A STUDY ON GROUND VIBRATIONS INDUCED BY METRO TRAIN MOVEMENT

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Abstract: *Nanotechnology deals with particles and system with dimensions of approximately 1 to 100 nanometers. The environment factors like ground vibration, temperature, humidity, acoustics, air velocity, Electro Magnetic Interference, Illumination and cleanliness will limit the performance of equipments used in nano manufacturing. Among all the environmental factors, ground vibration plays a major role in limiting the performance of the equipment. Some aspects of nanomanufacturing facilities like nanofabrication, nanometrology requires extremely stable environment with very stringent limits of ground vibration. This paper is focused on the study of vibrations induced by metro train movement. The study reveals that, the vibration induced by metro train is exceeding the limits as per the standard set by the National Institute of Standards and Technology (NIST).*

Keywords: *Vibration, Rail, Nano Metrology, Nanotechnology, Nanomanufacturing*

1. INTRODUCTION

Nanotechnology deals with particles and system with dimensions of approximately 1 to 100 nanometers. Nanomanufacturing involves scaled-up and cost-effective manufacturing of nanoscale materials, structures, devices, and systems.

In more simple terms, nanomanufacturing leads to the production of improved materials and new products. There are two basic approaches to nanomanufacturing, either top-down or bottom-up. Top-down fabrication reduces large pieces of materials all the way down to the nanoscale. This approach requires larger amounts of materials and can lead to waste of material. The bottom-up approach to nanomanufacturing creates products by building them up from atomic- and molecular-scale components. Novel properties emerge in biological, chemical, and physical systems, at dimensions in the range of approximately 1 to 100 nanometers.

The research equipment used by the nanotechnology research and manufacturing community is, in most of the cases, extremely sensitive to the environment in which it operates. Environmental factors like vibrations induced by rail traffic can limit the performance of the nanotechnology research equipments. Environmental ground vibrations can transmit to the equipment via its support structures. It is important to consider location of the building that will house nanotechnology equipments. If the existing environmental ground vibration exceeds the limits, in spite of selecting the best location, the building or equipment should be isolated from the vibration environment.

The equipments used in nanotechnology applications such as Transmission Electron Microscope, Atomic Force Microscope, Dual Beam System, Gauge Block Interferometer, Intelligent Ultra Precision Turning Machine and Nano Indenter are extremely sensitive to the ground vibration imission.

The degree of sensitivity of nanotechnology research equipments may be evaluated by comparison with more familiar generic vibration amplitudes. If the existing ground vibration level exceeds the generic vibration criterion for nanotechnology applications, the ground vibration has to be isolated at the source [1].

The vibration criteria or vibration analysis can be addressed by: (1) the analytical domain to be used for vibration data representation (time domain vs. frequency domain); (2) the metric to be used (displacement, velocity, acceleration); and (3) the statistical form, generally between instantaneous and energy averaged amplitude.

It is very important that the domain, metric and statistical form of a criterion and corresponding analytical methods should lend themselves to assessment of both analytical data (from predictive structural models) and measured data from a site or building. To do this they should provide a meaningful basis for the characterization of a vibration environment [2].

Ground vibration can be measured in terms of displacement, velocity or acceleration in either time or frequency domain. Time domain data have been quantified as a set of amplitudes as a function of time. Frequency domain data have been defined as a set of amplitudes as a function of frequency. Commonly time domain data is referred as time history and frequency domain data is referred as spectrum.

The time domain can work with either instantaneous amplitude or an average such as root - mean - square (rms). The instantaneous maximum vibration amplitude of positive peak and the negative peak has to be added in order to know the severity of the vibration level. The vibration level can be 0 to peak or peak to peak observed over a period of time.

In frequency domain analysis, the time domain data are transformed to spectra using the Fourier transform algorithm. Vibration spectra are characterized by their frequency bandwidth and in the context of vibration sensitive facilities, are most commonly stated as (1) constant bandwidth, (2) one-third octave bandwidth or (3) spectral density. The ground vibration can be measured in spectra in terms of velocity (rms) and compared with the generic vibration criteria.

