

Calculating Mixing Power

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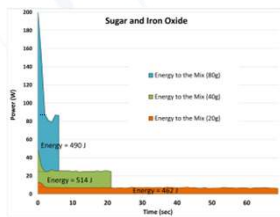


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Power Into the Mix

- Mix Power Transmission is Driven by the of the Resonator but is Dependent on Mix Properties
- Mix Power is a Quantitative Measure of Mixing Performance



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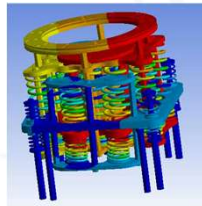
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Lumped Parameter Mixing Model

- Power Into the Mix is Driven by the Oscillating Motion of the Resonator and is Dependent on Mix Properties
- The Lumped Parameter Method is a Simplified, but Effective Approach that Correlates System Inputs with RAM Mixing Performance

Mixing Parameters	
RAM Parameters	Acceleration
	Frequency
	Temperature
	Vessel Pressure
	Processing Order
Vessel Choice	Vessel Dimensions
	Fill Height
	Order of Addition
Mix Material	Viscosity / Cohesion
	Density
	Particle Size



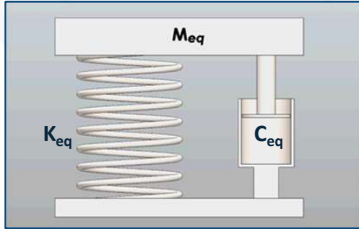
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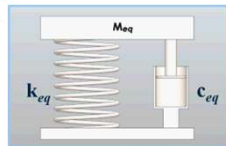
Lumped Parameter Mixing Model

• Mixing Parameters

Numerous Physical Parameters are Simplified to 4 Equivalent Lumped Mixing Terms

Mixing Parameters

RAM Parameters	Acceleration Frequency Temperature Vessel Pressure Processing Order
Vessel Choice	Vessel Dimensions Fill Height Order of Addition
Mix Material	Viscosity / Cohesion Density Particle Size



$$m_{eq}\ddot{x} + c_{eq}\dot{x} + k_{eq}x = f(t)$$

- m_{eq} = System Mass
- c_{eq} = Equivalent Damping
- k_{eq} = Equivalent Stiffness
- $f(t)$ = Motor Force

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Lumped Parameter Model & Resonance

- On Resonance Inertial and Potential Forces Exchange Without Loss

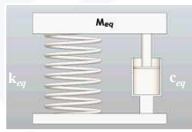
$$m_{eq}\ddot{x} + c_{eq}\dot{x} + k_{eq}x = f(t)$$

- Changes to Mix Power are Reflected in Changes to the Motor's Force

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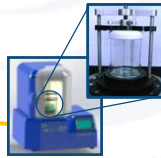
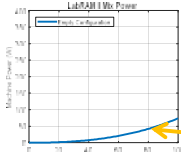
LabRAM II Mix Power Calculation

• Mix Power Requires a Baseline Comparison



Baseline Damping Components (C_{eq})

- Air Damping
- RAM Losses
- Motor Losses
- Auxiliary Uses



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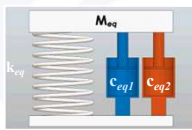
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LabRAM II Mix Power Calculation

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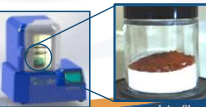
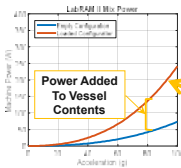


Baseline Damping Components (C_{eq1})

- Air Damping
- RAM Losses
- Motor Losses
- Auxiliary Uses

Mixing Damping Components (C_{eq2})

- Mix Power



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LabRAM II Mix Power Calculation

• LabRAM (Calculated and Empirically Validated)

$$P_{mix} = K_m \dot{x}(I_{loaded} - I_{baseline}) - R(I_{loaded}^2 - I_{baseline}^2)$$

I_{loaded} : Current with load (Amps)

$I_{baseline}$: Current without load (Amps)

K_m : Motor Constant

• You won't need this equation

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LabRAM Mix Power Calculators

- Worksheet can be used to simplify calculation based on historical data.
- Power Viewer app logs mix power in real time using a laptop.
- Custom baselines can be calculated on request.



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LabRAM Mix Power Calculators

- Mix Power calculated on a USB connected laptop
- Results graphed in real-time as the mix progresses

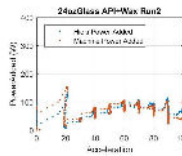
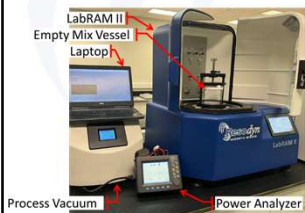


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Validating Mix Power Equation

- Mix power results validated using a line power analyzer



Test #	Test Description	Avg Error (W)	STD (W)	Relative Error
1	Water 200 gm Run 1	5.7	5.9	3.1%
2	Water 200 gm Run 2	5.7	6.3	3.1%
3	Water 200 gm Run 3	7.5	7.7	4.1%
4	Water 400 gm Run 1	11.3	16.2	2.7%
5	Water 400 gm Run 2	9.8	12.6	2.4%
6	Water 400 gm Run 3	7.6	7.9	1.8%
7	AlOx 200 gm Run 1	6.1	7.2	2.4%
8	AlOx 200 gm Run 2	4.1	5.0	1.6%
9	AlOx 200 gm Run 3	8.9	10.7	3.5%
Average		7.4	8.8	2.7%



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RAM5 Mix Power Calculation

- RAM 5 (Calculated)

$$P = \left(\frac{\Delta P}{100}\right) * \left(\frac{A}{100}\right) * (0.0385 * f^2 - 5.3849 * f + 208.04)$$

P: Mix Power (kW)
ΔP: %Power Change
A: Acceleration
f: Frequency

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Mix Power Considerations

- Each RAM Mixer has a Power Limit
 - Mixing above this limit Results in an ‘Over Current’ Error or an Inability to Reach the Desired Acceleration

LabRAM I	400 W
LabRAM II	600 W
OmniRAM	4.2 kW
RAM 5	24.7 kW
RAM 55	235 kW

- Mix Power is not the % Power
 - Mix Power measures power added to the mix in watts.
 - %Power measures current drawn by the motor.
 - Does not account for:
 - Velocity
 - System Losses
 - Vessels Selection
 - Voltage Fluctuations

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Mix Power Considerations

- Limitations when Measuring the RAM Mix Power
 - Small samples (<30 gm)
 - Low accelerations (<20 g)
 - Operating with a different vessel holder from baseline
 - Work done on air does not always contribute to material mixing in the vessel

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Summary

- Lumped Parameter Model Effectively Correlates System Inputs with the RAM Mixing Performance
- Mix Power Measures the Change in Power Level Relative to a Known Baseline
- Mix Power can be Calculated while Running or by Using a Run's Datalog

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Thank you for your time
and attention.



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