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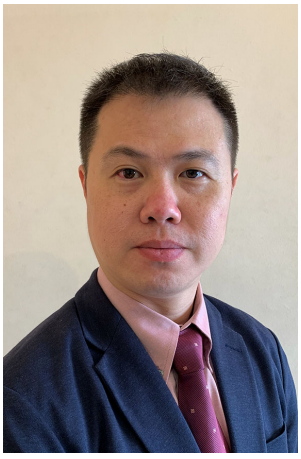
Preston Koh

Marketing Manager, Asia AMCA

Webinar Moderator

- Joined Asia AMCA in 2013
- Responsible for AMCA memberships in the Asia Region
- Responsible for Marketing activities & events in the Asia Region



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Introductions & Guidelines

- Participation Guidelines:
  - Audience will be muted during the webinar.
  - Questions can be submitted anytime via the GoToWebinar platform and will be addressed at the end of the presentation.
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  - To earn PDH credit for today, please stay clicked onto the webinar **for the entire program**.
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- From the attendee panel on the side of the screen, select the "Questions" drop down option.
- Type your question in the box.
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- Questions will be answered at the end of the program.

- If all of today's questions are not able to be answered live, we will follow up with the questions that are submitted in the question box via email.

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Vikas Shevale

- Director, Vibrosolve India Pvt. Ltd.
- Mechanical Engineer with 24 years of experience in the HVAC industry
- 19 years in the Fan industry, including marketing, operations, manufacturing and after-sales service
- Recent 5 years experience in providing vibration isolation systems and solutions for HVAC Applications
- Also, a Six-sigma Black Belt Professional

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Purpose & Learning Objectives

The purpose of this webinar is to revisit the Concepts of Vibration Isolation and it intends to have insights about:

1. Understanding the basic concepts of Vibration Isolation
2. Understanding the concept of Dynamic Load & its effect on support systems
3. Identifying the acceptable vibration levels for your installations
4. Do's & Don'ts of installations of Vibration Isolation Systems

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Sample Case Studies

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Case Study-1

A 2-Floor Food processing Factory, having two Compressors (75HP & 100 HP Capacity) installed on First Floor of the Building.

When the 75HP Compressor starts, after certain Time intervals, the whole building starts shaking. Office Floor, The Cabin Glass windows were Vibrating & creating panic among the occupants.

When this matter was raised to the OEM, they Visited & measured the vibrations on the compressor and they proved to the client that the vibration levels were within OEM acceptable limits.

It took almost 2 months time for the client to identify the root cause.

They corrected the “Vibration Isolation System” and the problem was resolved.

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Case Study-2

A 14-Floor IT Building having HVAC equipment (AHUs & Fans) installed on Terrace.

The client on 10th floor had complained about intermittent vibration on the floor of their conference room. The vibration increase was so strong that it was shaking the Tea-Cups on the conference table

As the building was already occupied and having multiple number of equipment running simultaneously, it was very difficult for the agencies to arrive at the root cause.

It took 3-4 months time for them to understand that the subject problem was due to an AHU-Fan mounted on terrace.

Finally, the problem was resolved by correcting “Vibration Isolation System” in the AHU.

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Case Study-3

A 13-Floor High-End Residential apartment at very prime location in the city.

A single old lady staying on 5th floor of the building. She had hung the photo of her late husband on the wall of the main hall in her residence.

She complained that, every morning she observed the photo in tilted position. She used to correct it in the day time. However, next morning, she was finding the photo in tilted position

It being an already occupied building and having multiple number of equipment running simultaneously, the technical teams could not find the root cause for almost six months time.

In between, it being a mental stress for her, she approached some Astrologer, Vaastu consultants & even carried out worshipping. But, no use.

She had almost decided to sell-off the property & shift to a new location.

Luckily, a technical expert,(the Vendor involved in installation of pumps in the premises) came to the help. He diagnosed & corrected "Vibration Isolation System" of a pump & the matter was resolved.

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There are many such kind of complaints experienced by us during recent few years.

In Older Installations, we observe that the HVAC Plantrooms, big size AHUs or Ventilation systems were located on ground floors, in general.

However, The High-rise building projects are very common nowadays and in these buildings the scenarios are different –

- For various reasons, the rotating equipment are mounted on Upper Floors, even on Terrace
- Use of Variable Frequency Drives is becoming very common due to Energy saving interests
- Use of Light weight construction material is preferred by the construction companies

This raise the possibility of increase in Vibration & Noise transfer to the occupants.

On the other hand, the expectations of the end clients is increasing towards having very smooth and silent environment in the occupancy areas

This is becoming a challenging task for the HVAC professionals in most of the projects.

For this, Right "Vibration Isolation Systems" can be a helpful tool for you….

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Scope

1. This webinar content is prepared more on application side of the isolation systems.
   The theory of vibration, formulae is kept to the minimum.

2. For ease of explanation, we will be considering “HVAC Fans” as an application example in this discussion.
   The basic concepts remain same for other equipment like Chillers, Pumps, Cooling Towers etc.

