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Review Article

A Review on Various Methodologies for AC Duct Cleaning

Avesahemad SN Husainy[1], Soyab A Jamadar[2], Harshad A Deshmukh[2], Roshan M Kanwade[2], Manoj P Karanjkar[2], Vishal J Kesharwani[2]

[1]Assistant Professor, [2]Student, Department of Mechanical Engineering, Sharad Institute of Technology College of Engineering, Yadrav, Kolhapur, Maharashtra, India.
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I N F O

Corresponding Author:
Soyab A Jamadar, Department of Mechanical Engineering, Sharad Institute of Technology College of Engineering, Yadrav, Kolhapur, Maharashtra, India.
E-mail Id:
soyabjamadar665@gmail.com
Orcid Id:
https://orcid.org/0000-0002-4500-1838
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A B S T R A C T

Cleaning of the AC ducts is the need because it creates problems such as the bad indoor air quality which results in health issues and it also causes the large maintenance of the system. The uncleaned air ducts become home for fungi, dust and harmful microbial. The causes and effects of this thing are mentioned following. The AC ducts can be cleaned through various methodologies i.e. conventional and by using robots. In the conventional system, there is manual cleaning by using some equipment. Cleaning the ducts by using robots would be a good solution for this. Different types of robot systems i.e. crawling robot, articulated robot and inspection robot are deployed for the application. There are different types of robots and their equipment according to size and type of duct. The cleaning of rectangular shape ducts is quite difficult than others. Finally, it results that cleaning ducts is the most important thing and using robots is the best methodology for it.

Keywords: AC Duct, Robot, Indoor Air Quality, Sanitation, Cleaning

Nomenclature

HVAC: Heat Ventilation and Air Conditioning
IAQ: Indoor Air Quality
PID: proportional–integral–derivative
CAD: Computer-Aided Drawing
HEPA: High-Efficiency Particulate Air

Introduction

IAQ is one of the most serious environmental concerns along with lead poisoning and hazardous wastes.[1] In metro cities, indoor air quality has been estimated to be five times poorer than the external air quality.[1, 2, 3] Possible causes of indoor air quality concerns include installation and design of the cooling and heating equipment, building design and construction, number of occupants, activities of the occupants, airborne pollutants and human physiological factors.[4, 5] HVAC units can turn into the sources of mould, fungi, and other different microbial contaminants. Dirt, dust, and fibrous constituents can gather inside the ductwork. The best way of retaining the good indoor air quality of residential buildings is to clean its HVAC system and ductwork regularly.[6] Air conditioners are machines that lower the temperature, extract humidity to make a comfortable atmosphere, and distribute it to all parts of the building to provide more human relaxation. These days its demand is increasing exponentially; the distribution methodologies have also become diversified leading to the whole system. These distribution channels need inspection at a regular period to preserve its high efficiency and to minimize the losses of consequences produced by the air conditioners.[7] The HVAC system in a building contributes significantly to the indoor air quality and additionally, it

performs an important role in maintaining thermal comfort in the interior environment of a building. There is the contamination of the HVAC system with dust under the normal operating conditions and there is proof of that. This dust avails a reservoir for the microbes to increase rapidly.[8] AC ducts are at the position of the structure where we can't clean it manually. We need to use a vacuum or cleaning robot to perform the task. If we do not clean the ducts then it leads to serious problems in the sense of air quality, health issues and also it will affect the maintenance of the system. We require a good and feasible solution to clean the ducts. Also, it is a requirement here that we have to sanitize the ducts as there is the production of fungi, microbes due to the collection of dust. Hence there should be the integration of the sanitation process with the cleaning of ducts. The occupants using the HVAC system may get exposed to the biologic, physic, and chemical contaminants due to the absence of maintenance and cleaning of the duct system. These systems can make higher exposure of these agents on the personnel involved in the maintenance and cleaning of these systems which can make a threat to the respiratory health of respective personnel. Figures 1 and 2, illustrate common situations found in these types of systems.[9]

Figure 1.Air duct accumulated with dust.[9]

Figure 2.Presence of insects in the air ducts.[9]

Concern for Indoor Air Quality

Studies abroad have proven that the HVAC system involves 70% or greater of all IAQ problems and that most are due to insufficient care and maintenance of the system. The air ducts, which are the "lungs" of a building, can collect deposits of construction dirt, dust, cigarette tar, smoke, insects, and different airborne contaminants. Dirty air ducts can additionally emerge as an ideal breeding ground for mould spores, mildew, pollen, bacterial colonies, and different health-threatening microorganisms. The occupants are exposed to all this dirt as they constantly breathe this air from the duct as well as growths of fungus and mould inside the coils and drain pans of the air handling units.[10]

HVAC Sanitation Methods

Contact Vacuum Method: This method involves cleaning of interior duct surfaces by the use of vacuum. Exit openings and outlets are used to gain access to vacuum. The cleaner head of the vacuum machine is introduced into the duct at the opening furthest upstream. Vacuuming proceeds downstream slowly enough to enable the vacuum to fetch all dirt and dust particles. The vacuum device is withdrawn from the duct and inserted through the next opening when observations indicate the section of the duct has been cleaned sufficiently, this process is repeated for the next duct openings.

