

Automatic climbing mechanism for façades, especially glass façades

Field of application of the invention

The invention relates to an automatic climbing mechanism for façades, especially glass façades, with a drive comprising endless lines of controllable vacuum suction devices. The automatic climbing mechanism can carry a glass cleaning robot for example. Other applications relate to automatic climbing mechanisms for inspection work, renovation and transport work to be carried out on façades or similar, oblique, perpendicular or overhanging smooth surfaces.

Prior Art

For travelling over perpendicular or inclined façades, in particular glass façades, automatic climbing devices are known which use electromagnetic force (DE 27 37 619 A1) or vacuum for adhesion, the term "vacuum" more accurately signifying low pressure. With regard to the type of movement concerned a distinction is made in vacuum technology between walking mechanisms and traversing mechanisms, which should be taken into account in the following.

Currently walking mechanisms only reach working speeds of up to 1 m/min. The movement is performed periodically with stopping breaks. In order to achieve working speeds of 1 m/min half of the vacuum suction devices need to be released, lifted and pushed forward. After this the suction devices are lowered and reconnected. Finally, the remaining suction devices have to be moved on using the same procedure. In this way the available holding force continually fluctuates between 50% and 100%. If the suction devices are moved forward or follow on in pairs or individually, the speed of travel drops to considerably below 1m/min. A further disadvantage is the high cost of controlling and monitoring the individual movements. An advantage of such devices is that they are easy to steer by lateral alignment at right angles to the direction of movement, and they are able from the beginning to overcome smaller obstacles, such as glass façade profiles. Walking devices are described in DE 198 35 038 C1, DE 199 07 437 A1, EP 0 401 120 A1, US 4 674 949 and US 5 551 525.

Traversing mechanisms can reach greater working speeds of 3 m/min to 10 m/min. The movement is performed uniformly without stops and the work cycles: release suction devices, lift, move forward, lower and reapply suction, can be carried out simultaneously for the suction devices concerned. The continually available holding force thus only fluctuates between 80% or 90% and 100 %. The lower control costs are also an advantage, as the work cycles can be forcibly controlled. The disadvantage of known traversing mechanisms is their inadequate steerability, such as with lateral placing at right angles to the direction of travel and the inability of the basic mechanism to overcome façade profiles or similar obstacles on perpendicular walls, such as in particular glass façades. The wheel geometry does not provide sufficient bearing surface and is relatively unsuitable for supporting suction devices. Examples of traversing mechanisms are described in DE 197 27 421 C2, DE 296 22 167 U1, EP 0 505 956 A1, US 5 487 440 and US 6 090 221.

In the case of traversing mechanisms chain drive technology, which has been used for a long time for armoured crawler vehicles and tracked vehicles, is currently the most practical solution. However, the rotating driving means, such as chains, bands, cables or belts, which are to perform the forward movement, still have to be provided with suction devices. The term "chain" is used here loosely to refer to all suitable driving means without implying any restriction to this alone.

The principle is based on the fact that each suction device secured to a chain runs in an endless loop. The suction devices facing the driving surface are pressurised with vacuum and hold the mechanism on the façade. Once the chains have been set in motion the respective rear suction devices need to be aerated, so that said suction devices can be detached from the driving surface and the chains can pivot said suction devices about 180°. The suction devices that have just been pivoted away thus point away from the direction of the driving surface. In this position the suction devices are transported in travelling direction and pivoted again by 180° so that the suction devices again face the travelling surface. Then vacuum is applied and the suction devices become active once more and can secure the mechanism to the driving surface. Once the mechanism has moved forward by means of the suctioned suction devices the latter are again aerated and pivoted. This procedure is continually repeated during travel for each individual suction device.

The known chain mechanisms for façades differ mostly only in how they place or lift or pivot away the suction devices after pivoting in parallel on the travelling surface (DE 29 622 167 U1), and in how the vacuum is supplied (EP 505 956 A1).