3. The discussion will be based on Spring-Mass concept, which is more relevant to the applications under discussion. We will be assuming the Damping element to be negligible i.e. no vibrating energy is lost by friction, heat or other means

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Vibration & its Terminologies

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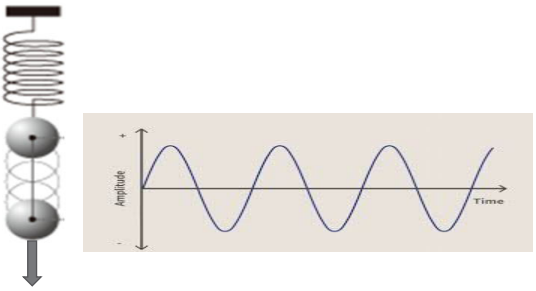
What is Vibration ?

- Any motion that repeats itself after an interval of time is called Vibration or Oscillation
- Vibration in motorized equipment is an oscillation of machines and components, such as drive motors, driven devices (fans, pumps, compressors etc), and the bearings, shafts, gears, belts and other elements that make up mechanical systems.



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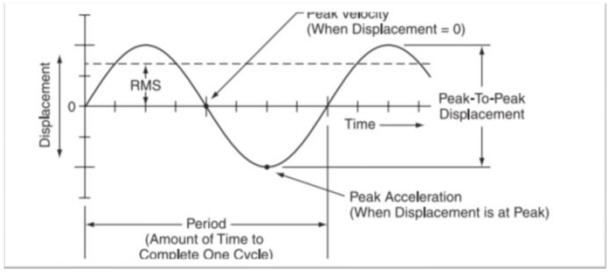
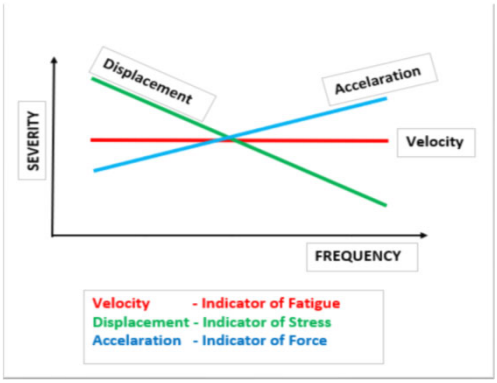
Units of Vibration

- 8 KEQP'LC'$ J MIEQRAB
- ' EPMI>@BJ BKQ†7EB'AEPQ>K@B'>'PQQR@QRQB'U LSBP'LO'SP'O>QBP'QQLJ 'EQP'QBQBQBK@B'LO'QBPQMLPEQELK†
- 9 BIL@KQV‡/QEP'5 >QB'LC'@E>KDB'LC'AEPMI>@BJ BKQ"/QEP'QEB'U B>PRQB'LCQEB'PMBBA'>QT EI@E'QEB'U >PP'EP'SP'O>QEKD'ARQEKD'EQP'LP@EI>QELK†
- $ @@BIBO>QELK‡/QEP'QEB'O>QB'LC'@E>KDB'LC'SBIL@KQV†7EB'DQB>QBO'QEB'O>QB'LC'@E>KDB'LC'SBIL@KQV'QEB'DQB>QBO'QEB'CLO@BP'") øJ >,'LK'QEB J >@EKBP†



Frequency = 1/Period



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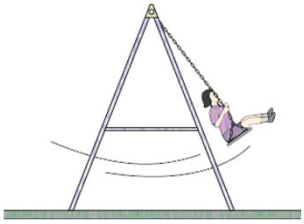
Types Of Vibration

Free Vibration :

- These have a constant amplitude and constant period and the main factor is that they are not under any external influences.
- For the amplitude to remain constant, the system has no damping. But this is possible only in theory as damping will always occur.



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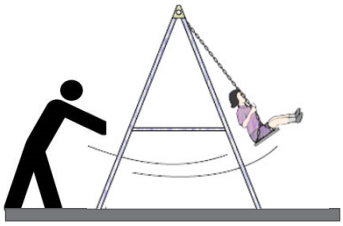
Types Of Vibration

Forced Vibration :

- When a body oscillates by being influenced by an external periodic force, it is called forced oscillation.
- For example, when you push someone on a swing, you have to keep periodically pushing them so that the swing doesn't reduce



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Forced Vibration – Example-1

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Forced Vibration – Example 2

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Forced Vibration – Dynamic Forces

- As you can see in the above videos, the vibrating fans are continuously exerting Dynamic forces on its supporting system
- Over a period of time, these dynamic forces creates stresses & causes damage to the supporting system
- Hence, while designing the Supporting foundation systems, designers take the details of Dynamic Load of the equipment from OEMs & apply safety factors accordingly.

  They aim to make the support structure (like building floors, Base-Channel, platforms etc) as Strong as required.

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Causes of Forced Vibration

- Unbalance in the rotating components
- Misalignments in the installation
- Bent shafts
- Faulty Bearings
- Aerodynamic forces in the running fan
- Loose or missing anchoring etc.