Air Sweep Method: In this method, a vacuum collection device is connected to the downstream through an opening and section being cleaned. Compressed air, with 160 and 200 psi air pressure, is inserted inside the duct by a hose terminating in a 'skipper' nozzle. This nozzle is manufactured in such a way so that the compressed air propels it simultaneously inside the duct. This removes dirt and debris which, converts into airborne, are sucked out downstream through the duct and out of the system by the vacuum collection device.

Rotary Brushing Method: This technique includes the use of a vacuum collection gadget linked together to the downstream end of the section being cleaned through an opening. A negative air device is used on sections of the ductwork which is HEPA equipped. A rotary brush is inserted into the ductwork, and simultaneously, it is rotated either mechanically or manually to remove dust and debris.[1]

Literature Review Y. Tanise et.al [11] in their study presented the development of the robot which cleans the duct by using the crawling motion. There are cleaning units fitted on the crawling robot which is used to clean the ducts as the robot moves forward. The robot is designed for 75 mm of diameter duct and 70 mm curvature radius. The robot moves in the duct-like the motion of the earthworm. The robot gives 99% of the cleaning performance. Figures 3 and 4 show the structure of the crawling motion robot.

Figure 3.The appearance of the robot

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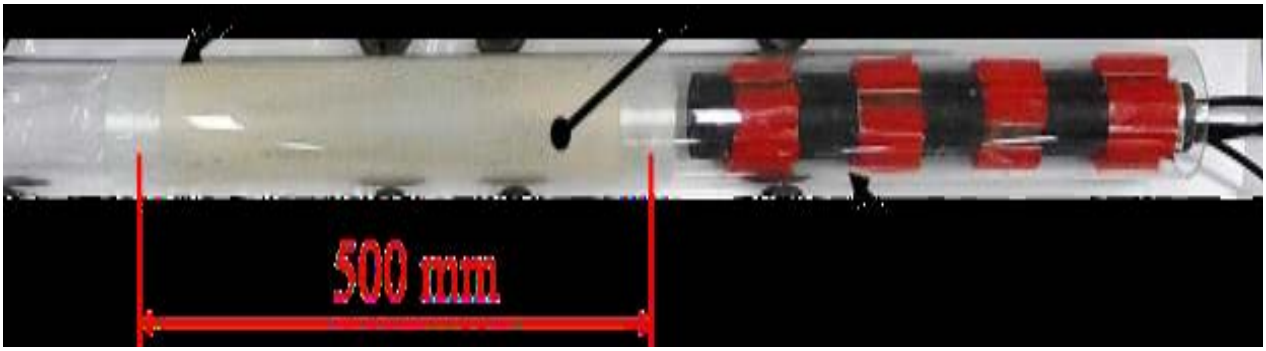

Figure 4. Experimental arrangement for duct cleaning

Marina Mijanovic Markus et. al [12] presented in their study about the conceptual arrangement of the robot for cleaning the air duct. The main targets are to clean the ducts by a cleaning brush joined to the robot, and ducts inspection by using a camera, which will provide the good conditioned air supply to the occupants. It is tough to develop a universal robot that can clean all of the ducts since there are many different shapes and sizes. There are numerous robots designed for cleaning and inspection of the ventilation system, but most of them have issues with different types of geometrical shapes ventilation channels come in. This robot can clean rectangular, as well as circular ventilation ducts. The wheels of the robot are attached to the duct accurately. This is done by fitted tyres with a huge friction coefficient. Brushes can be mounted on the robot, and they can move vertically utilizing linear actuator with a stroke length of 50 mm and power of 36 W.

In additional cleaning equipment, there are three types of brushes also:

- Brush with Pneumatic Whips
- Rotational Brush with Round Cross Section
- Brush with a rectangular cross-section

To clean different types of ventilation ducts and perform different kinds of cleaning there are different types of brushes to the robot. We have to choose the correct brush for the job depending on the state and shape of the ventilation duct. The brush can also be situated in a horizontal position so that it not only cleans the floor and roof of the duct but also the side walls. Figure 5 shows a robot designed to clean the duct.

