

Process Parameters for Resonant Acoustic Mixers (RAM)

Yew Tian Geng¹

Supervisors: Dr. Philip Gill², Mr. Peter Wilkinson²

1. Abstract

In this study the suitability of Resonant Acoustic Mixing (RAM) technology for the mixing of solid composite propellants is evaluated. A method to quantify the degree of mixing uniformity was first realised using UV-Vis spectroscopy and a statistical approach. By measuring the concentration of a dye marker inside a sample taken from a mixture and calculating the standard deviation between results from different samples, a quantitative indicator on the degree of mixing uniformity can be obtained. Using this methodology, we have shown that pre-mixing the binder and plasticizer, and the application of vacuum reduced mixing times from 60 min to as low as 5 min. These mixing times are a significant improvement from conventional mixers, especially during small scale developmental work.

2. Background

- Solid-liquid mixing is usually performed using “blades”. Traditional mixers present some inherent limitations. Impeller movement creates dead spots in the material. High shear contributes to excessive particle size reduction. Conventional mixing requires the blades to be as close to the vessel as possible. Increased clearance may lead to dead zones, too little and there is a risk of scrapping which is hazardous in explosives mixing. There is also a risk of contamination.
- The Resonant Acoustic® Mixer (RAM) by Resodyn Acoustic Mixers, Butte, Montana, USA is a novel mixer which uses low frequency (approximately 60 Hz) and high intensity to obtain material agitation. There are no impellers in RAM, which eliminates many of the inherent weaknesses of conventional mixers. The in-container technology also reduces the risk of contamination.

3. Experimental Section

- An inert binder/plasticizer/filler system (30 g) was used for each mixing trial.

Table 1. Inert binder/plasticizer/filler system.

INGREDIENT	WT.-%
Hydroxyl terminated polybutadiene (HTPB)	13
Dioctyl sebacate (DOS)	9
^a Sugar Coarse, 248 µm	60
^a Sugar Fine, 16 µm	20
Dye	0.1

^a Sugar, bimodal, coarse/fine ratio is 3:1.

- Experimental setup (L) and mixing vessel (R) shown below:

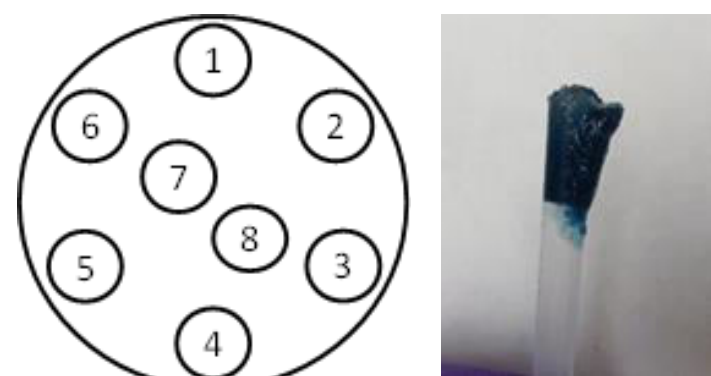


- Mixing trials and parameters used (L) and sampling protocol (R):

Table 2. Mixing trials and parameters used.

Exp	t (min)	Acc (G)	Pre-mix	Vacuum
1.1	7.5	70	No	No
1.2	15	70	No	No
1.3	30	70	No	No
1.4	45	70	No	No
1.5	60	70	No	No
1.6	75	70	No	No
2.1	2.5	70	Yes	No
2.2	5	70	Yes	No
2.3	7.5	70	Yes	No
2.4	15	70	Yes	No
2.5	30	70	Yes	No
2.6	45	70	Yes	No
2.7	60	70	Yes	No
2.8	75	70	Yes	No
3.1	2.5	70	Yes	Yes
3.2	5	70	Yes	Yes
3.3	7.5	70	Yes	Yes

Exp (Experiment), t (time) and Acc (Acceleration)