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Types of Support Systems

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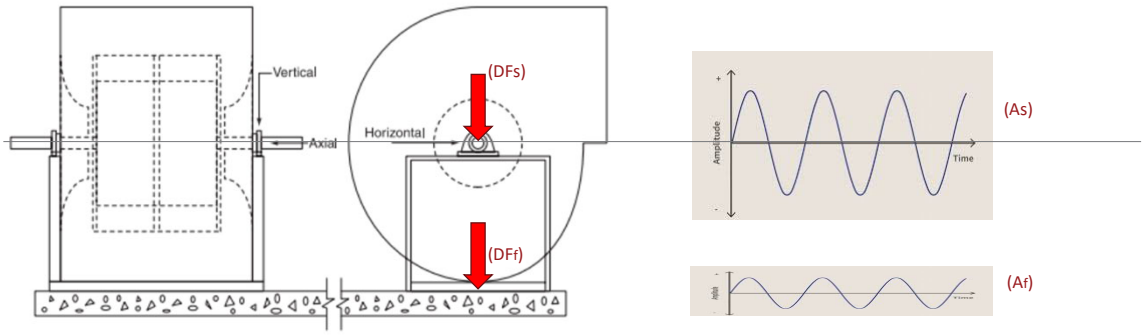
1. Rigid Support System



$DF_f = DF_s$

$A_f \leq$ (25% of As)

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Rigid Support System – Dynamic Forces - Like a Hammering Effect

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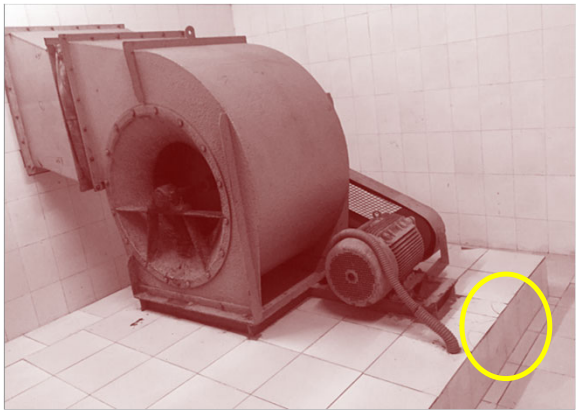
Rigid Support System – Case Studies



Case - RS1

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Rigid Support System – Case Studies

Case – RS2

Case – RS3

Case – RS4

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Rigid Support System – Case Studies

Case- RS5

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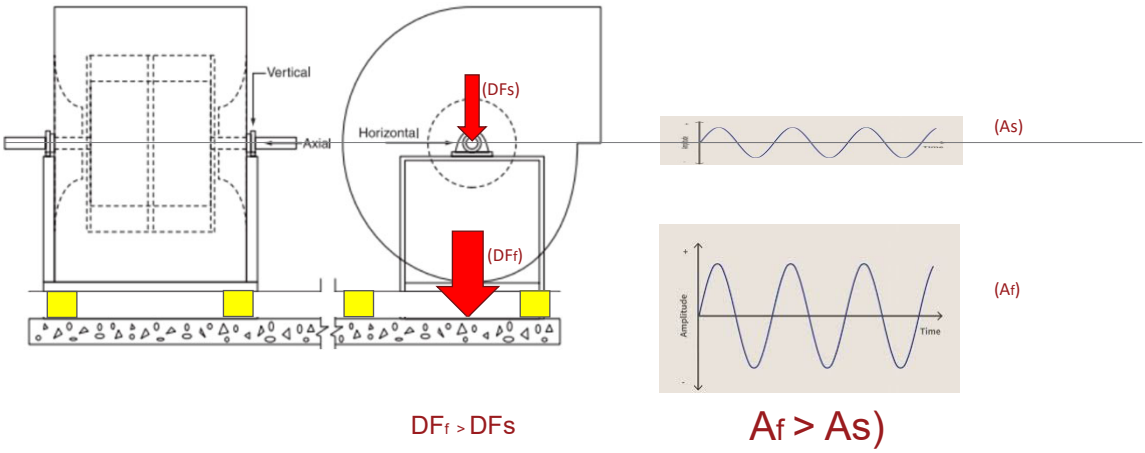
2. Resonating Support System



$DF_f > DFs$

$A_f > As)$

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Natural Frequency & Resonance

- Like every human being possess certain natural sentiments; every mechanical system possess a natural frequency
- It is a frequency at which the system would like to vibrate at
- It is an inherent property of the system and it depends on its MASS and STIFFNESS

- Higher the MASS, lower the natural frequency.
- Higher the STIFFNESS, Higher the natural frequency

$$f_n \propto \sqrt{\frac{k}{M}}$$

- Having a number of natural frequencies is not a problem
- However, it becomes a matter of concern if the frequency of the Dynamic Forces of the vibration source coincides with Natural frequencies of the support system

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What is Resonance

- Resonance is a situation when the Frequency of the Dynamic Forces of the vibration source coincides with Natural frequencies of the support system
- In Resonance, there is substantial increase in the amplitude of the vibration

Input Output

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Resonance – Attention needed during design & installation stage

- Resonance is a reason for many catastrophic failures of civil structures
  e.g. Collapse of Takoma bridge in 1940, due wind induced forces
- In HVAC equipment, OEMs take great care during design stage to ensure that the natural frequency of any of the component does not coincide with the operating speed range
- Similarly, it should be ensured by the installation teams, that the Natural Frequencies of the support system does not fall within the operating speed of the equipment

