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Acceleration Components Measurements in Vertical Traversing Elevators using MEMs and Wireless Signals

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Abstract

Twelve lifts in a University and adjoint campus buildings, all traversing vertically 6-7 floors are taken up for study here. From the start to stop continuous movement is observed and their accelerations in mutually perpendicular directions are measured. They are sensed by MEMS accelerometers and the signals are picked up by an Arduino platform. This Arduino mother board transmits wireless signals that can be picked up by any computer or laptop or a mobile phone. The trends of these signals indicate smooth, highly jerky, sideward movements dominating etc., Subjective feeling of maintenance crew can help in decision making related to maintenance activity. Better than that will be the measurement based decision like the one shown in this work. A combination can lead to still better decisions where predictive maintenance heuristic taken up here can be handy for crew. A correlation is discussed in this work.

MEMS accelerometer, connection to IoT mother board, compact packaging are done suitably to give records for the accelerations. Being cost effective and records leading to decisions helping maintenance personnel are the advantages of this method. Correlations can be established if needed with lab equipment.

Keywords: vertical elevators in buildings, accelerations measured through MEMS, Records displayed indicating trends, maintenance decisions, wireless signals deployed through IoT methodology, Correlations with other signals.

INTRODUCTION

MEMS technology is integration of silicon based microelectronics with micromachining technology leading to sensors highly useful in mechanical sciences and engineering. These smart sensors have created revolutionary solutions to the problems arising in multiple fields, specialisations all resulting in emerging markets. MEMS refer to the systems that have sensors, actuators, circuits, control units, micro-electronics and mechanical systems incorporated in a chip which is of micro scale. With the advancement in the technology, integrating multi chips produced a unique MEMS chip which is high in terms of performance and accuracy.

Pressure sensors, Accelerometers (inertial sensors), micro-mirrors, gear trains, Miniature robots, Analysers are just a few of MEMS devices to mention for various applications. Accelerometer is a dynamic sensor which has wide range of sensing capability. These accelerometers are selected based on different characteristics such as range, sensitivity, output, application, number of axes, bandwidth, amplitude stability, mass, dynamic range etc., Accelerometer sensors work on various principles such as piezoelectric effect, Hall Effect, null tolerance, servo force balance, strain gauge of which the most commonly used sensors work on piezoelectric effect.

These MEMs sensors dominate the market of smartphones which is a combination of IoT technology and MEMs. The applications which are possible using these MEMs sensors combined with IoT technology are too many and unimaginable. Functions like health monitoring, remote controlling, code scanning, movement sensing, GPS tracking etc., are all possible in a smartphone because of the accelerometer sensors, photo sensors, proximity sensors, gyroscopes which are installed in it through IoT. This IoT technology is now emerging in industrial market, namely IIoT, to make operation, monitoring and maintenance of systems conceivable through automation and computers. This IIoT (Industrial IoT) applications include lot of opportunities like building automation, asset tracking, machine monitoring, M2M revolution, seismic monitoring, smart factories, smart cities and robotics. These various opportunities will expand the role, need and also development of MEMS sensors in IIoT.

LITERATURE REVIEW

Sensors and related technology have been influencing the world of measurement and analysis since decades. The science of materials used in sensor technology is growing exponentially and continuously. Of all those sensors being used for different purposes, accelerometer sensors have made significant strides in vibration analysis and acceleration measurement. The size, shape and geometry of MEMs (NEMs too!) have made them even more attractive and suitable for ever increasing applications. They are also considered extraordinary and unique in the present day context. Use of these MEMs sensors made non-contact measurement and three axes related analysis conceivable and implementable. [1]

MEMs accelerometers find increasing science and engineering applications in a large number of cases like handling equipment, telecommunications, medical, mining etc., The applications are ranging from pressure measurement to detection of motion of various parts in both machines and human body. [2] The rapidly developing advancements, Growing interest in measurement procedures particularly wireless/remote/contactless types have their advantages. They are simple, easy to obtain, accurate, light weight, occupy less space (very low volume), configurable anywhere, reliable and interdisciplinary-friendly. Hence they are also attracting many experts all over.