During or in the initial stage of nanotechnology building planning project, it is common that the exact instruments will be used are not known. This is due to experimental work processes have not yet been established, or building that going to accommodate the instrument that does not exist. For this reason it is common to select one or several "generic" vibration criterion curves, which are intended to represent entire classes of tools or

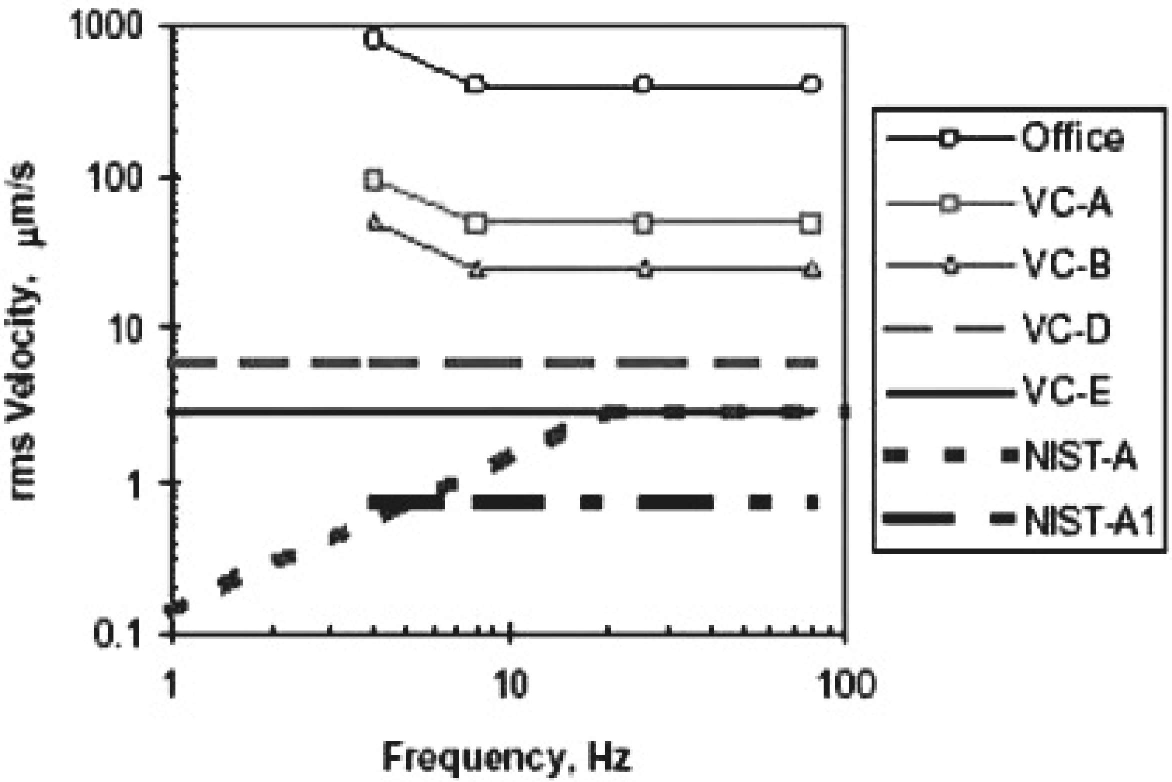

Fig 1. Common Generic Vibration Criteria in the form of Velocity Spectra [1]

processes as shown in Figure-1. These curves have been evolved based on the experience with the requirements of similar equipments, consideration of the scale of analysis coupled with knowledge of typical engineering practice tool design, the limits of what is achievable for the more stringent curves, and other considerations [3].

The particular ground vibration criterion to be followed for the nanotechnology facility depends upon the nature of nanotechnology equipments used in the research activities. The table-1 depicts the general guidelines to select a particular generic vibration criteria template, which can be verified later by comparison with actual equipment requirements. This phase is very important to establish relationships between available generic vibration criterion and the type nanotechnology equipments used in research in the early design stage to achieve an efficient and cost effective design.

With vast literature review, no information is available on the vibration induced by metro train. Hence, this work is taken up to find the effect of movement of metro train on ground vibrations.