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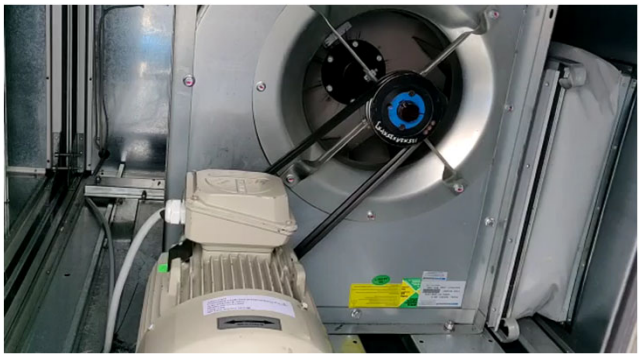
Resonance – An example



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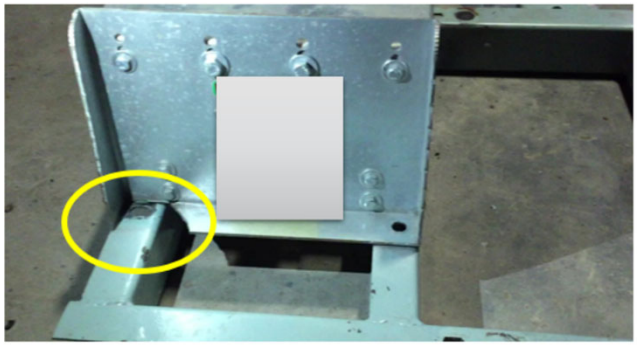
Resonance – An example



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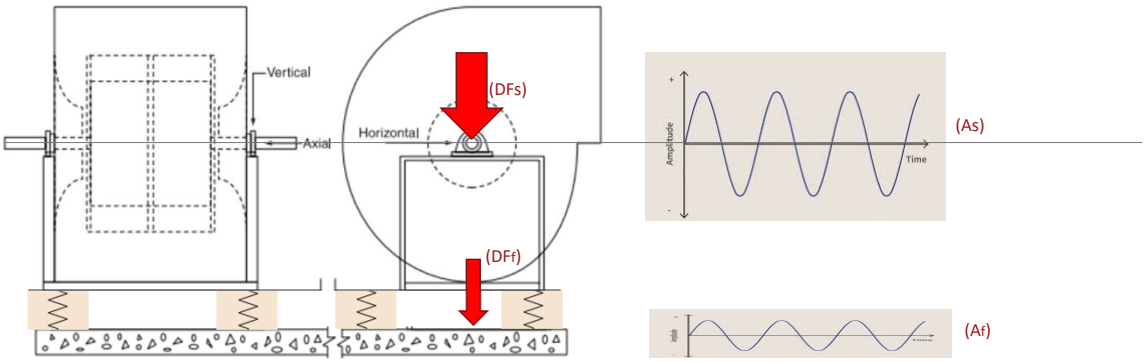
3. Flexible Support System



$DF_f < DF_s$ $A_f < A_s)$

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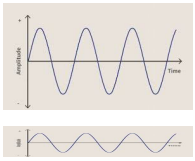
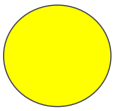
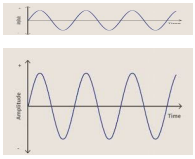
What is the Right Support System ?

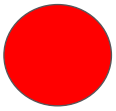
Rigid Support System $DF_f = DF_s$



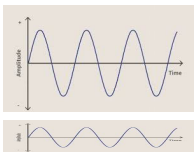


Resonating Support System $DF_f > DF_s$





Flexible Support System $DF_f < DF_s$



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FLEXIBLE SUPORT SYSTEM
(VIBRATION ISOLATOR TYPES & TERMINOLOGIES)

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What is Vibration Isolator ?

Vibration Isolator is a flexible element placed between the Equipment & the supporting structure. It helps to reduce the transfer of vibration force from the equipment to the supporting structure




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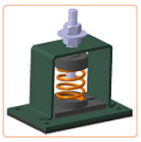
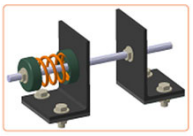
Isolator Types

Spring Type Isolators

Restraint Type Spring Isolators



Axial Thrust Retainers



Rubber Type Isolators

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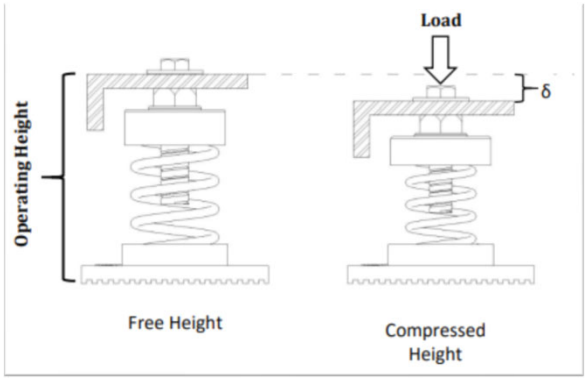
Isolator Deflection

Isolator deflection (δ) = (Isolator Height without Load– Isolator height after installation of the equipment)



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Isolation Efficiency Vs Dynamic Force