Recent advancements permit integrating sensors, hardware ,(wireless / remote) transmission modules all in single unit carried by individuals amid regular day to day existence to screen parameters like activity, health condition, and even environmental properties surrounding them. [3] Other advancements like acceleration detecting gloves, utilized as a remote wearable mouse guiding gadget, a remote wearable console, hand movement and signal detecting devices, virtual melodic instruments, and PC gaming are in boom. [4]

Every organization or industry includes several electromechanical systems which need maintenance for proper working for different environs in their life cycle. One of the most commonly used assemblage or systems is an elevator system which consists of many rotating and mobile parts that needs occasional support for sheltered and long run. [5] MEMs accelerometers are attaining significance in condition monitoring of different mechanical equipment like elevators. [6] Elevator system is a combination of moving and rotating parts, which in time might be subjected to wear and tear at every use, the failure of the system resulting at some indefinite point of time. Various types' components like ropes, guideways, may be gears sometimes, motors and their controls, sensors, actuators are some crucial parts may show up one-shot failure when they are not monitored. If not exact condition monitoring observation by the maintenance

personnel that an elevator is running with ' jerks' or it is having lateral vibrations felt by the users are common in routine practices. A smooth and safe running of elevators indicates the quality of maintenance. No matter what the cause is too much or excessive changes in accelerations ("jerks) are unwanted and should be done away with through maintenance activity.

PROBLEM STATEMENT & METHODOLOGY

Measurement of Acceleration components for Vertical Traversing Elevators is important for their safety and efficient working. The long and continuous usage of the elevators in such conditions may lead to only breakdown maintenance that is costly .In general break-down maintenance is substituted well by periodic-maintenance all over.

Already existing devices like portable vibration meter, acceleration sensor etc., give extreme readings or ranges. Recording devices are costlier for noting the acceleration changes and patterns that help better in the case of elevators. But through the usage of MEMS and other wireless devices like Tri-axial accelerometer, the measurement of DVAJ (Displacement, Velocity, Acceleration, Jerk) standards accuracy increases significantly. Using the Arduino, Accelerometer and a Bluetooth module, the signals obtained are transmitted to the mobile phone through an App known as ‘Bluetooth Graphics’.

In this work, both measurement and inspection of acceleration components for the vertical traversing elevators is aimed through a compact packaging of the above mentioned components. This compact packaged device is placed inside different elevators present in the area of interest. The device can be held in hand too by any maintenance crew. The main idea is to sense the changes in the acceleration components and also sudden jerks during the traversing. For this, various Elevators in the University are tested by placing the compact packaged device on the floor of the vertical traversing elevator. The output obtained from the accelerometer is generally a voltage signal so through appropriate programming of the Arduino, the voltage obtained is converted into the required acceleration value. Based on the changes in the acceleration values, different graphs are plotted where jerks in any direction can be sensed and seen graphically if plotted.

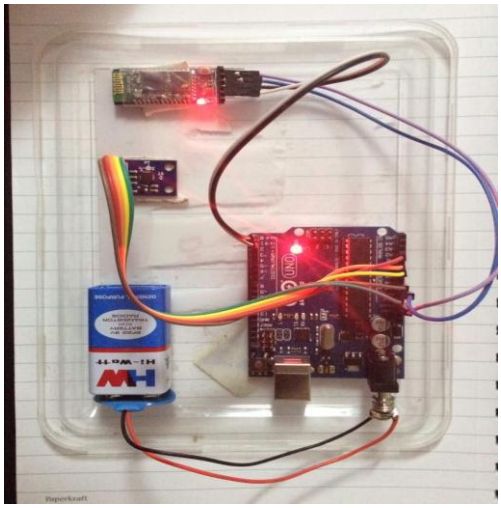


Fig (a): Compact packaging

Fig (b): Equipment to be placed inside elevator

An Arduino UNO Micro-controller board which is simple and generally used for the communication among the devices. It can be programmed quite easily which is commonly used by the people for different applications. The following are its specifications: AtMega 328p, 9V of operating voltage, length of 68.6 mm, width of 53.4 mm and a weight of 25g. A USB cable is provided to connect arduino to PC or laptop for the programming. [7]

Fig(c): Arduino UNO

An ADXL-335 Accelerometer by piezo-electric effect senses the slightest change in the acceleration where the change in the voltage is observed. The output obtained can be digital or even analog. Low power Tri-Axial +/- 3g with 4mm x 4 mm x 1.45 mm of dimensions is used in this work.

