A REVIEW ON DEVELOPMENT OF WALL CLIMBING ROBOT FOR CLEANING PURPOSE

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Abstract. This paper present a concept of climbing robot with the help of vaccum motor, inspired by trek-o- bot model and trek-o-bot vaccum motor method which help to climb the wall. For designing climbing robot conceptually based on an up-to-date literature review. The proposed method is illustrated with a case study of on-going research, the investigation of an adaptable and energetically autonomous climbing robot, in Loughborough University. With an external attachment given to the robot for the cleaning purpose.

Keywords: Concept of Climbing of robot, Modification to Wall Cleaner

Introduction: Climbing robots are unusual mobile robots that exhibit energy autonomous behavior, have a robust and efficient adhesion mechanism, an agile locomotion mechanism and intelligent sensors integrated together such that they can adapt to various wall surfaces and 3D terrains to conduct given tasks. Climbing robots may be capable of replacing human beings to perform dangerous and tedious operations with high efficiency and low cost for terrestrial and space applications. The health and safety problems can be protected, freeing human beings from risky tasks in hazardous or difficult-to-access environments. Meanwhile, the cost for applying operators or scaffolds can be minimised. Since the seminal work achieved in [1], numbers of climbing robots [2, 3, 4, 5] have been designed to clean high-rise buildings (cleaning), inspect large structures like bridges, solar power plants and confined pipelines etc. (inspection), detect cracks in oil tanks, aircrafts, and nuclear power plants etc. (testing), paint and maintain surfaces of ship hulls, wind turbines and conduct welding for stainless steel tanks etc. (construction and maintenance), deal with anti-terrorism missions or reconnaissance in urban environments (security), and/or for entertainment and education. In addition, climbing robots may be regarded as appropriate vessels for enhancing the autonomy and adaptability of mobile robots, and challenging the boundaries of existing technologies to form coherent systems integrated from diverse technologies.

CASE STUDY:

There are three key issues associated with designing and prototyping this type of robots: 1) adhesion method, 2) locomotion mechanism and 3) actuation mechanism.

Climbing robots should be thin and light as thinner ones are harder to peel off from a vertical surface and lighter ones are more stable on the substrate [6]. It is complicatedand costly treatments such as chemical processes. Floating oil and grease cling to skimming media more easily thanwater, and challenging and important to design a proper adhesion method guaranteeing reliable climbing on various wall surfaces whilst not sacrificing flexible mobility and large payloads. Although various climbing prototypes have been seen since the 1980s, there is no general engineering recognized design method that can be applicable to designing and prototyping climbing robots. A concept selection methodology for the initial-design-stage of climbing robots is identified and proposed based on an up-to-date literature review in this paper. Also, there is no advanced climbing robot that has full autonomy and adaptability. Most climbing robots have a tethered design or on-board batteries to support themselves. The former method enables robots to have sufficient power; however, the weight of cables and their limited lengths may confine their locomotion capability. The latter method enables robots to have some autonomous behavior. However, most batteries are not good enough to support long-duration tasks. By using energy autonomous systems [7] with novel control methods (such as semantic control [8]), climbing robots may realize long-range, long-endurance missions without the need for manual or conventional re-fuelling, and enjoy a high level of energy autonomous behavior like living creatures, and thus the adaptability and autonomy level of robots may be enhanced.

There are five major categories of adhesion methods in climbing robots that have been summarized in this work and can be seen in Fig. 1. It should be noted that only one representative paper for a certain type was cited although various other papers exist.

