 2D ensemble of the service robot projected for periodical cleaning operations of the glass frontage of buildings, presented in figure 1 consists in the following constructive elements:

Bolt nut M16 (1); holder (2); piston (3); hose I (4); lid (5); bolt nuts M8 (6); coupling (7); pneumatic cylinder (8); devices holder block (9); double lid (10); device bloc (11); sensor I (12); sensor holder (13); security ring (14); safety cable (15); sensor holder II (16); sensor II

(17); electric cable (18); hose (20); cylindrical hose I (21); coupling (22); coupling bolt nut (23); cylinder I (24); lid II (25); piston (26); leg (27); sucker holder (28); sucker (29); hose I (30); hose II (31); coupling (32); hose III (33); hose IV (34); distribution plate (35); screw M6 (36); bolt nuts M16 (37); collar (38); sponge I (39); sprayer (40); sponge hull I (41); jigger (42); liquid tank (43); sponge (44); shim for gathering (45); shim holder (46); hose V (47); spraying pomp (48); intake pomp (49).

The projected robot gauge is $500 \times 1200 \times 500\ mm$. Sticking the robot on the vertical surface of building glass wall for cleaning by washing is realized progressively, by the contact of the 6 vacuums connected with flexible pipes to the vacuum robot system. For driving and controlling the robot at distance a program is realized with the help of the computer. The cleaning system is composed from two sponges, sponge I and sponge II placed between the lateral mobile suckers.