Fig (d): Accelerometer sensor view

Fig (e): Accelerometer connections view

Bluetooth module is a device connected to the Arduino which can receive the information from the Arduino Board and send it to the PC or a laptop or a cell phone through either software or an app installed in the cell phone. The Bluetooth module of low power around 3.3V, frequency of 2.4-2.524 GHz with an in-built antenna is used in this work. [8] Its dimensions are 30mm x 14 mm x 2.2 mm.

Fig (f): Bluetooth device

Fig (g): Bluetooth module

EXPERIMENTS CONDUCTED & RESULTS:

The compact packaged MEMS equipment is mounted on the various elevators in the University and campus during the normal duration of working hours. The analysis is carried out for the vertical traversing elevators. The elevators normally run smoothly indicating no jerks that are felt subjectively by the users. Various plots are obtained for all 12 elevators under study. The plots obtained are periodical in nature for most of the elevators. Jerk is observable for a few of them which is of course clearly identified in the records.

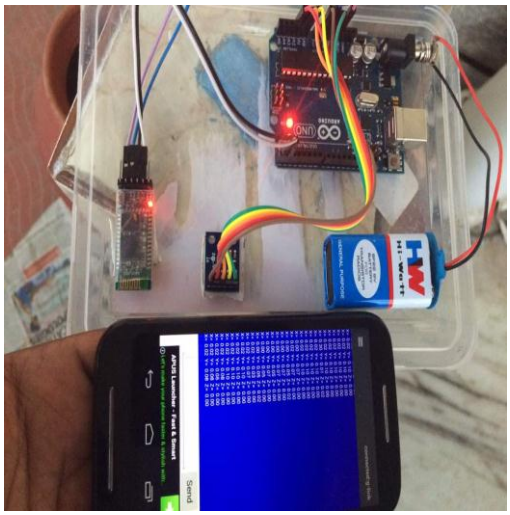
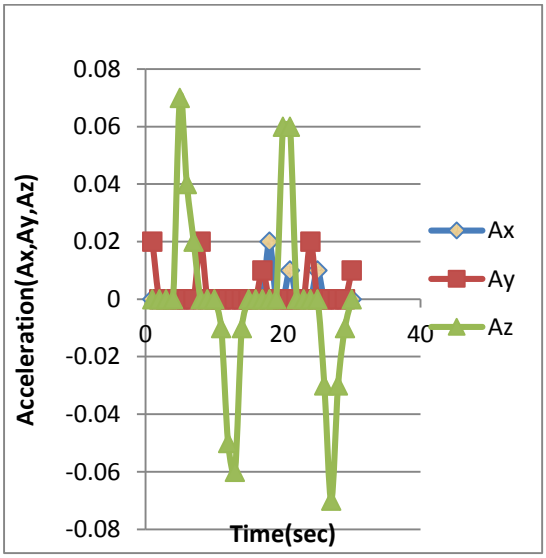


Fig (h): Complete MEMS equipment **Fig (i):** Equipment mounted on elevator floor

Following are the graphs plotted for the elevators in the university at different locations. The most troublesome and the smoothest elevators are identified with the help of MEMS equipment. They tally with the opinion and experience of users and supported by maintenance crew. The grading user gives and the measured ones matching is no wonder. But one measurement matching with all the accumulated past experience is the real promise in the methodology used in this work. Interviews with maintenance crew also confirm the findings.