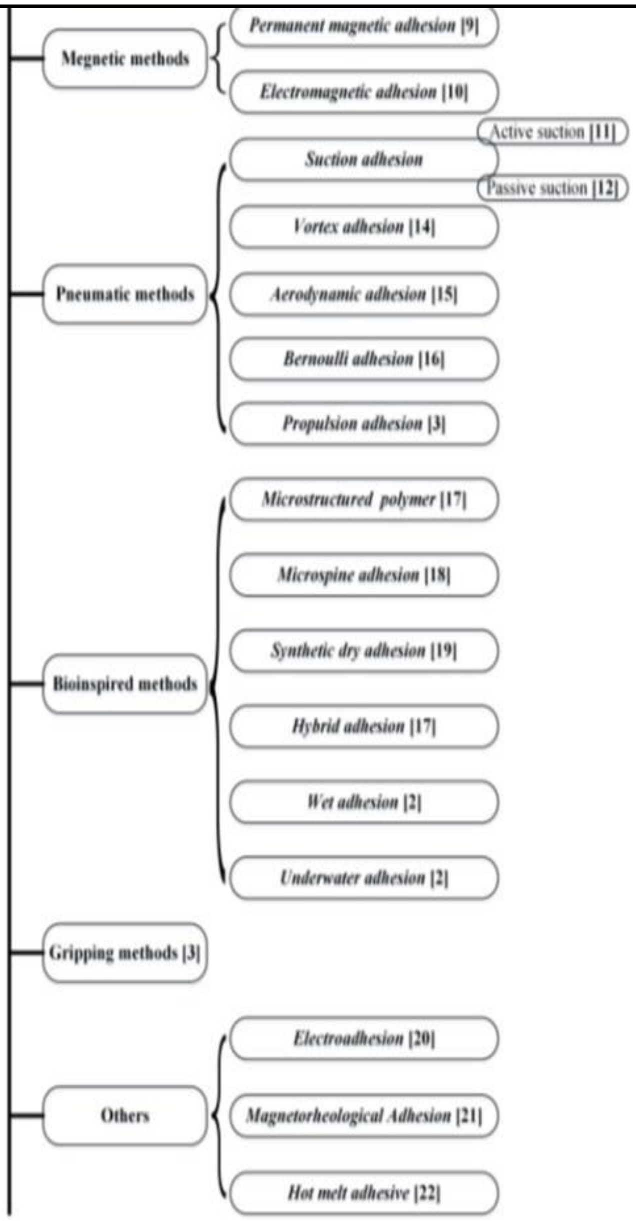


Fig. 1 Adopted adhesion methods in climbing robots Magnetic adhesion methods [9, 10] may offer fast and reliable mobility and large adhesion forces. However, they are only useful on ferromagnetic surfaces and not energy efficient. The suction-based adhesion methods comprise active suction methods [11] and passive suction methods [12]. Suction-based climbing robots may climb over surfaces with any material and strong attachment forces, but are only useful on relatively smooth and non-porous surfaces, cannot be used in space applications, noisy, bulky, and comparably high energy consumption, although several

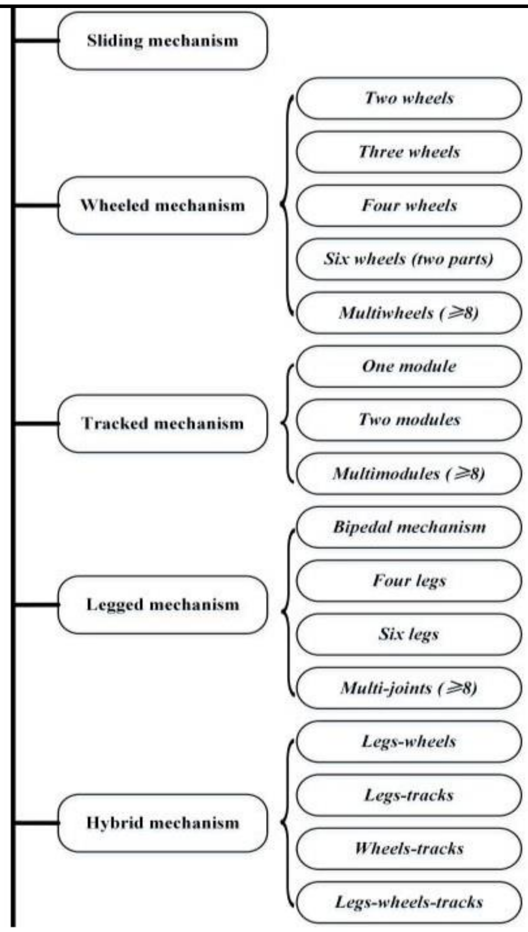
Improvements, such as a more efficient negative pressure generation mechanism [12] and a noise-less mechanism [13], have been achieved. Vortex adhesion [14], inspired by the tornado, is quieter and more efficient as it does not require sealing devices and aspirators to generate the vacuum. Although an improved version of vortex adhesion, known as aerodynamic attraction, has been proposed [15] to enhance the payload capability and overall mobility, they operate with an unavoidably loud noise, cannot be used in space applications and significant energy consumption still exist. Although Bernoulli-based adhesion, inspired by Bernoulli grippers, suffers from air stream noises and cannot be used in space applications, it has an edge over other methods in terms of high force/weight ratio and good adaptability to various surface conditions [16]. Propulsion-based climbing robots may climb various wall surfaces and are suitable for tasking in large areas with good mobility, but they make a loud noise during operation, have significant energy consumption (usually tens of watts), cannot be used in space applications and are difficult of control [3]. The micro-structured polymer based adhesion method [17] is sensitive to contaminate and dusts, making climbing robots using this mechanism only useful on smooth and clean surfaces However, their self-cleaning capability is not mature, making them suffer from contaminate and dusts. Also it is expensive and difficult to prototype robustly. A hybrid adhesion mechanism incorporates several mechanisms together, such as a combination of micro-spines and micro-structured polymer pads [17]. In this way, bio-inspired climbing robots can have greater adaptability to climb on various wall surfaces and conduct complicated wall transitions (such as vertical wall to ceiling transition). However, this method is not mature enough yet and may result in