2. EXPERIMENTATION

The ground vibration due to metro train is evaluated at Central Manufacturing Technology Institute (CMTI). Tumkur Road, Bangalore. The ground vibrations are evaluated at surface level at a distance of 50 meters from the metro train track. The metro train travels at a height of 8 meters from the ground level. The metro train consists of 3 coaches and the trains were running at their rated speed of approximately 35km/hour with normal commuter load. The very high sensitivity low 'g' accelerometer with nominal sensitivity of 10V/g was used for ground vibration measurements. During the measurements, the nominal sensitivity of the accelerometer was amplified to 100V/g using the amplifier. The very high sensitivity of the accelerometer can measure the very low frequency and very low amplitude ground vibrations. The accelerometers are firmly fixed to the concrete block to measure the ground vibrations in three mutually perpendicular directions as shown in Figure-2 and the concrete block was firmly embedded inside the soil. The metro train induced ground vibration signals are continuously recorded using the DAT Recorder and also analyzed parallelly using the real time FFT Analyzer to study the phenomenon of metro train induced ground vibrations over a period of one day at each measurement location. The noticeable environmental activities during the measurements are observed and documented.

Table 1: Common Generic Vibration Criteria [6]

Category	Criterion	Definition
Human Sensitivity (Research Offices)	ISO Office	400 to 800 µm/sec (16,000 to 32,000 µin/sec)
Generic General Laboratory (Space, Optical Microscopes, Epitaxy, CVD)	VC-A	50µm/sec(2000 µin/sec), Relaxed below8 Hz
	VC-B	25 µm/sec(1000 µin/sec), Relaxed below8 Hz
High sensitive lab (Photolithography, Nanofabrication) (Metrology, Surface Characterization, SEM, SPM, AFM)	VC-D	6 µm/sec (250 µin/sec)
	VC-E	3 µm/sec (125 µin/sec)
	NIST-A	0.025 µm (1µin) displacement for 1≤ f ≤20 Hz ; 3µm/s (125 µin/sec, or VC-E) Velocity for 20<f ≤100Hz
Ultra Sensitive lab (Instrument Development)	NIST-A1	6 µm/sec (250µin/sec) for f ≤ 5Hz; 0.75 µm/sec (30 µin/sec) for 5<f ≤ 100Hz

3. RESULTS AND DISCUSSION

The recorded ground vibrations signals were replayed and only the metro train movement events were extracted from the signals. The extracted events were analyzed in real time FFT analyzer to obtain the metro train induced ground vibration velocity spectrum in three mutually perpendicular directions. The analyzed metro train induced ground vibration spectra are compared with the generic vibration criterion. The existing metro train ground vibration exceeds the generic

