

# RAM Mix Coupling

Justin Whaley  
Engineering Manager  
Resodyn Corporation



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## Coupling In Practice



**Talc**  
Material free flowing with chaotic motion relative to vessel



**Solids Loaded Paste**  
Material quiescent relative to vessel

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Coupling Coefficient

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## Calculating Coupling Coefficient

Coupling Coefficient  $C_c$  is empirically determined based on Natural Frequency equation

$$C_c = (f_{empty} - f_{mix}) \frac{C1}{M_{mix}}$$

$f_{empty}$ : Frequency of an empty vessel  
 $f_{mix}$ : Frequency with mix material  
 $C1$ : Machine specific constant  
 $M_{mix}$ : Mass of mix material added

Machine Constants

|           | lbm / Hz | gm / Hz |
|-----------|----------|---------|
| LabRAM I  | 0.95     | 431     |
| LabRAM II | 1.3      | 590     |
| OmniRAM   | 11.7     | 5.3 kg  |
| RAM5      | 34       | 15.4 kg |



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### Application #1: Equivalent Mass

#### • How much material can I mix?

- Each Mixer has a maximum equivalent mass payload capacity
- Many users assume this is the TOTAL mass!

| Model     | Maximum 100g Equivalent Mass |
|-----------|------------------------------|
| LabRAM I  | 4.2 lbm                      |
| LabRAM II | 5.5 lbm                      |
| OmniRAM   | 80 lbm                       |
| RAM 5     | 375 lbm                      |
| RAM 55    | 3100 lbm                     |



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### Application #1: Equivalent Mass

#### • Easy to calculate but we find classes of materials exhibit normal ranges\*

Typical Pastes: 0.4 – 0.6

Typical Powders: 0.1 – 0.4

\* Approximations may vary

#### • Coupling used when Calculating Total Equivalent Mass

- Used when determining Total Equivalent Mass which is the mass affecting the resonator

$$M_{Eqv} = M_{Tooling} + M_{Live} \times C_c$$

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### Application #1: Equivalent Mass

#### • How much material can I put on my mixer?

- Example: Calculating maximum amount of material that can be mixed by a LabRAM II with a 5" Vessel Holder

$$M_{Live MAX} = \frac{M_{MachineLimit} - M_{Tooling}}{C_c}$$



5.5lb

$C_c$

2.4lb

- Conservative: 3.1 lbm
- Typical Paste\*: 5.2 lbm
- Typical Powder\*: 7.8 lbm

Typical Powder could have 150% Free Capacity

5" Vessel Holder 8oz Jar

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### Application #1: Equivalent Mass

- How much material can I put on my mixer?
  - Example: Calculating maximum amount of material that can be mixed by a LabRAM II with a 5" Vessel Holder

$$M_{Mix\ Max} = \frac{100}{A_{max}} \frac{M_{Limit} - M_{Tooling}}{C_c}$$



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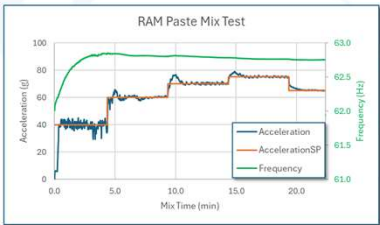
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### Application #2: Starting Frequency

- Coupling means the resonant frequency will change even if mix mass remains constant



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**EXTREME**  
Coupling

Note: This probably doesn't apply to you.

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### What is Extreme Coupling

- Standard coupling model only permits coupling coefficients in the 0 – 1 range but this model conflicts with observations
- Extreme coupling can occur when mix material acts like a lumped mass on the vessel creating a 4-mass system
  - Cohesive Powders, Milling Media, & Decoupled Paste



10

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11

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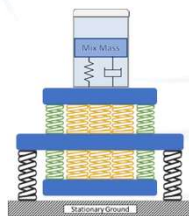
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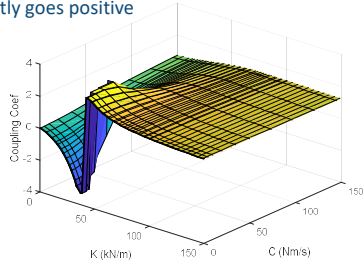
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### Modeling RAM as a 4-Mass System

- Extreme Coupling is a function of both stiffness and damping of the mix material
- As stiffness increases, the coupling goes negative then abruptly goes positive



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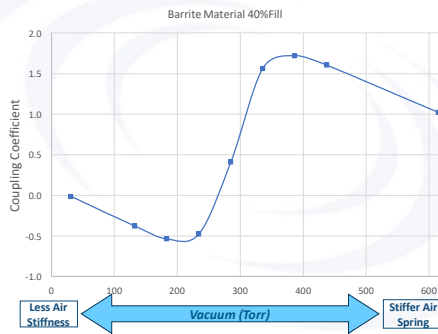
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### Early Evidence of a 4-Mass System



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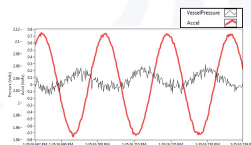
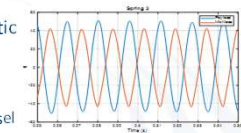
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### Phase Angle Influences Extreme Coupling

- Phase angle of the coupled mass determines if you're adding kinetic or potential energy to the resonator
  - Coupling Coefficient < 0  
Mix Material Out of Phase with Vessel
  - Coupling Coefficient > 1  
Mix Material In Phase with Vessel  
Material force can exceed  $\rho gh$



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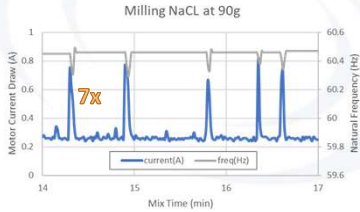
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### Impact of Extreme Coupling

- Extreme coupling can interfere with resonant frequency tracking and produce power surges



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### Impact of Extreme Coupling

- Extreme coupling can interfere with resonant frequency tracking and produce power surges
- Interferes with the max acceleration de-rate which puts onus on user not to exceed payload of the resonator
  - Possible but has not been observed

17

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### Impact of Extreme Coupling

- Extreme coupling can interfere with resonant frequency tracking and produce power surges
- Interferes with the max acceleration de-rate which puts onus on user not to exceed payload of the resonator
  - Possible but has not been observed
- Extreme coupling can be a stable mixing regime

18

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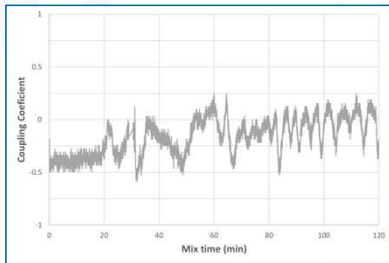
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### Stable Mixing with Extreme Coupling

Resodyn developed the mixing plan for a RAM5 client's cohesive powder which experienced extreme coupling



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### Summary

- Coupling Coefficient is a convenient metric for the behavior of mix material relative to the vessel
- Primary uses for coupling coefficient
  1. Predicting maximum mix mass at an acceleration
  2. Consideration for the starting frequency
- Extra care required in the unlikely case of extreme coupling
- Use Resodyn as a resource for unusual mix problems!



20

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Thank you for your time  
and attention.



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