A great disadvantage of the continually running mechanisms is that they cannot overcome obstacles of more than about 1 cm, such as e.g. glass façade profiles. Furthermore, only very small trimming steering movements can be carried out. They also are of high mass and structural height due to their construction.

Subject matter of the invention.

The objective of the invention is to provide an inexpensive and operationally reliable automatic climbing mechanism of low mass and structural height which moves relatively fast and continually both forwards and backwards and which travels by remote control very securely on inclined, perpendicular or overhanging façades over greater distances, overcomes façade profiles of more than 1 cm up to at least 4 cm in height, can be steered so effectively that it can turn on the spot, is not suspended on cables or similar means, can preferably be used for climbing robots for cleaning glass façades, as well as for transport, renovation and inspection work and has minimised control costs and energy consumption for its operation.

The objective of the invention is achieved according to the features of claim 1. Preferred embodiments and further developments are described in the subclaims.

By means of the invention a continually and relatively fast automatic climbing mechanism is created for robots, which independently climbs up an oblique, perpendicular or even overhanging façade, overcomes façade profiles of at least 4cm in height, can turn on the spot, requires comparatively low control and energy costs and is not suspended on cables or similar means.

The automatic climbing mechanism according to the invention has two chain track guides which unlike known chain drives do not run perpendicular to the driving surface but parallel to the driving surface of the vehicle, i.e. are in a flat position,

whereby the suction devices moved along the chain track guides continually maintain their parallel position to the driving surface. The suction devices thus point continually to the driving surface, regardless of whether they are active or inactive. In a further development of the invention slides attaching backwards to the suction devices perform perpendicular lowering and placing of the suction devices on the driving surface and perpendicular lifting and returning of the suction devices into the starting position. The slides thus maintain a parallel and constant distance between the mechanism and the driving surface and thereby ensure the required ground clearance for overcoming obstacles, such in particular glass façade profiles.

The slides are guided along the length of the chain track guides and are connected together by the chains or functionally equivalent driving means. In this case the term "slide" refers to all functionally suitable guiding components for suction devices.

Examples of embodiments of the invention.

The invention is explained in more detail by way of examples of embodiments.

In the attached drawings:

Fig. 1 shows a first variant of chain track guides of a mechanism in plan view,

Fig. 2 shows a further variant of chain track guides of a mechanism in plan view,

Fig. 3 shows a further variant of chain track guides of a mechanism in plan view,

Fig. 4 shows a further variant of chain track guides of a mechanism in plan view,

Fig. 5 shows a further variant of chain track guides of a mechanism in plan view,

Fig. 6 shows the view according to Fig. 1 from a front side,

Fig. 7 shows the view according to Fig. 4 from a front side and

Fig. 8 shows the side view of a slide.

Functionally equivalent components are allocated the same reference numbers in all of the Figures.

According to Figures 1 and 6 two chain track guides 1, 2 of a traversing mechanism each comprise an exact straight guide 1 for forwards and backwards movement or up and down movement on a façade and an exact part-circular guide 2 for rotating and turning on the spot. The two part-circular guides 2 have such a radius and are spaced apart from one another in such a way that an imaginary full circle can be completed with middle point M around both part circles. Between the straight guides 1 and the part-circular guides 2 there are drive wheels 3a, 3b or turning wheels 4 for driving rotating chains 5 and guiding them into the chain track guides. The drive wheels 3a, 3b also act as turning wheels on the opposite side of the purely turning wheels 4. Suction devices 7, 9 secured to slides 6, 8 run round with the chains 5.