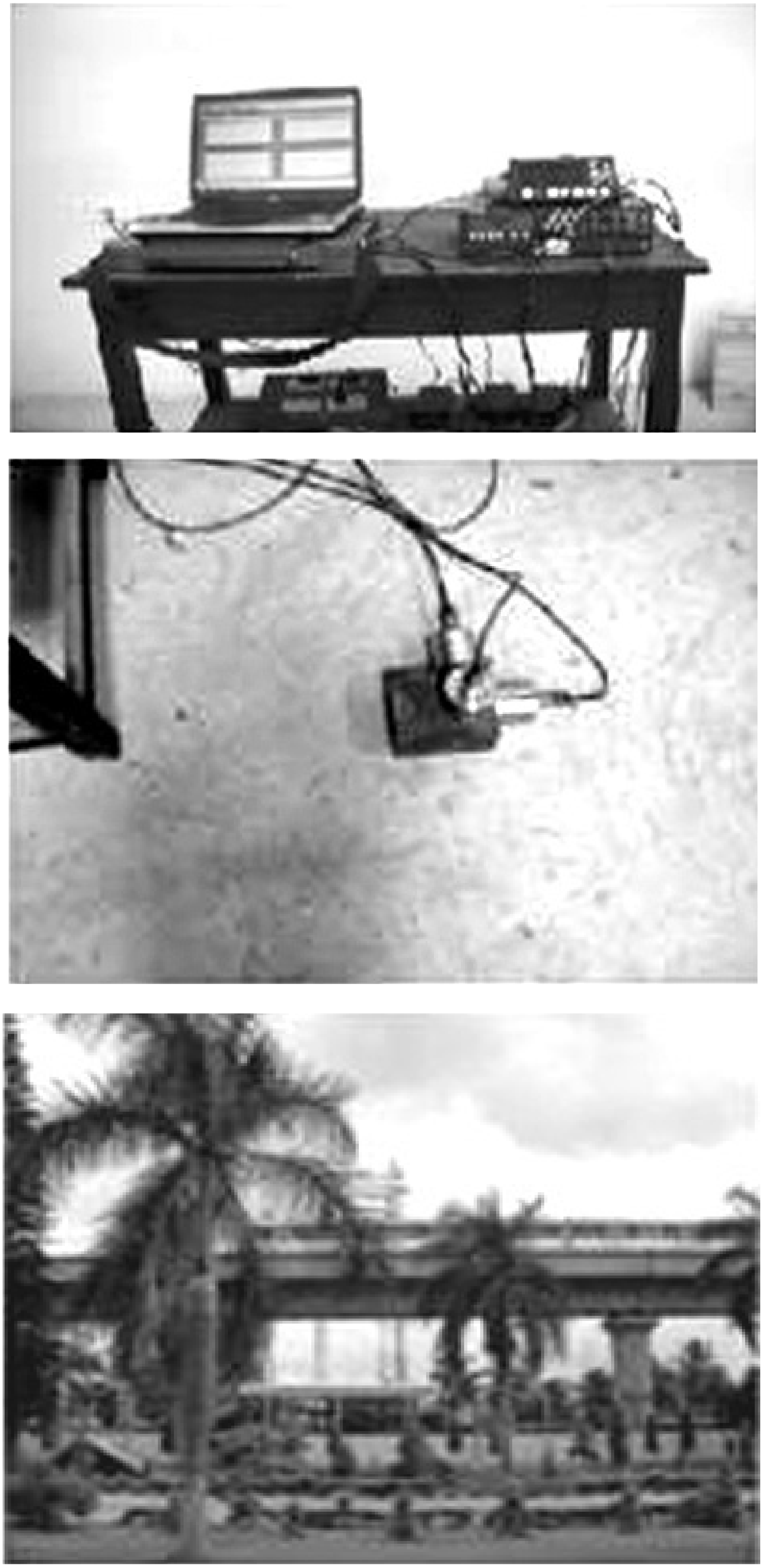

Fig 2. Ground Vibration Measurement Setup

vibration criterion like VC-E as depicted in Figure-3. The generic vibration criterion VC-D, VC-E and NIST-A is used for high sensitive lab which houses nanotechnology facilities like photolithography, nanofabrication, nano metrology, surface characterization, SEM, SPM, AFM.

The maximum vibration displacement level of 0.455 and 0.765 micrometer peak to peak was measured in the frequency band of 1 to 5 Hz in Horizontal direction and in the frequency band of 5 to 10Hz in vertical direction respectively. The displacement level of the order of 0.36 micrometer was measured in the frequency band of 10 to 30Hz. The NIST-A generic ground vibration criterion applicable to high sensitive nanotechnology laboratory depicts the displacement amplitude limit value of 0.025 micrometer in the frequency range of 1 to 20Hz. The measured displacement level due to metro train movements exceeds the CMTI nanotechnology laboratory requirements of 0.1 micrometer and also the generic vibration criterion of NIST-A and VC-E for nanotechnology applications.

4. CONCLUSION

The effect of metro train induced ground vibrations at CMTI sensitive laboratories for nanotechnology facility has been presented. The metro train induced ground vibrations exceeds the generic ground vibration criterion like NIST-A and VC-E for nanotechnology facilities/equipments. The existing metro train induced ground vibrations are several