relatively bulky structures. Snail-inspired wet adhesion is rarely used and underwater adhesion climbing robots [2] are specially used in water. They will not be reviewed in this paper. Gripping-based climbing robots have been prototyped to travel along 3D irregular environments and

rough surfaces, such as poles, pipes and bridges, beams and columns, wire meshes, natural environments and manmade structures [4]. However, they cannot be used on smooth surfaces. Although the adhesion forces generated per unit area by electro-adhesion is relatively weaker compared to other methods, and it may fail in high-moisture environments, electro-adhesion is a promising approach enabling robots to have several advantages, including being adaptable to various

wall surfaces, having simpler and lighter structures, being quiet and fast in locomotion and ultra-low energy consumption (usually microwatts) [20]. The magneto rheological fluids (MRFs) based adhesion method enables climbing robots to adapt to a wide range of surface conditions with relatively large clamping pressures [21]. However, the climbing robot adopting this mechanism cannot climb at the moment and some fluids may be left on wall substrates. Hot melt adhesive (HMA) based adhesion can achieve some of the highest adhesion forces (150 newton per square centimeter)

and has enabled the robot to have strong adaptability to any solid surfaces and unstructured terrains. However, they are low in speed, have large energy consumption, and usually leave traces behind [22]. With regard to the locomotion mechanisms, five major categoriessummarized in this work can be seen in Fig.2.



3 Proposed Conceptual Design Method

One of the best attempts to indicate the effect of project complexity or size may be the VDI model [25]. Since climbing robots are relatively complex systems and can be divided into several key subsystems aforementioned, a conceptual design selection method inspired by the VDI model is proposed and demonstrated in Fig. 3. It should be noted that this concept method is greatly subjected to user requirements, but is reasonable as any design should satisfy sufficiently with user
Requirements.

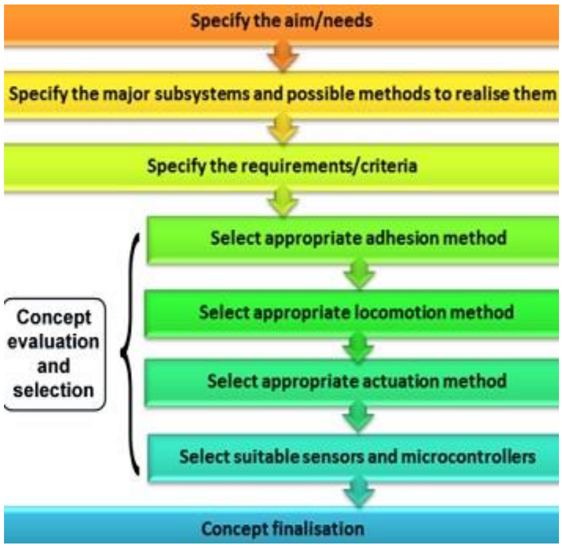


Fig.3

The proposed method starts with specifying the aim or needs to be satisfied as precisely as possible, before specifying the major subsystems and their possible solutions based on functional analysis
(Such as the functional tree method). The investigation of an adaptable and energetically autonomous climbing robot for indoor applications is the aim of on-going research in Loughborough University.

Acknowledgment

This paper introduces the developed climbing robot that Climbs a vertical wall with continuous motion using a vacuum system operated by a mechanical valve. The Linear climbing speed of the robot reaches 15m/min. It is a Self-contained robot in which vacuum pump and power supply are integrated. The mechanical system and climbing mechanism were described. By optimization experiment using Taguchi methodology to maximize vacuum pressure and minimize the fluctuation of vacuum pressure of suction pads, the control factors having influence on climbing performance have been optimized.

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