Disseminating mechatronics research results via science exhibitions

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Abstract

Introduction

Engineering skills shortages in the UK is a problem that has been identified by business and industrialists [i,ii] with four out of five manufacturers experiencing recruitment difficulties because of lack of skilled graduates though there is a paradox with more engineering graduates likely to be unemployed [iii] probably because they are seeking specific careers to fit their training. However, the main problem is that too few engineers have been trained over the past 20 years with young people at age 10 or 12 perceiving science and mathematics to be too difficult and opting for easier subjects. It takes a decade or more to produce a professional engineer. Therefore, if this age group does not choose engineering as a career then shortages are inevitable.

The Royal Society and the Royal Academy of Engineering in the UK, amongst others, have been actively promoting Science, Technology, Engineering and Mathematics (STEM) by showing young people and their parents its practical application and role in developing innovative products and processes. The aim is to excite young people, particularly girls aged 11-14 years, to pursue careers in STEM with inspirational messages about engineering and diverse role models.

This paper reports our role in taking this message to young people and the lay public by practically demonstrating the application of mechatronics engineering to develop wall climbing and swimming mobile robots for a wide range of industrial inspection tasks. These robots have been developed to provide access to very large safety critical infrastructure without having to erect scaffolding or to make expensive and time consuming preparation to gain access to a test site.

The selection of an exhibit for the Royal Society's summer science exhibition is a competitive process with only about twenty exhibits selected from all UK universities and national science laboratories. Our exhibit was selected for the 2010 summer science exhibition to celebrate the 350th anniversary of the Royal Society. The exhibit was titled "Robot Detectives: Sherlock Holmes meets Spiderman". The following year, 2011, the exhibit was displayed in the Royal Academy of Engineering zone at the "Big Bang" event in the London Excel Centre.

Robot Detectives: Sherlock Holmes meets Spiderman

The idea was to develop an interactive display where visitors could remotely control a wall climbing robot to find a hidden defect in a steel plate using ultrasound NDT and understand the technology and science used for adhesion of the robot to a surface and the two most often used techniques for non-destructive testing i.e. ultrasound and eddy currents. This exhibit would show the combined use of the fundamental disciplines of mechatronics i.e. engineering the mechanics of the climbing robot, developing the servomechanisms to actuate the robot, developing control systems to remotely operate the robot, and developing the sensor systems and intelligence to find hidden defects in steel structures (e.g. corrosion and cracks). Since our robots use different types of adhesion techniques to climb on ferrous or non-ferrous surfaces, it was considered important to show our permanent magnet adhesion robots and our Vortex climbing robots that generate negative pressures to climb on brick, glass and concrete structures. We have also developed pipe climbing robots that can climb inside or outside a pipe. Therefore we required the means to show these robots.

From the outset it was decided to involve our undergraduate students on the Design courses to generate ideas and designs for the exhibit. They were divided into teams and given a brief to design the exhibition stand to showcase three wall climbing and two pipe climbing robots. They were required to draft text messages and their wording to relay ideas to visitors who will have a short time to grasp the message. In addition, the exhibit was required to show the science required to adhere the robots to a ferrous wall by concentrating magnetic flux in the right direction. This was done by developing three levitrons using only permanent magnets and no control devices. One of the magnetic levitation exhibits floated a spinning magnet over a ring magnet by concentrating magnetic flux using a concentric concentrator. The other two levitated a system of magnets to show how friction effects could be minimized in wind turbines. The ultrasound technique of non destructive testing was explained by using a 5MHz ultrasound probe and a KrautKrammer flaw detector. The Eddy current technique was explained by building a "time machine" which unexpectedly slowed the fall of a disc magnet through a vertical copper tube and by setting a puzzle where a visitor had to identify six covered blocks of different materials using a small permanent magnet.

Figure. Wireless wall climbing robot inspects welds with phased array ultrasound.

Figure. The Strongman robot carries a payload of up to 50kg.

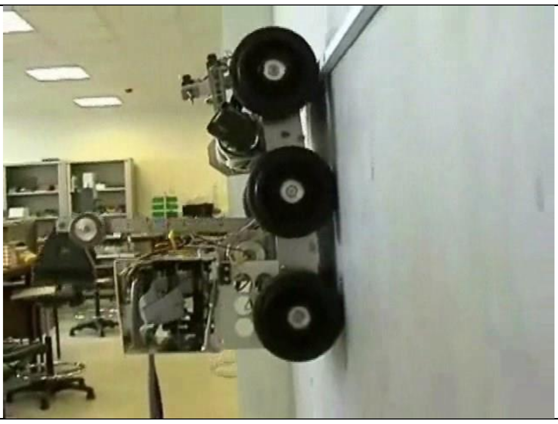

Figure. Surface changing autonomous robot avoids obstacles and climbs over small ridges.

Figure. Underwater robot to inspect tank floors for underside corrosion and climb on tank walls.