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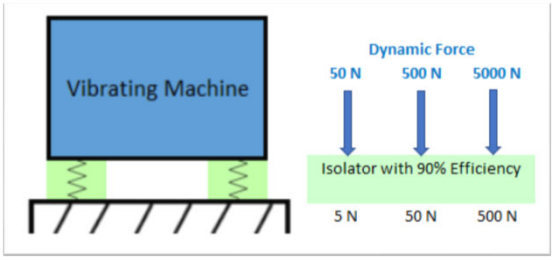

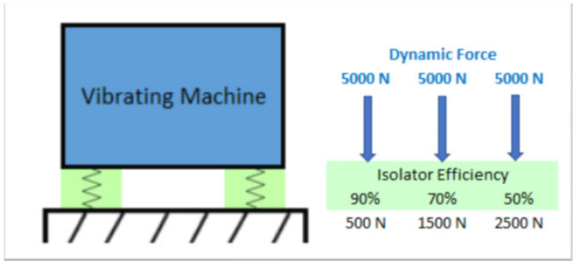

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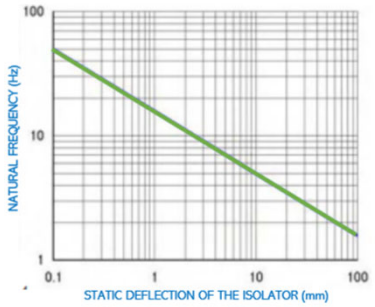
Isolation Efficiency Formula

$$\text{Isolation Efficiency (\%)} = \left(1 - \frac{1}{\left(\frac{fd}{fn}\right)^2 - 1}\right)$$

f_d = Disturbing frequency (i.e. Lowest of the Fan speed or Motor speed)

f_n = Natural Frequency of the support system

$f_n \propto \frac{1}{\sqrt{\delta}}$, Where δ is the deflection of the isolator



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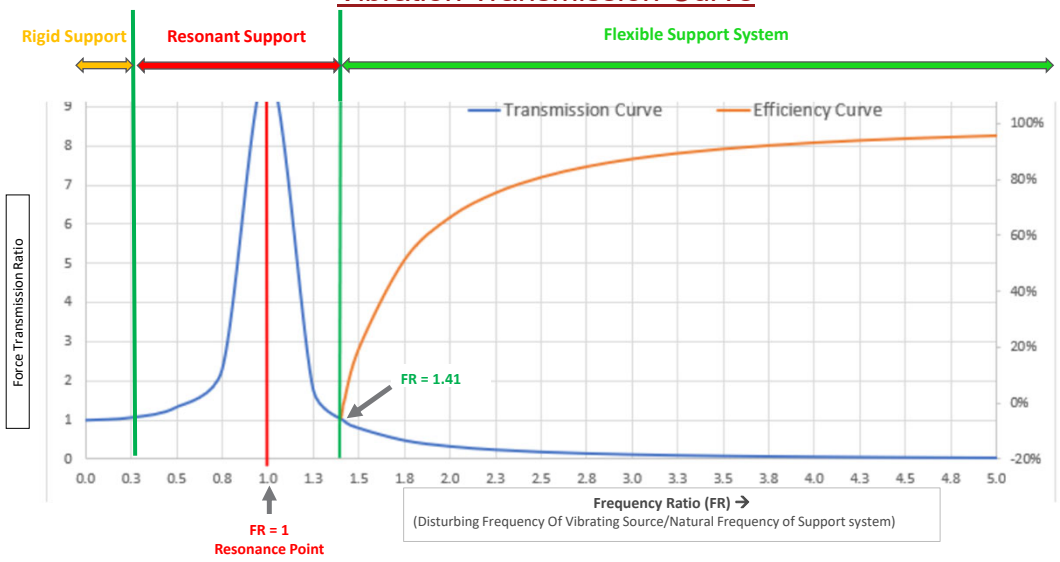
Vibration Transmission Curve



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Vibration Transmission Curve

In order to get Good Isolation Efficiency and keep the installation away from the Resonance; we need to keep the Frequency Ratio on Higher Side

Note - For Isolation Efficiency of 90%; FR = 3.31

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GUIDELINES BY ASHARE

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ASHRAE Guidelines – Summary chart for Isolation - fan Application

