APPENDIX A

A.1 Root Mean Square (RMS)

\[ x_{RMS} = \sqrt{\frac{1}{n} (x_1^2 + x_2^2 + x_3^2 + .. + x_n^2)} \]

Where \( n \) is the number of instantaneous values and \( x \) is the magnitude of the signal at the particular instant.

A.2 Frequency Weighted Root Mean Square (FWRMS)

The Frequency Weighted Root Mean Square (FWRMS) of BA is computed as per the ISO 2631 standards. The vibration spectrum consists of many independent frequency components \((\omega_i)\), where \( i = 1, 2, \ldots, n \). As per the ISO guideliness, a weighting coefficient \( W_i \), should be applied to the acceleration associated with each frequency \((\omega_i)\).

\[
FWRMS = \left( \frac{1}{T} \int_0^T b^2(t) dt \right)^{\frac{1}{2}} \tag{A.1}
\]

where

\[
b(t) = \left( \sum_{i=1}^{n} (W_i y_i(t))^2 \right)^{\frac{1}{2}} \tag{A.2}
\]

where each steady-state vibration acceleration \( y_i(t) \) is calculated in \( m/s^2 \), see
Figure A.1 Vertical vibration exposure criteria curves

Table A.1 Ride comfort definition as per ISO 2631

<table>
<thead>
<tr>
<th>Weighted RMS of Body (m/s²)</th>
<th>Uncomfortable Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.315</td>
<td>Not Uncomfortable</td>
</tr>
<tr>
<td>0.315–0.63</td>
<td>A Little Uncomfortable</td>
</tr>
<tr>
<td>0.5 – 1</td>
<td>Fairly Uncomfortable</td>
</tr>
<tr>
<td>0.8 – 1.6</td>
<td>Uncomfortable</td>
</tr>
<tr>
<td>1.25 – 2.5</td>
<td>Very Uncomfortable</td>
</tr>
<tr>
<td>&gt; 2</td>
<td>Extremely Uncomfortable</td>
</tr>
</tbody>
</table>
A.3 Classification of Random road -ISO 8606

Table A.2 Classification of random road as per ISO 8606

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Types of Road</th>
<th>Road roughness values $(10^{-6} m^3 cycle^{-1})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Very good</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>Good</td>
<td>4</td>
</tr>
<tr>
<td>3.</td>
<td>Moderate</td>
<td>16</td>
</tr>
<tr>
<td>4.</td>
<td>Poor</td>
<td>64</td>
</tr>
<tr>
<td>5.</td>
<td>Very poor</td>
<td>256</td>
</tr>
</tbody>
</table>

Figure A.2 Random road classification

A.4 EXPERIMENTAL SET UP DETAILS

A.4.1 Actuator

- Model - SL 18
- Input voltage - 24V DC
- Max. Load - 50N /11 lbs /5 kg
- Max. Speed= 230 mm/sec= 9 inch/sec
- Stroke Range - 4 inch/ 100 mm
- Duty Cycle - 20%
- Operation Temperature - (-10 C to 65 C)
- Limit Switch - Factory present limit

**Figure A.3 Speed Characteristic of actuator**

- Bi directional control for one brushed DC motor
- Support motor voltages ranges from 6V to 30V
- Maximum current up to 13 A continuous (without heat sink at 25 degree C) and 30 A peak (10 second).
- Current limiting at 30 A
- 3.3V and 5V logic level input.
- Speed control PWM frequency up to 20 KHz (Actual output frequency is same as input frequency)
- Support TTL PWM from microcontroller
A.4.2 Wheel specifications

- Outer diameter - 200 mm
- Width - 50 mm
- Tyre stiffness - 639.5 N/deg
- Damping co-efficient - 1200 Ns/m

A.4.3 Road input Arrangement

- Pulley Outer diameter - 90 mm
- Belt width - 100 mm
- Belt Length - 1100 mm
- Conveyor speed - 150 to 1500 rpm
• Motor type - AC induction motor
• Power - 3Hp
• Speed - 1500 rpm
• Speed Ratio - 1:1
• Auto Transformer - 0 - 440V, 5HP

A.4.4 LVDT sensor specifications

• Excitation Voltage - 4kHz at 2 Vpp
• Type - Spring Loaded
• Input= 0 to 50 mm
• % Output - 0 to 1V
• Material - Stainless steel
• Accuracy - 1% of full scale division
• Linearity - 0.2% of full scale division

![Figure A.5 Block diagram of Signal conditioning circuit in LVDT](image)

A.4.5 Data Acquisition System

• USB data acquisition system (VUDAS 100)
• 8 channel - 8- bit Analog to digital convert
- 8 Digital I/O ports
- 8 Digital to analog converter (8-bit)
- True plug and play
- USB TMC Standards
- Remote Interface
- Hi-Speed USB 2.0 (480 Mbps)
- USB TMC Class Device
- Converter type - Successive Approximation
- Analog inputs - 8 single ended, 4 differential ended
- ADC : Single Dual Channel ADC
- Simultaneous sampling : 2 Channel
- Input resolution : 12 bit
- Sampling rate : 2msps
- Input range - (0 - 5) V
- Analog Output : 4 Channel
- No. of DAC : 2
- Output resolution - 14 bit
- Output range - 5V
- Speed : 2msps
- Digital I/O
- Digital inputs - 16
- Digital outputs - 16

A.4.6 Signal Conditioning Circuit

- Power Supply -To switch ON /OFF the unit
- LVDT (1-3) Interface- To interface the LVDT with signal conditioner
• Test Point (1-3) -To measure the LVDT output voltage (0-5) V
• Load Cell Interface - Interface the load cell to the board
• Test Point 4 -For measuring the output voltage (0-5)V
• Directional control valve - Provision to interface the directional control valve
• Test Point 5 - To measure the Directional control valve 1 voltage
• Test Point 6 - To measure the Directional control valve 2 voltage