If the mechanism needs to move in a straight line on a façade perpendicularly upwards or downwards, all slides 6 within the two straight guides 1 need to be made to move out and the associated suction devices 7 charged with vacuum. Said suction devices 7 are thus the only ones to be suctioned onto the driving surface. All other slides 8 and suction devices 9 are located in the initial position, this means that the slides 8 are moved in and their suction devices 9 are not under vacuum. If the drive wheels 3a, 3b are driven evenly in opposite rotational direction (drive wheel 3a clockwise and drive wheel 3b anticlockwise) the mechanism moves forwards in a straight line, for example up a glass façade. However, if the drive wheel 3b is driven clockwise and the drive wheel 3a anticlockwise the mechanism moves in opposite direction without a turning manoeuvre, for example down a glass façade. If one of the slides 6, 8, which is moved along the two chain track guides 1,2 by the two chains 5, reaches a straight guide end or a straight guide beginning, it is reversed. The part-circular guides 2 exert no influence. This means for the slides 6 within the two straight guides 1 on reaching the straight guide end: switch off vacuum production and then move slides into the initial position. At the same time for the slides 8 outside the two straight guides 1 on reaching the straight guide beginning it means: switch on vacuum and then move out slides.

If a suction device 7 touches the driving surface D (Fig. 6) it is pressed firmly by environmental air pressure against the driving surface D, and thus said suction device 7 supplies a proportion of the required holding force. If the suction device 7 on moving out its slide 6 on a façade profile P (Fig. 6), which is controlled by sensor, the advancing movement of the slide 6 stops automatically. In this way the mechanism is effectively prevented from being pushed off a perpendicular façade. In addition, the production of vacuum in the suction device 7 concerned is deactivated. On leaving the straight guide 1 the slide, now slide 8, is again reversed and moved into the initial position. As can be seen in Fig. 6 the lift of the slides 6, 8 or the clearance of the suction devices 7, 9 in the initial position over the driving surface D determines the maximum height of obstacles that can be overcome, i.e. in particular façade profiles P.

In order to change the direction of travel and perform turning manoeuvres the mechanism is stopped and pivoted or turned whilst standing. For this the slides 8 within the two part-circular guides 2 need to be moved out and the associated suction devices 9 charged with vacuum so that they adhere to the driving surface D. Only then are the suction devices 7 on the two straight guides 1 aerated and the slides 6 moved into the initial position. Thus only the suction devices 9 of both part-circular guides 2 are adhered to the driving surface D, which within the two part-circular guides 2 describe the imaginary circle with the middle point M. All other slides 6 are located in the initial position, that is, the slides 6 are moved in and their suction devices 7 are not under vacuum pressure.

If both drive wheels 3a, 3b are driven uniformly in the same rotational direction anticlockwise, then the entire mechanism pivots clockwise around the middle point of the circle M, which is prescribed by the two part circular guides 2. If both drive wheels 3a, 3b are rotated evenly in clockwise direction the driving mechanism pivots anticlockwise about the middle point M. If one of the slides 6, 8, moved along the chain track guides by the chains 5, reaches a curve guide end or a curve guide beginning then it is reversed. The two straight guides 1 exert no influence. This means for the slides 8 inside the two part-circular guides 2 on reaching the curve guide end: switch off vacuum and then move the slides 8 into the initial position. For the slides 6

outside the two part-circular guides 2 on reaching the curve guide beginning it means: switch on the vacuum and then move out slides 6. If a suction device 9 touches the driving surface D it is pressed by environmental air pressure firmly onto the latter. In this way said suction device 9 generates part of the required holding force.

If on moving out the slide 8 the suction device 9 hits a façade profile P, which is controlled by sensor, the advancing movement of the slide 8 stops automatically, whereby the mechanism is prevented from being pushed off the façade. In addition, the provision of vacuum to the suction device 9 concerned is deactivated. On leaving the part-circular guide 2 the slide 8 is redirected and moved into the initial position. As can be seen from Fig. 6 the lift of the slides 6, 8 or the clearance height of the suction devices 7, 9 in raised position above the driving surface D determines the maximum height of obstacles to be overcome, i.e. in particular of façade profiles P.

The two chain track guides of the mechanism are supported by a left and a right frame section 10 or are formed directly by the frame sections 10, whereby connecting bridges 10 connect the two frame sections 10 securely together.