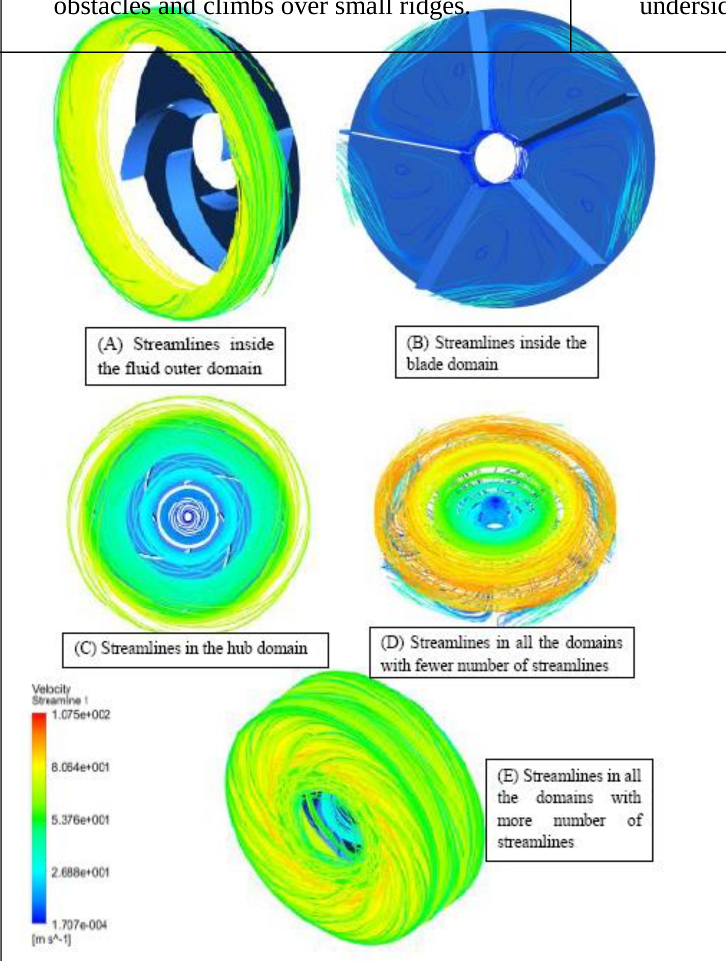

Figure 3-10 isometric view to show the streamlines inside the vortex chamber in the blades

Figure. Pipe climbing robot at the Royal Society exhibition

Figure. The robot detectives exhibit at convocation of the Fellows of the Royal Society, Royal Festival Hall

Figure. The Robot Detectives exhibit in the Royal Academy Of engineering Zone.

Figure. View to show climbing robots, pipe climbing robots and Ultrasound NDT.

Figure. School pupils visiting the Big Bang event


Figure. School children interacting with the magnetic levitation exhibits.


Figure. Internal pipe climbing robot

Figure. The BBC filming the radio controlled Vortex robot

Figure. Submersible robot controls depth with active buoyancy and travels on tank floor using wheels to test for underside corrosion

Figure. Underwater robot climbs on pressure vessel walls to test shell welds.

Figure. The Vortex robot with vision system climbing on glass surface

Figure. The Vortex robot.

Motion of a magnet induces eddy currents in a material which tends to resist the motion. Using this fact, the "Time machine" is demonstrated by asking a visitor to drop a disc magnet in a long vertical plastic pipe and catch it at the other end with the same hand. This becomes an exercise in fast reactions. After the visitor is able to catch the dropping magnet he/she is challenged to do it again but this time with a much shorter copper pipe. The expectation is that it will emerge in a shorter time and hence quicker reactions will be required. Much to their surprise the magnet emerges in a much longer time. The falling magnet induces eddy currents in the pipe which oppose motion and slow down the fall.

[i] Brian Groom, Lack of engineers threatens UK recovery, say industrialists, Financial Times, www.ft.com (16th March 2014)
[ii] John Perkins, Review of Engineering Skills, Department of Business Innovation and Skills, https://www.gov.uk/government/uploads/system
[iii] Stephen Harris, The skills shortage paradox,The Engineer, http://www.theengineer.co.uk/in-depth/analysis/the-skills-shortage-paradox/1017639.article, 6th December 2013

Figure. Magnetic flux concentration of a ring magnet to levitate a spinning disc magnet

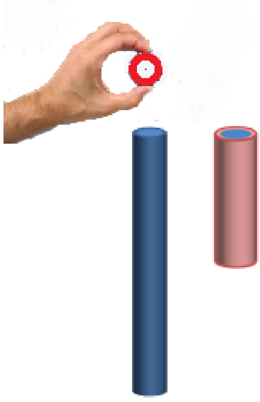

Figure. The "Time Machine" to demonstrate generation of eddy currents by a falling magnet

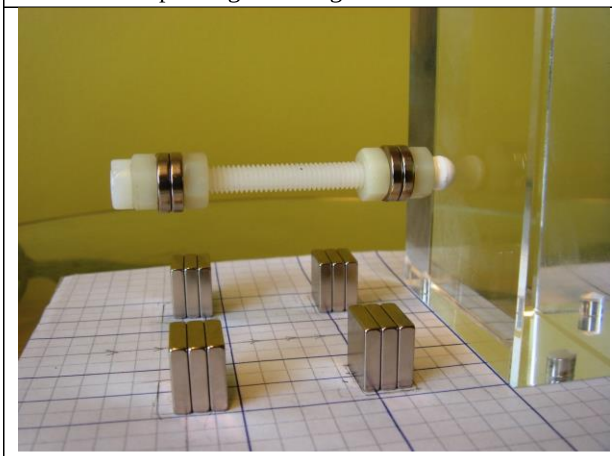

Figure. Quasi levitron with a system of permanent magnets

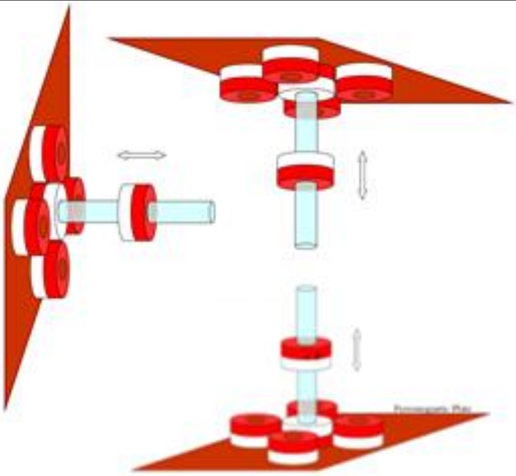

Figure . Stable equilibrium of a system of permanent magnets