Equipment Type	Motor HP, Static Pr.	Fan Speed (RPM)	Slab on Grade			Upto 20 ft. Floor Span			20-30 ft. Floor Span			30-40 ft. Floor Span			Note
			Base Type	Isolator Type	Min. Defl. (mm)	Base Type	Isolator Type	Min. Defl. (mm)	Base Type	Isolator Type	Min. Defl. (mm)	Base Type	Isolator Type	Min. Defl. (mm)	
Centrifugal															
Upto 560mm	All	All	B	Rubber	6	B	Spring	19	B	Spring	19	C	Spring	44	9, 19
630 & Above	Upto 40 HP	Upto 300	B	Spring	64	B	Spring	89	B	Spring	89	B	Spring	89	8, 19
		300 to 500	B	Spring	44	B	Spring	44	B	Spring	64	B	Spring	64	
		501 & above	B	Spring	19	B	Spring	19	B	Spring	19	B	Spring	44	
	50 HP & Above	Upto 300	C	Spring	64	C	Spring	89	C	Spring	89	C	Spring	89	2,3,8,9,19
		300 to 500	C	Spring	38	C	Spring	44	C	Spring	64	C	Spring	64	
		501 & above	C	Spring	25	C	Spring	44	C	Spring	44	C	Spring	64	
Axial Fans,															
Upto 560mm	All	All	A	Rubber	6	A	Spring	19	A	Spring	19	C	Spring	19	4, 9
630 & Above	Upto 50mm SP	Upto 300	B	Spring	64	C	Spring	89	C	Spring	89	C	Spring	89	9.0
		300 to 500	B	Spring	19	B	Spring	44	C	Spring	64	C	Spring	64	
		501 & above	B	Spring	19	B	Spring	44	B	Spring	44	B	Spring	44	
	Above 50 mm SP	Upto 300	C	Spring	64	C	Spring	89	C	Spring	89	C	Spring	89	3, 9
		300 to 500	C	Spring	44	C	Spring	44	C	Spring	64	C	Spring	64	3, 8, 9
		501 & above	C	Spring	19	C	Spring	44	C	Spring	44	C	Spring	64	

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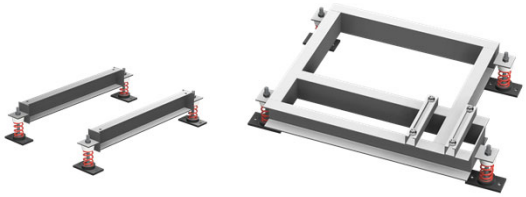
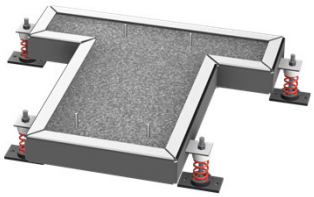
ASHRAE Guidelines – Base Types



Type B – Structural Rail or Common Base



Type C – Inertia Base

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ASHRAE Guidelines – Notes

Note	Details
Note 2	For large equipment capable of generating substantial vibratory forces and structure-borne noise, increase isolator deflection, if necessary, so isolator stiffness is at least 0.10 times the floor stiffness.
Note 3	For noisy equipment adjoining or near noise-sensitive areas, see the text section on Mechanical Equipment Room Sound Isolation.
Note 4	Certain designs cannot be installed directly on individual isolators
Note 8	To avoid isolator resonance problems, select isolator deflection so that resonance frequency is 40% or less of the lowest operating speed of equipment.
Note 9	To limit undesirable movement, thrust restraints (Type 5) are required for all ceiling-suspended and floor-mounted units operating at 2 in. and more total static pressure.
Note 19	Inertia bases (Type C) are recommended for all Class 2 and 3 fans and air-handling equipment because extra mass permits the use of stiffer springs, which limit movement. Thrust restraints (Type 5) that incorporate the same deflection as isolators should be used for all fan heads, all suspended fans, and all base-mounted and suspended air-handling equipment operating at 2 in. and over total static pressure.

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ASHRAE Guidelines Vs Normal Installation Practices in our region

We find a big difference in the general practices followed by the industry in our region vis-à-vis the guidelines of ASHRAE Handbook. Few examples as follows -

Parameter	ASHRAE Guidelines	General Practice in our Region
Type of Isolator	Except fans upto 560mm size on-Grade; all other sizes are to be with spring type isolator	Except very few projects, majority of them; irrespective of fan sizes; use Rubber Type Isolators
Thrust Retainers	To be used for fans with 50mm Static Pressure and above	Rarely used
Inertia Bases	For Class-2 and Class-3 construction fans; Inertia Bases are to be used	Inertia bases are Rarely used for fans

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Reduction in Dynamic Loads – Useful for Civil Construction Designs ?

Considering above difference; we have following questions in mind –

- With use of Correct Vibration isolation systems; we can drastically reduce down the dynamic loads of the HVAC equipment; will it give considerable help towards optimisation of the corresponding Civil Construction design, without compromise in safety standards ?

If so, It would be advisable to optimise on the resources of the project as well as facilities by

- using correct isolation systems,
- reducing the dynamic loads transfers
- Using vibration-monitoring systems to monitor the dynamic loads in regular operations

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VIBRATION ACCEPTANCE CRITERIA (AMCA 204-20)

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Fans Application Categories for Vibration

Application	Examples	Driver Power Limits, kW (hp)	Fan Application Category, BV
Residential	Ceiling fans, attic fans, window air-conditioning unit	≤ 0.15 (0.2) > 0.15 (0.2)	BV-1 BV-2
HVAC and agricultural	Building ventilation and air-conditioning systems; commercial systems	≤ 3.7 (5.0) > 3.7 (5.0)	BV-2 BV-3
Industrial process and power generation etc.	Baghouse, scrubber, mine, conveying, boilers, combustion air, pollution control, wind tunnels	≤ 298 (400) > 298 (400)	BV-3 BV-4
Transportation and marine	Locomotives, trucks, automobiles	≤ 15 (20) > 15 (20)	BV-3 BV-4
Transit and tunnel	Subway emergency ventilation, tunnel fans, garage ventilation	≤ 75 (100) > 75 (100)	BV-3 BV-4
	Tunnel jet fans	ALL	BV-4
Petrochemical process	Hazardous gases, process fans	≤ 37 (50) > 37 (50)	BV-3 BV-4
Computer chip manufacturer	Clean room	ALL	BV-5