The slides 6, 8 on the frame side support slide guides 18 (Fig. 8) in a sliding or roller design for secure guiding along the rotating chain track guides, as is explained in more detail for Fig. 8.

The suction devices 7, 9 of both endless chains 5 need not, viewed in forwards and backwards direction, as illustrated, run synchronously at one height, they can be offset relative to one another which further improves their adhesion to the driving surface D and overcoming of façade profiles P or similar obstacles. A corresponding, greater or lesser offset of the suction devices 7, 9 relative to both endless chains 5 is set automatically according to operating conditions.

In Fig. 2 a further variant is shown, which also operates with two chain track guides 1, 2. Unlike the variant according to Fig. 1 the straight guides 1 run on the outside and the part-circular guides 2 with their imaginary circle midpoint M are on the inside. In this way the track width widens when driving straight on and the mechanism stands more securely on the driving surface. This can be an advantage for a climbing robot

performing specific work on a façade. However, this arrangement requires a larger number of suction devices 7, 9 and four additional turning wheels 4. Of course, the suction devices running at right angles to the direction of travel must always be raised, regardless of whether a straight or rotary movement is to be carried out. Apart from this the driving sequences correspond in working principle to the variant described in detail above according to Fig. 1 and Fig. 6, and for this reason the driving sequences are not described again here.

Both chain track guides 1, 2 of the mechanism are again supported by a right and a left frame section 10 which are connected securely together by connecting bridges 10. The design of the slides 6, 8 is identical to the design according to Fig. 1, Fig. 6 and Fig. 8.

Fig. 3 shows a further variant. It differs from the variant according to Fig. 1 in that the two chain track guides 1, 2 of the mechanism each comprise two parallel exact straight guides 1 for forwards and backwards drive or lifting and lowering on a façade and each have two exact part-circular guides 2 connecting the straight guides 1 for rotating and turning on the spot. The total of four part-circular guides 2 are spaced apart from one another and designed to have a radius such that an imaginary full circle can be drawn with a middle point M as rotational point for the mechanism. Between the inner straight guides 1 and the connected part-circular guides 2 drive wheels 3a, 3b or turning wheels 4 are attached, in order to drive and guide rotating chains 5. In addition, further turning wheels 4 are arranged between the outer straight guides 1 and the part-circular guides 2. The drive wheels 3a, 3b also serve as turning wheels. Suction devices 7, 9 secured onto slides 6, 8 rotate with the endless chains 5.

For driving in a straight line either the suction devices 7 on the inner straight guides 1 or the suction devices 7 on the outer straight guides 1 can be used depending on the control used. By using the outer suction devices 7 on the outermost straight guides 1 the driving track widens and the mechanism stands more stably on the driving surface. This can be an advantage for a climbing robot performing specific work. For rotational movements the suction devices 9 on the part-circular guides 2 are used.

Both chain track guides 1, 2 of the mechanism are in turn supported by a right and a left frame section 10 which are joined securely together by connecting bridges 10.

The driving sequences correspond in principle to the aforementioned variants for which reason a detailed description is unnecessary at this point.

In Fig. 4 and Fig. 7 a variant with two chain track guides 1 in straight line is shown which at their turning ends are turned by a reversing drive wheel 3a, 3b and in opposite direction by a turning roller 4. The total of four straight guides 1 only permit a forward and backward movement of the mechanism. In order to widen the driving track in an advantageous manner for active driving each outer suction device 7 of the two outer straight guides 1 are used, and for returning the then lifted suction devices 7 the two inner straight guides 1 are used.

For rotation the mechanism is suspended in a rotary frame 11 which is rotatable in the plane relative to the mechanism, the supports of which are also provided with slides 12 and suction devices 13. In this way, the rotary frame 11 can be raised and lowered. The rotary axis 14 for the mechanism and rotary frame 11 passes through the middle point M of the rotary frame 11 and a central connecting bridge 10 which bridges the two frame parts 10 of the mechanism. In the moved out position of the suction devices 13 the mechanism is raised relative to the rotary frame 11 and thus to the driving surface D (Fig. 7) and can be steered by motor about the rotary axis 14.