Wootae Jeong et.al [13] revealed in their study that compelling air-duct-cleaning methods have been studied to enhance the quality of the ventilation duct network broadly utilized in industries and buildings. Duct cleaning robots and devices to enhance their operability in the dark and limited space inside the duct using the programmed devices. Hence there are intelligent controllers, sensors, skid-steering capacities, and brushing-arm mechanisms for different ventilation-duct-cleaning robots that have been created. In specific, mechanical brushing methods

Figure 5.Small inspection robot and cleaning robot

have been efficiently connected for the evacuation of dust collected interior air-duct surfaces with linkage-arm-based mechanical brushes. There interactive forces between the brush and the target surface of the inner duct during the cleaning process by the rotating brush of the cleaning arm. In the dynamic demonstrating of the mobile robot, the duct surface induces wheel slippage in the lateral direction due to the contact forces between the rotating brushes so it requires a skid-steering control mechanism.

Therefore, it is essential to build a dynamic model of the system including unknown factors such as nonlinear deformation of the filaments of the brush and unknown friction coefficients at each contacting point of the cleaning mechanism to achieve compelling control of the duct-cleaning robot. Besides, the tangential loads of the mobile robot and the reciprocating motion of the upper-arm brush result in an imbalance of the centre of mass of the robot. The duct-cleaning procedure is done by rolling brushes on the moving robot touching the inside duct surfaces at a constant velocity. The mobile robot should be located on the reference trajectory, which is composed of points necessary for the brush to keep the pressure on the inner side of the duct. The theory of perfect speed tracking needs a complete dynamic model without consideration of external-disturbance affects in velocity control, unknown

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dealing forces in the brushing mechanism can create the control system unbalanced by transmitting all force to wheels and the base of the duct.

Irtishad Ahmad et.al [6] in their study focused on the relationship between the HVAC duct cleaning procedures and the betterment in indoor air quality. The study was carried out in the form of inspection done in two special houses with the same build of ducts and similar floor plans. The survey consisted of measuring the indoor air quality using various techniques in three phases i.e. before during and after the cleaning process. The study was carried out for different pollutants like aerosols, fungi, dust present in indoor air. The study concluded that the air sweep method works best for the reduction of pollutants from the ducts.

Alexey Bulgakov et.al [14] explained that the work is straight forward and does not require sophisticated manipulations hence articulated robot is employed. To control the mobile robot there are few ways. In this paper, most time again we noticed the application of PID regulator because of its simple structure and functionality. On the other hand, to minimize nonlinear effects such as friction and saturation of the DC motor the development in artificial intelligence, adaptive control is used. Figure 6 describes the conceptualization robot.

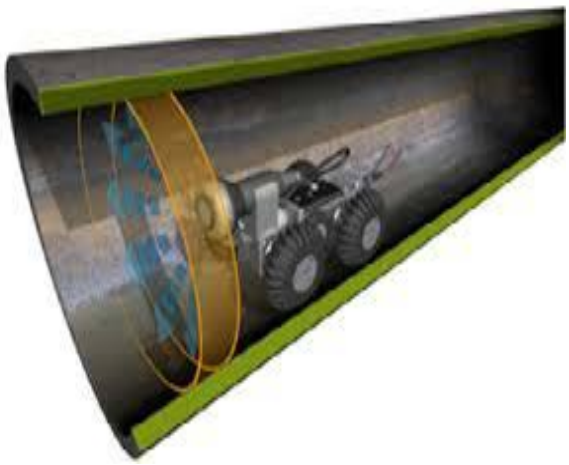

Figure 6.Autonomous/ Tele robotic concept design for AC duct cleaning

Filipe Santos et. al [15] presented a design of a rover in which after further research, the usage of a tread was selected but at first, it was projected to use wheels as a means of movement. The telecasting of the images to the operator was necessary so that the rover could move skillfully or carefully inside the air ducts to the idea to work. A wireless interface connected the robot and the operator to overcome this issue. The sanitization and maintenance of the air-conditioning system are possible because of brushing the duct, bactericide, and fungicide applications etc. are carried out. Figure 7 shows the movement of the rover.

Figure 7.Tread driven movement in air duct

Conclusion

In this review paper, the various types of AC duct cleaning methodologies are mentioned. AC duct cleaning has become a need as the serious and adverse effects of not cleaning it are concerned. The review consists of all the different types of robots and methodologies which are used to clean the AC ducts. The ducts may be cleaned by the conventional but there are adverse effects on the individual working on it. Hence there should be the use of proposed robotic systems for cleaning it. We can use different types of brushes and robots concerning the size and type of robot. From research reviews, we found that we can add so many advanced techniques and features to optimize the cleaning process. After going through all these research reviews it can be concluded that duct cleaning is an essential factor and we can achieve it by using various types of robots.

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