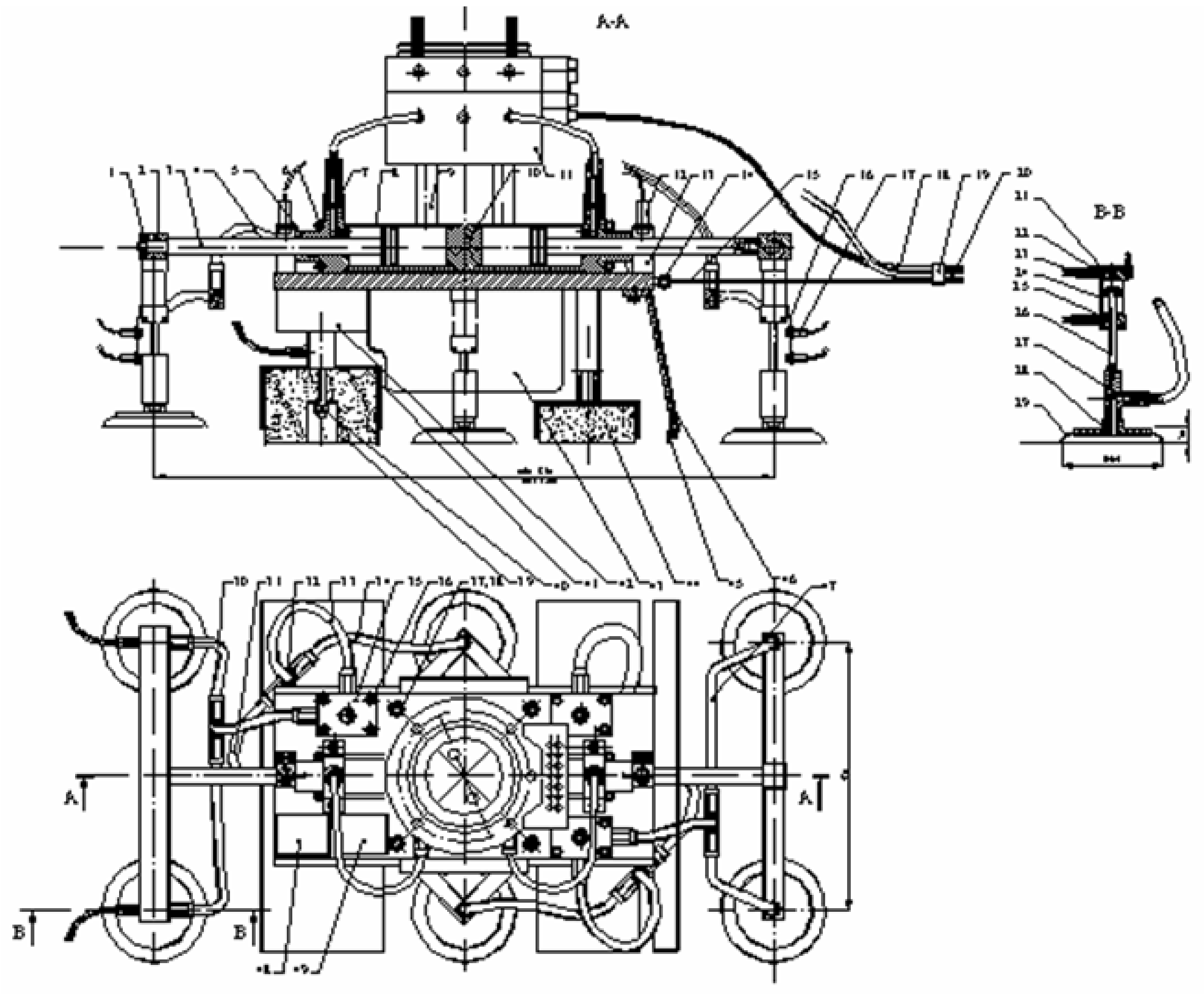

Figure .2. The 2D ensemble drawing of the vacuum robot for cleaning the buildings frontage.

The pneumatic and electrical energy supplying system is located on the building roof-top. Also the program conceived for this operation is introduced and memorized in the command and direction system of the computer which serves the robot.

The existent interfaces between the mechanical system of the robot and the operating systems, the informational system and the driving system of the robot are realized by a mixed interface which assures the remote movement conditions of the robot. The necessary commands for the vertical movement of the robot, with the objective of cleaning the frontages are transmitted by a operating and commanding electric cable, a flexible pipe made of steel, which assures an extra protection in case of accidental detachment of the cupping glass. The tree elements have considerable lengths and the length is chosen taking account of the height of the cleaned buildings. They are together bounded, with help of some clamps, resulting a convoluted band on a cylinder like a headgear, foreseen with a cable guiding system which assures a uniform twine in successive coating along the headgear.

3. Description and function of the frontage cleaning robot

The glass frontage cleaning robot operates in an automatic way on vertical, its race for cleaning being realized from up to down, and it's assisted by a human operator. After a study the operator chooses a spot from where the robot will start the cleaning operation; the robot is positioned with the two central suckers on the wall; in the next phase will come the command given tot the cleaning and moving installation of the robot, the cycle is running in the following way:

The spraying pump (48) sprays with pressure the cleaning solution continuously in the interior cavity of the sponge I (39), the sponge execute a vibrating movement o the glass surface, the vibration movement being impregnated by the jigger (42) trough the sponge hull (41).

The vertical movement from up to down of the robot on the surface of the building is realized with the help of the 4 lateral suckers and the 2 central suckers in the next way:

In the first phase the two central suckers are vacuumed, realizing in this way attachment of the robot on the glass surface. Once the stability assured the lateral suckers are un-vacuumed and detached from the glass drawn back with 20mm. This drawing back is realized by the two pneumatic engines with double action.

On the two pneumatic engines leavers are placed position sensors which send information to the driving system, establishing the correct value of the sucker leg race, accordingly to the claimed conditions.

The lateral suckers are elevated together with their holder, fixed at the end of the pistons rod (3 and 3”) of the pneumatic engine (8) being moved simultaneously downwards (according to the movement way) with one step.

The value of the movement step is established within the program and the value of its linear size is according to the constructive parameters of the robot, its value being adjusted by an operator by placing on the lateral lids two movement sensors and on the pistons rod of the pneumatic engine a slider ring, and its position is read by the sensors, limiting in this way the movement of the suckers holders till they reach the established step and memorized in the command system.