A further variant of a mechanism is shown in Fig. 5, in a much schematicised view, as with all other variants. Again two endless chains 5 with suction devices 7, 9 are used, not with mirror-symmetrical or symmetrical chain track guides but with asymmetrical chain track guides 1, 2. A first chain track runs in two straight guides 1 which at their ends are only turned by a drive roller 3a and a turning roller 4. The chain 5 rotates suitably narrowly. The second chain track is formed by a part-circular guide 2 and further straight guide 1, whereby the part-circular diameter is greater than the length of the three equally long straight guides 1. The part circle is thus flattened externally and parallel to the two straight guides 1 of the first chain guide by the additional straight guide 1. For driving in a straight line the inner straight guide 1 or the outer straight guide 1 of the first chain track guide 1 and the straight guide 1 are used on the

outer track of the second chain track guide 1, 2. For rotation the part-circular guide 2 of the second chain track guide 1, 2 is used, whereby the rotational point M is asymmetrical relative to the centre of the mechanism. The advantage of this variant is the very secure adhesion of the mechanism to a façade both when driving straight on and rotating and fewer suction devices 7, 9 are needed than in the variant according to Fig. 3.

Both frames 10 of the mechanism with the endless chain tracks are connected securely together by connecting bridges 10. The slides 6, 8 are designed in a similar way to the preceding variants.

The driving sequences correspond in principle to those of the first variant for which reason a detailed description is not provided here.

In Fig. 8 a slide 6, 8 suitable for all variants is highlighted as a component group. It consists in this example of a pneumatically operated piston cylinder unit. In order to obtain an especially compact and yet stable structure of the slide, the piston rod 15 of the slide is fixed and the cylinder 19 is guided by using its outer contours height-displaceably in a prismatic cylinder guide 17, whereby a support 16 for the slide guide 18 and the piston rod 15, the piston rod 15 with the not shown piston and the cylinder guide 17 form a cohesive, stable component group, and the cylinder 19 supports the suction device 7, 9 at its lower end. Laterally acting forces are not absorbed by the piston rod 15 but by the cylinder guide 17 and the cylinder housing. The slides 6, 8 are chain driven on their slide guides 18 along a rotating chain track guide 1, 2 which are either formed by a frame section 10 or supported by the latter. In order to reduce friction a roller guide can be provided.

On the upper side of the suction device 7, 9 control elements, not shown in more detail, for the suction operation are arranged. Each suction device 7, 9 has an ejector for producing adhesive force through low pressure which is supplied via a pressure ring line to each chain track guide 1, 2. For rapid detachment from the driving surface D compressed air is blown in to remove the vacuum in the suction devices 7, 9. A microcontroller together with sensors and pneumatic control and regulating elements controls the time sequence of the slide and suction states. In this way the retraction

force for the suction devices 7, 9 and the suction force of the activated suction devices 7, 9 is influenced advantageously depending on the retraction path of the slide 6, 8 (obstacle), whereby only in the fully moved out position of a suction device 7, 9 can the full support force and the full vacuum be produced, in order to avoid lifting off the mechanism in the case of larger obstacles. If such an obstacle is detected the mechanism stops automatically and waits for an appropriate driving manoeuvre. Additionally, in drive operation it is continually checked whether there is sufficient adhesive force to prevent the mechanism from falling off the façade. If the pre-programmed adhesive force looks as if it might become insufficient, for example because too many suction devices are not in contact with the driving surface, (driving track end, façade opening, façade bend, unsuitable drive track quality, interruption in the supply of compressed air or in vacuum on a suction device inter alia), the mechanism stops automatically.