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Vibration Limits –Testing in Factory

Fan Application Category, BV	Rigidly Mounted mm/s (in./s)		Flexibly Mounted mm/s (in./s)	
	Peak	RMS	Peak	RMS
BV-1	12.7 (0.50)	9.0 (0.35)	15.2 (0.60)	11.2 (0.44)
BV-2	5.1 (0.20)	3.5 (0.14)	7.6 (0.30)	5.6 (0.22)
BV-3	3.8 (0.15)	2.8 (0.11)	5.1 (0.20)	3.5 (0.14)
BV-4	2.5 (0.10)	1.8 (0.07)	3.8 (0.15)	2.8 (0.11)
BV-5	2.0 (0.08)	1.4 (0.06)	2.5 (0.10)	1.8 (0.07)
Note: Peak values are widely used in North America and are made up of several sinusoidal waveforms that do not necessarily have an exact match with RMS values. They also may depend to some extent on the instrument used.				

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Vibration Limits –Acceptable Criteria at Site

Condition	Fan Application Category	Rigidly Mounted mm/s (in./s)		Flexibly Mounted mm/s (in./s)	
		Peak	RMS	Peak	RMS
Startup	BV-1	14.0 (0.55)	10 (0.39)	15.2 (0.60)	11.2 (0.44)
	BV-2	7.6 (0.30)	5.6 (0.22)	12.7 (0.50)	9.0 (0.35)
	BV-3	6.4 (0.25)	4.5 (0.18)	8.8 (0.35)	6.3 (0.25)
	BV-4	4.1 (0.16)	2.8 (0.11)	6.4 (0.25)	4.5 (0.18)
	BV-5	2.5 (0.10)	1.8 (0.07)	4.1 (0.16)	2.8 (0.11)
Alarm	BV-1	15.2 (0.60)	10.6 (0.42)	19.1 (0.75)	14.0 (0.55)
	BV-2	12.7 (0.50)	9.0 (0.35)	19.1 (0.75)	14.0 (0.5)
	BV-3	10.2 (0.40)	7.1 (0.28)	16.5 (0.65)	11.8 (0.28)
	BV-4	6.4 (0.25)	4.5 (0.18)	10.2 (0.40)	7.1 (0.28)
	BV-5	5.7 (0.20)	4.0 (0.16)	7.6 (0.30)	5.6 (0.22)
Shutdown	BV-1	NOTE 1	NOTE 1	NOTE 1	NOTE 1
	BV-2	NOTE 1	NOTE 1	NOTE 1	NOTE 1
	BV-3	12.7 (0.50)	9.0 (0.35)	17.8 (0.70)	12.5 (0.49)
	BV-4	10.2 (0.40)	7.1 (0.28)	15.2 (0.60)	11.2 (0.44)
	BV-5	7.6 (0.30)	5.6 (0.22)	10.2 (0.40)	7.1 (0.28)

Notes:
1. Shutdown levels for fans in Fan Application Grades BV-1 and BV-2 must be established based on historical data.
2. Peak values are widely used in North America and are made up of a number of sinusoidal waveforms. The peak values do not necessarily have an exact match with RMS values and also depend on the instrument used to some extent.

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VIBRATION ISOLATOR SELECTION & INSTALLATION (DO's & DON'Ts)

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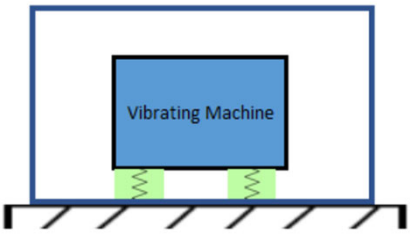
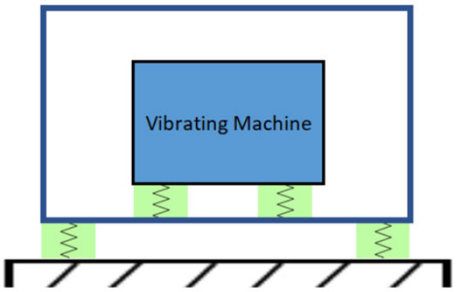
(Internal+External) Isolation….To avoid



Only Internal Isolation



Internal Plus External Isolation

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Highrise Buildings – Avoid Floor Resonance

In case of Upper Floor installations, give necessary considerations towards Natural Frequency of the Flexible floors while selection of the Vibration Isolator for the equipment

(Deflection of the Isolator > 10*Deflection of the Floor)

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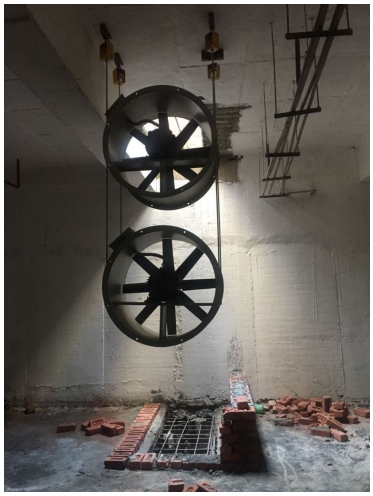
Avoid Multiple Axial Fans on Single line of Isolators/Tie Rod