The sucker holders reaching a new position, transmit the signal throughout the sensors and now the driving system command the pistons (2 and 26”) to move, moving also the suckers holder (28) and the sucker (29) on a distance equal with 20mm, coming back in contact with the glass surface.

In the next phase the simultaneous vacuum of the 4 suckers, and after 10 seconds after the vacuum of the lateral suckers the other two central suckers are un-vacuumed. Sponge 1, sponge 2, the shim and the suckers go down slowly controlled on the guidance hull.

In this way sponge 1 washes by vibration with the help of the washing liquid, the central suckers slip freely, sponge 2 (44) absorbs the washing solution left on the window surface, because is connected to the intake pump (49), and the shim for gathering with the rubber shim assures the perfect cleaning of the glass surface. The liquid absorbed by sponge 2 is filtered from impurities and afterwards is reintroduced in the circuit.

This cycle is repeated continually until the cleaning robot reaches the building base, position detected by the robots proximity sensors or by a camera which can be mounted on the robot. At each step made by the robot the bobbin on which is rolled the electric cable, hose, the security cable are spinning in the deployment way so that it will not cause any tensions in the package mentioned before.

The proximity sensors indicating the base of the building announce the operator by sound, he orders the un-vacuuming of all the suckers, clears out the robot with the help of a telescopic stick attached to the bobbin, he moves it on the next sector (sector equals the sponge width) and pulling the robot to the buildings roof.

This operation is realized by rolling the cable package on the bobbin, foreseen with a rolling and driving package device, disposed on a single row in a uniform coating, avoiding the blocking or the strangulation of the hose.

At each robot lift on the buildings roof sponge 1 for washing and sponge 2 for absorption are replaced for cleaning, washing and eliminating the impurities and the level of the washing is checked and refilled if needed.

An interesting observation of this robot is the fast couple between the robot and the command system. This assures the electrical, energetically and informational connection with robot 1.

This robot can be managed by a single human operator.

It’s recommended to avoid using it in low temperatures and in bad meteorological conditions, rain, and high wind.

The use of this robot assures a high cleaning quality, cleaning that couldn’t be realized in another way.

4. The calculation of the vacuum operating force

For secure functioning of the projected vacuum robot we made a series of calculation in the scope of determining the precise fixing forces realized by the robots suckers when going in contact with the vertical surface of the building walls. The calculus relations used have as objective to find the minimum diameter of the robots suckers (D), knowing the objects weight, in our case the robot, or the calculus of the grabbing forces (F), knowing the suckers dimension.

$$F_i = A_S \cdot \Delta_p \ [N] \qquad (1.)$$

where: F_i – the developed force of the sucker

A_S – suckers area

Δ_p – depression

For a number of suckers is obtained: $I = \frac{\pi \cdot D^2}{4} \cdot n \cdot c \cdot \mu \cdot \Delta_p = m \cdot g$ (2.)

where:

D – the diameter of a sucker
n – number of the suckers ; ($n = 4$)
c – safety coefficient ; ($c = 0,4 - 0,6$)
μ - friction coefficient ;(μ = 0,14)
m – robot's weight ; m = (50 Kg)
g – gravity acceleration ; g = (9,81)

$$D = \sqrt{\frac{4 \cdot m \cdot g \cdot 9,81}{\pi \cdot \Delta_p \cdot n \cdot c \cdot \mu}} \quad [mm] \tag{3.}$$

Using relation (3) we can determine the minimum diameter of the sucker so:

$$D_{\min} = \sqrt{\frac{4 \cdot 50 \cdot 9,81}{\pi \cdot 0,7 \cdot 4 \cdot 0,5 \cdot 0,14}} = \sqrt{\frac{1962}{0,61}} = 56,71\, mm$$

The diameter of the sucker will be chosen constructively $D = 60\ mm$

We'll obtain from relation (1.) the necessary force developed by the sucker:

$\Delta_p -$ depression = -0,7 daN/cm^2

$$A_S = \frac{3,14 \cdot 60^2}{4} = 2826\ mm^2$$

$$A_S = 28,26\ cm^2$$

$$F_i = 28,26 \cdot 0,7 = 19,80\ daN$$

$$F_i = 19,80\ daN$$

The vacuum force of grabbing of the four suckers is obtained with the help of relation (2.)

$$F = \frac{3,14 \cdot 60^2}{4} \cdot 4 \cdot 0,5 \cdot 0,14 \cdot 0,7 = 563,70\ N$$

$$F = 56,37\ daN$$

The projected vacuum robot weights approximately 30 kg, and the calculations have been
made for a weight of the robot of 50 kg.

In figure 3 are presented the 3D and 2D of the standard cylindrical vacuum suckers, by the type of suckers usually utilized in the construction of vacuum climbing robots, and in table 1 are presented the suckers product codes, put at disposal by the company, containing some technical characteristics too.

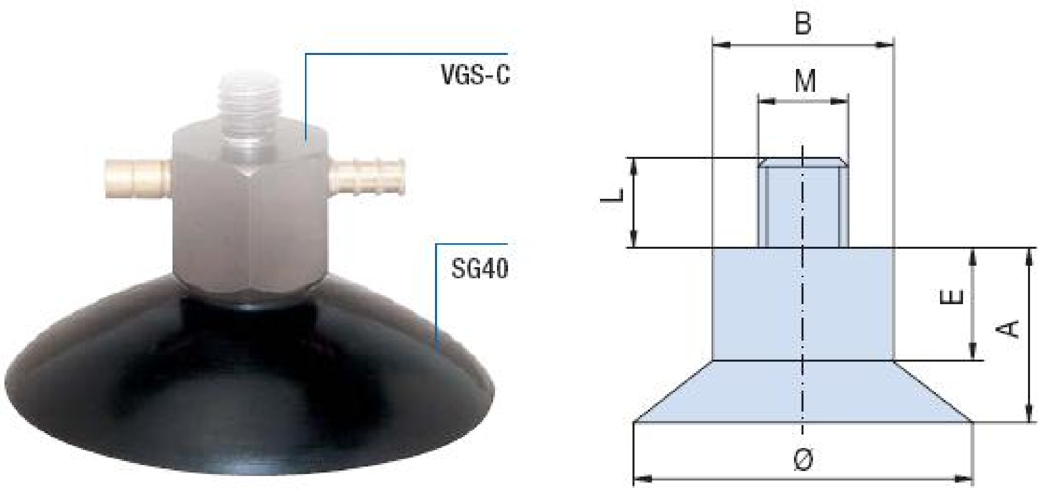

Figure 3. The 3D and 2D drawings of the cylindrical vacuum suckers.

Table 1

Cod: *Of The Cylindrical Vacuum Suckers*						
SG25	SG30	SG35	SG40	SG60	SG85	SG130
Force [N]						
29,40	42,40	57,70	75,40	170	340	769
Dimention ∅ [mm]						
25	30	35	40	60	85	130
Dimention A [mm]						
11	12	12	14	16	36	42
Dimention B [mm]						
8	8	8	15	15	25	25
Dimention E [mm]						
6	6	6	4	4	12	12
Dimention L [mm]						
6	6	6	10	10	10	10
Dimention M [mm]						
M5	M5	M5	M8	M8	M12	M12

5. Conclusions

The implementation of the new architecture on the frontage of the buildings with glass walls attracts many types of periodically washing and cleaning services. The manual cleaning of the frontage of these buildings implies high costs because the manual cleaning/washing conditions are sometime hard to be realized.

The constructed option of the vacuum robot destined for cleaning the frontages, presented
and described in this paperwork has as an objective the replacement of the human operator from the heavy, risky, hard duties.

The vacuum robot makes possible the robotized operations of washing, cleaning, verifying, the range of services which can be made by it can be extended when needed.

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