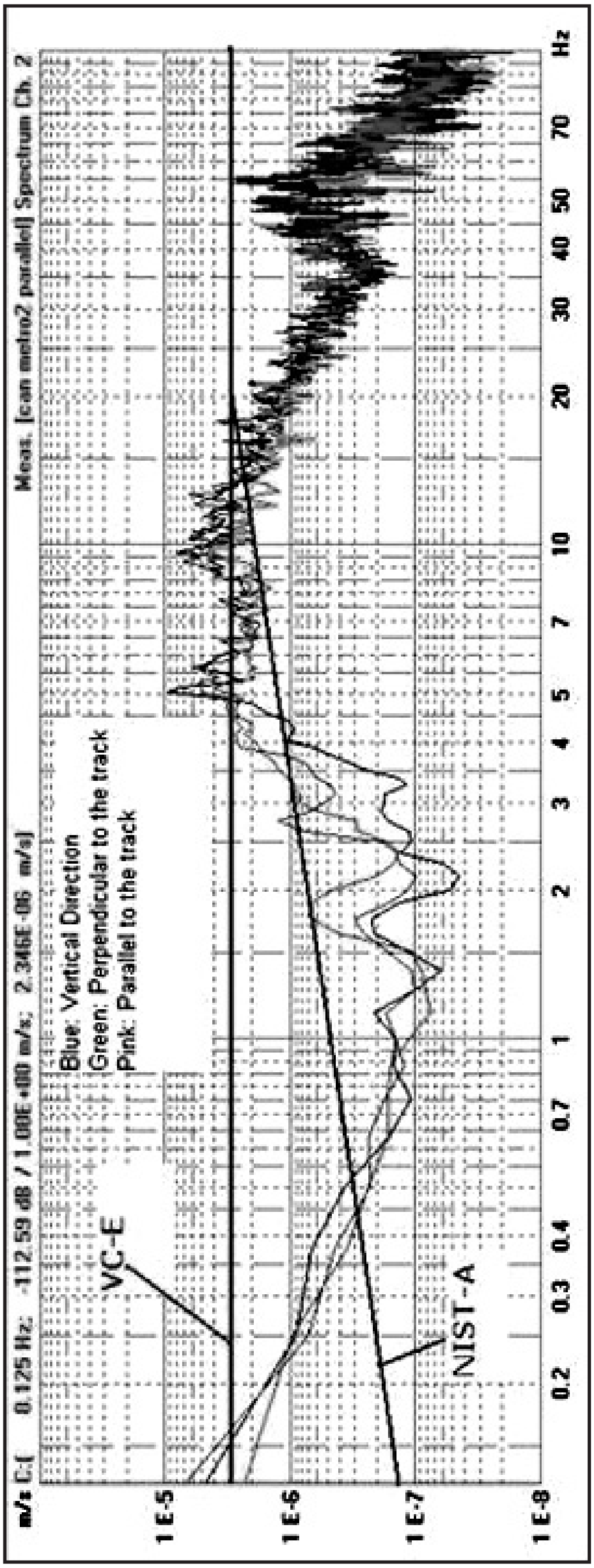

Fig 3. The Comparison of Metro Train Induced Ground Vibration and Generic Vibration Criterion

times higher than the CMTI nanotechnology laboratory ground vibration requirements. The imission of metro train induced ground vibration to the nanotechnology facilities needs to be minimized by isolating the ground vibration.

REFERENCES

1. The Effects of Ground Vibrations on Nanotechnology Research Facilities. Michael Gendreau, Hal Amick and Tao Xu, Colin Gordon & Associates, San Bruno, California, USA. 11th International Conference on Soil Dynamics & Earthquake Engineering & 3rd International Conference on Earthquake Geotechnical Engineering, 7-9th January 2004. pp 905-910.
2. On generic vibration criteria for advanced technology facilities, Hal Amick, Colin Gordon & Associates, San Mateo, California. Journal of the Institute of Environmental Sciences, September/October 1997. pp 35-44.
3. A study of environmental conditions for Nanometrology Labs, Prakash Vinod, J Ramachandra Kiran, M Girish Kumar and P V Shashikumar. 1st National Conference on Advances in Metrology, 16-18th February 2011.
4. Ground vibration investigation for establishment of nano manufacturing technology facilities. M Girish Kumar, Prakash Vinod and P V Shashikumar. International Conference on Advances in Metrology – AdMet 2009.
5. Vibration data representation for advanced technology facilities. Hal Amick, Colin Gordon & Associates, San Mateo, California. 12th ASCE Engineering Mechanics Conference, California, 17-20th May 1998. pp 306-309.
6. "Addressing the environmental challenges of the NIST Advanced Measurement Laboratory" Ahmad Soueid, Hal Amick, Theodore Zsirai presented at Buildings for nanoscale research and beyond", a SPIE Conference, 31st July-1st August 2005 ◘