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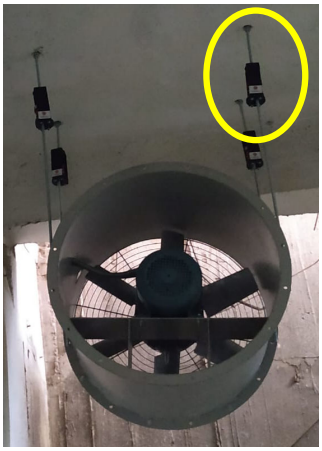
Reduce down on Degrees of Freedom



Intermediate Placement of Isolators leads to multi-directional movement of the tie-rod; which may lead to its premature failure

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Upper Floor installations – STRICTLY Avoid Rigid Support systems

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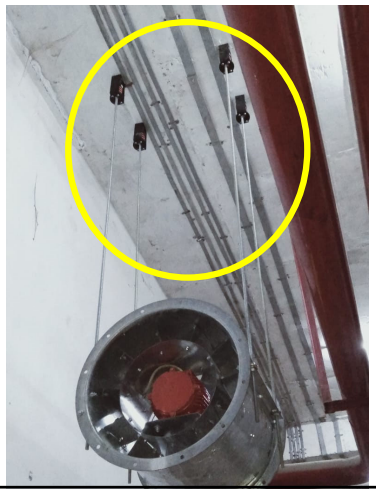
Limit the Length of Tie Rods to avoid Axial Thrust stresses



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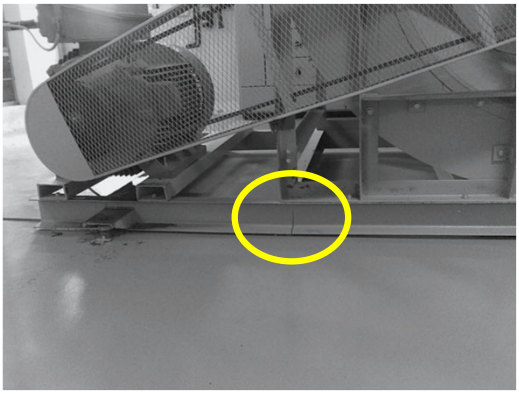
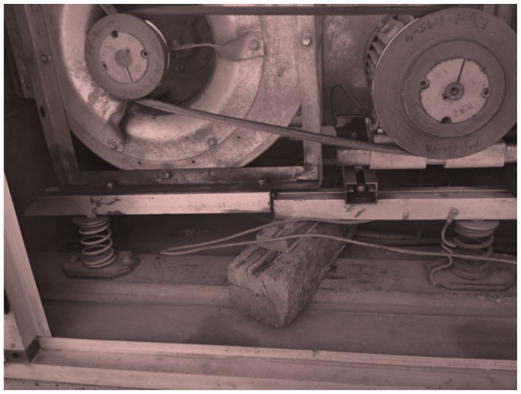
Avoid Longer span of Base channel





(Maximum distance between two isolator < 10*Height of the Base Channel)

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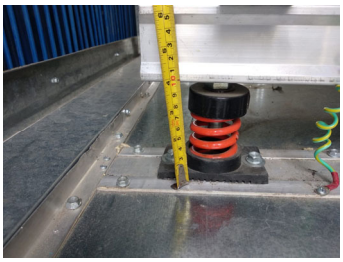
Carry out Height adjustment of isolator to achieve Levelling of the Base Channel



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Ensure Levelling of the Base Channel during Fan operation

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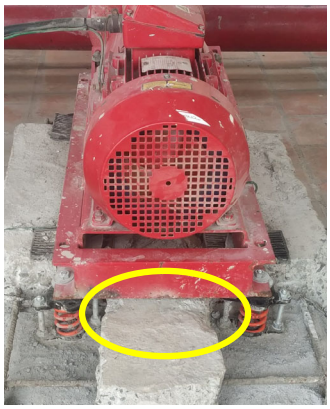
Avoid Short-circuiting



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Ensure Safe & Proper Installation Practises

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EC Fan Wall Systems

- In Recent Time, usage of EC Fan array system is increasing in the industry.
- The EC Fan OEMs make their fan holding structures stiff enough to avoid its resonance during fan operation
- The AHU manufacturers install these fans in rigid manner to the AHU structure & even the EC Fan OEMs approves such practice
- Over a period of time, there is possibility that the rigidity of the AHU structure may reduce due to constant dynamic loads & may lead to component failures
- This depends on the factors like
  - Balancing standard adapted by the EC Fan OEMs
  - Number of fans in the Fan Array
  - Operating range of the Fan (Lowest frequency of operation)
  - Proper maintenance of the EC Fans
- To have longed life of the fan & AHU Structure, we suggest for the flexible type support structure for EC Fan Arrays

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Let's hope, this webinar would be helpful for you towards having smooth, trouble-free & long life functioning of your equipment & Structures

Thank You

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Thank you for your time!

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Questions?

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