Reference Numbers

- 1, 2 chain track guide
- 1 straight guide of a chain track guide
- 2 part-circular guide of a chain track guide
- 3a, 3b drive wheels
- 4 turning wheels
- 5 chain
- 6,8 slide of the mechanism
- 6 slide, driven in a straight line
- 8 slide, driven in a partial circle
- 7,9 suction devices
- 7 suction device, driven in a straight line
- 9 suction device, driven in a partial circle
- 10 right and left frame with connecting bridge
- 11 rotary frame
- 12 slide of the rotary frame
- 13 suction device of the rotary frame slide
- 14 rotary axis
- 15 piston rod
- 16 support
- 17 cylinder guide
- 18 slide guide
- 19 cylinder housing
- M middle point of the part-circular guides 2
- D driving surface (façade)
- P façade profile

Claims

1. Automatic climbing mechanism for façades, especially glass façades, with a drive comprising endless lines of controllable suction devices, characterised in that the suction devices (7, 9) rotate in the driving plane and their suction sides always point to the driving surface (D).
2. Automatic climbing mechanism according to claim 1, characterised in that the currently activated suction devices (7, 9) of an endless line rest on the driving surface (D) and currently inactivated suction devices (9, 7) of an endless line rotate at a distance from the driving surface (D), which is equal to or greater than the height of obstacles (P) to be overcome.
3. Automatic climbing mechanism according to claim 1 or 2, characterised in that the suction devices (7, 9) of each endless line rotate in a track guide (1, 2) and are connected together by a drive means (5).
4. Automatic climbing mechanism according to claim 2 and 3, characterised in that the suction devices (7, 9) are secured to slides (6, 8), which are drawn along the tracks guides (1, 2) of the mechanism by the drive means.
5. Automatic climbing mechanism according to claim 3 or 4, characterised in that a chain-wheel driven chain (5) functions as the drive means for the suction devices (7, 9).
6. Automatic climbing mechanism according to at least one of the preceding claims, characterised in that at least two straight guides (1) driven in the same direction and running parallel to one another in the mechanism are used for driving the mechanism straight on (forwards drive, reverse drive).
7. Automatic climbing mechanism according to claim 6, characterised in that the mechanism is suspended with its extendable suction devices (13) on a rotary frame (11) which is rotatable in the drive plane relative to the mechanism.

8. Automatic climbing mechanism according to at least one of claims 1 to 6, characterised in that the track guides (1, 2) are divided into straight guides (1) and part-circular guides (2).
9. Automatic climbing mechanism according to claim 6 or 8, characterised in that the outermost straight guides (1) are used for driving straight on.
10. Automatic climbing mechanism according to claim 8, characterised in that at least two part-circular guides (2) driven in the same direction of two track guides (1,2) are used for rotating the mechanism (clockwise, anticlockwise).
11. Automatic climbing mechanism according to one of claims 1 to 4, characterised in that an ejector is arranged on every suction device (7, 9) to generate holding force at low pressure, which is supplied via a pressing ring line, and compressed air can be blown into each suction device (7, 9) to equalise the low pressure.
12. Automatic climbing mechanism according to claim 4, characterised in that a slide (6, 8) comprises a pneumatically drivable piston cylinder unit (15, 19), whereby the cylinder (19) can be moved vertically along a vertical cylinder guide (17), which forms a compact subunit with the piston rod (15) and a support (16) of the slide (6, 8) with the slide guide (18) secured thereon, which subunit runs in the track guide (1, 2) of a frame section (10) of the mechanism, and whereby the vertically guided cylinder (19) supports the suction device (7, 9) underneath.
13. Automatic climbing mechanism according to one of claims 1 to 12, characterised in that a drive control system monitors the adhesive force of the mechanism on a façade and stops the mechanism if the required degree of adhesion is not reached.

14. Automatic climbing mechanism according to one of claims 2 to 13, characterised in that a drive control system initiates the lowering and placing of the suction devices (7, 9) onto the driving surface (D) and raises and returns the suction devices (7, 9) to the initial position.
15. Automatic climbing mechanism according to claims 1 to 10, 13 and 14, characterised in that the suction devices (7, 9) are replaced by magnetic adhesive elements.