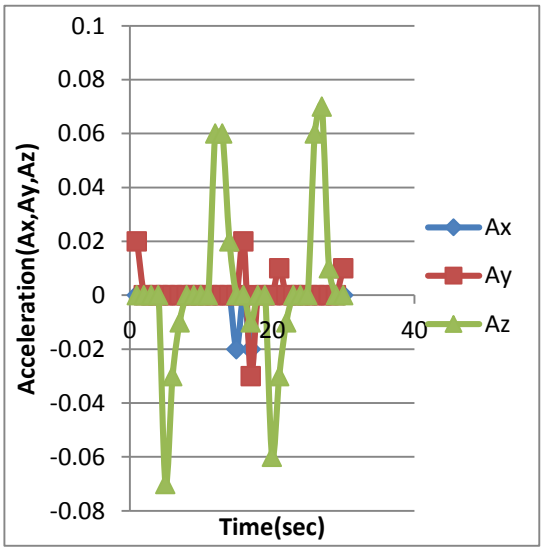


Fig (l): C-block odd lift-1 **Fig (m):** C-block odd lift-2

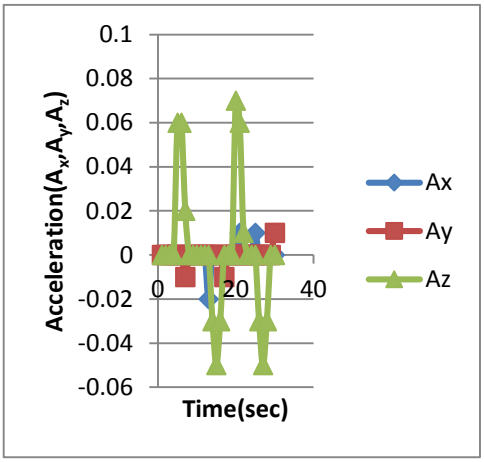


Fig (n): C-block Even lift-1

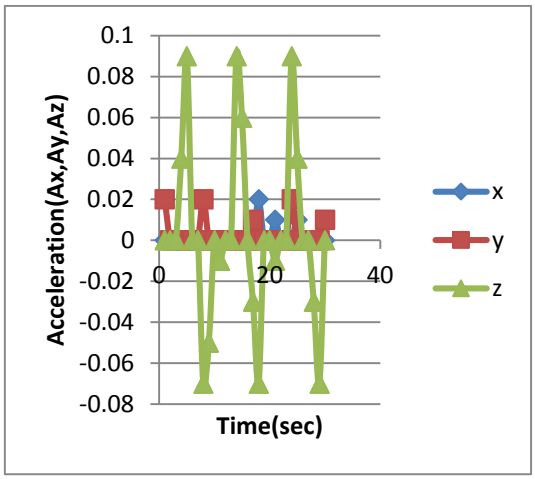


Fig (o): Fed block Boys

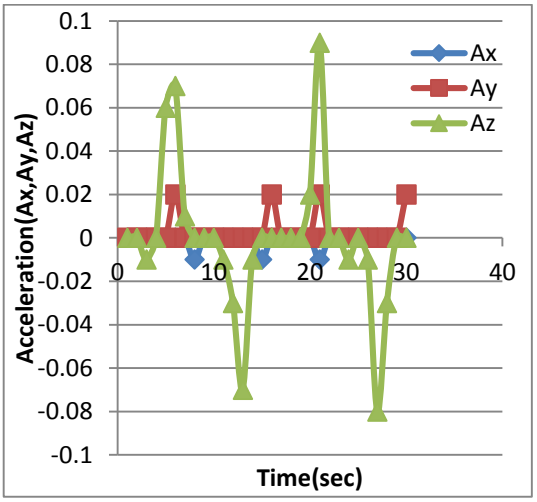


Fig (p): Fed Block Girls lift

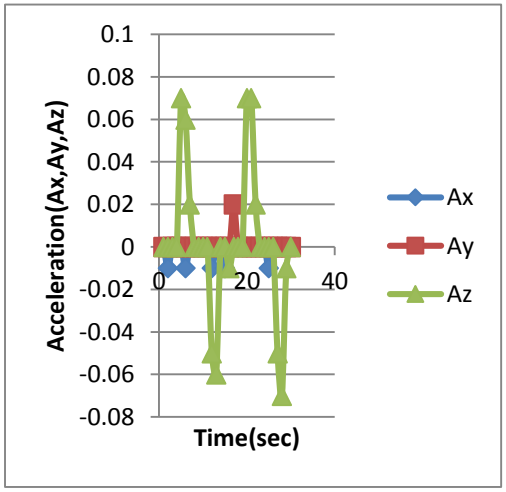


Fig (q): Administration block

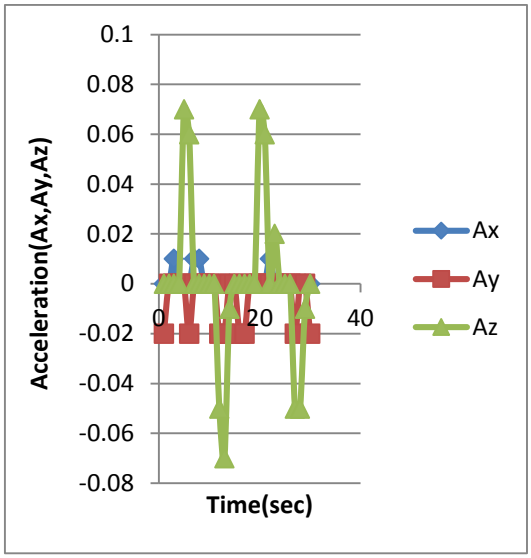


Fig (r) : Staff quarters right lift

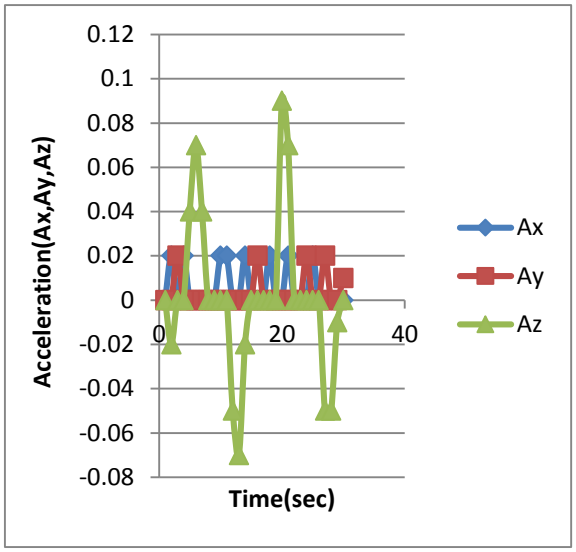


Fig (s): Staff quarters left elevator

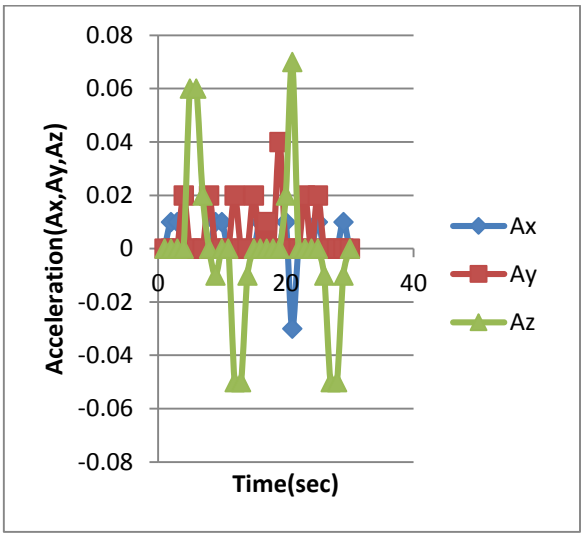


Fig (t): Library block right side elevator

CONCLUSIONS

MEMS Output signals can be made wireless and hence internet friendly. Any IoT platform and blue tooth combination can bring the signal profile to the screen of P.C, lap-top, mobile etc., Signals being relative for the pattern recognition needs, they do not require time to time calibration. Otherwise, the diurnal temperature variations (27-

44 degrees Celsius) in the present case do impose calibration on MEMS based device. Elevator smoothness or roughness in traverse can be judged from the acceleration pattern that decide the need or otherwise of attention and related maintenance action. Most frequent maintenance- needed to least maintenance needed elevators are easily identified straight away that tally with user's reports. Lateral movements need not be always indication of incipient malady whereas 'jerky' movements in vertical direction can be quite often so.

A correlation with either motor current or other vibration signatures as well as a full FFT based analysis shall certainly reveal the complete truth. But, that is not included in the present study as it is not the objective.

A cost effective, no-calibration needed, highly user friendly MEMS & IoT based hand held device is the sole objective of this work which is achieved.

Integration to Velocity, Displacement and differentiation to jerk are also under investigation.

Elevator traverse Smoothness as well as vertical upward movements without jerks indicate acceleration changes that are different component wise as well as individual variations of accelerations in the direction vertical travel. In a previous work of the authors calibration of the MEMS is discussed which was done with a pendulum. [1]

FUTURE SCOPE

MEMS connected to any IoT platform and blue tooth can be taken as the immediate large gain of Mechanical Sciences and moving part studies no matter where one comes across. Now that there are MEMS with built in transmitters available there is immense scope. Broadly coming under the class M2M Machine to Machine it is possible to develop high accuracy, compact, easy to build and cost effective devices of this type. Educational experiments in Mechanical Sciences can be built invariably needing all the said components. A more clearly visible Coriolis acceleration in action, C.F forces, Tangential accelerations, resultants will all be clearly appreciated by the future generations in a better manner. MEMS having built-in wireless as well as those assisted by IoT platforms have immense scope in several applications and education.

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