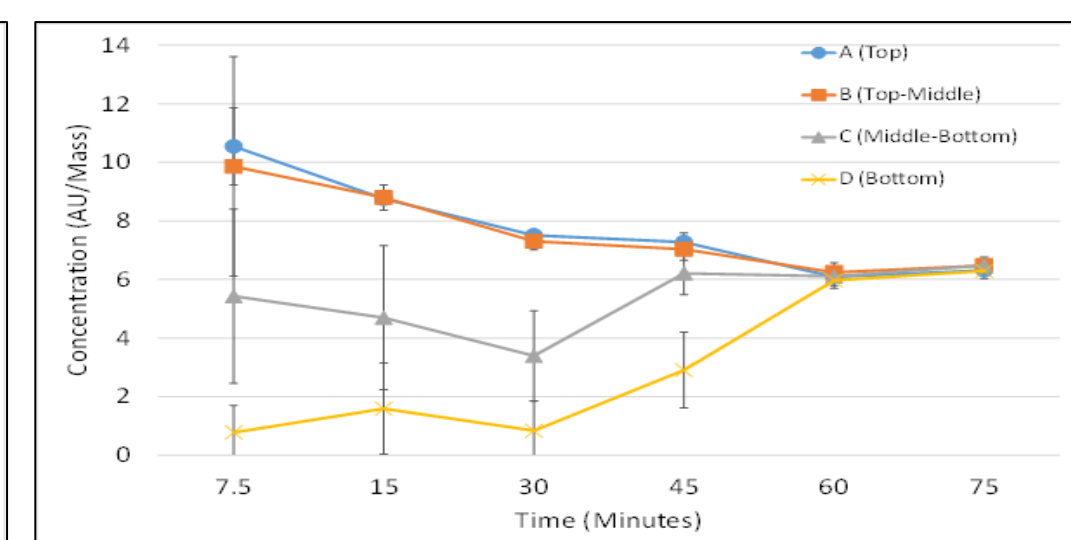
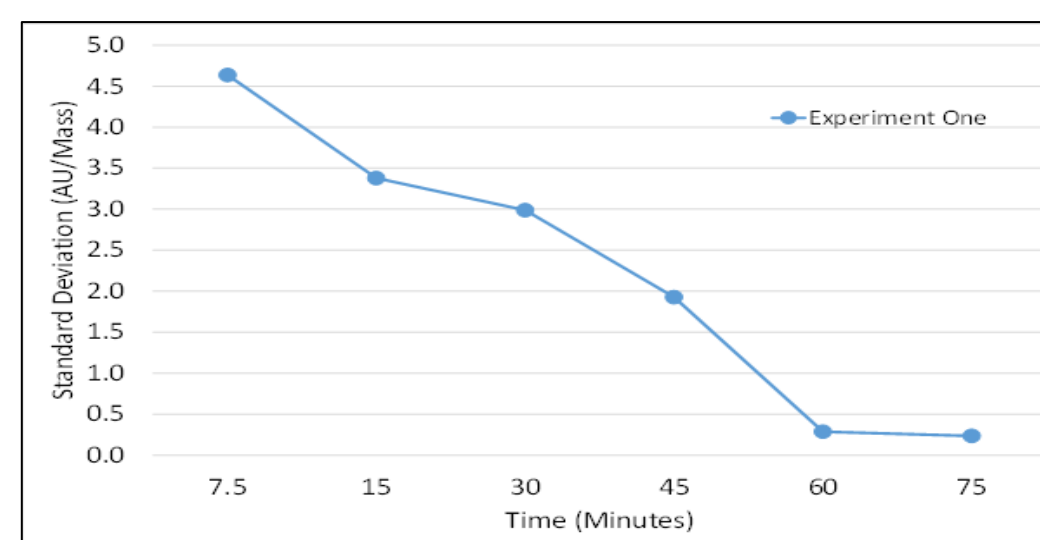
(L) Sampling map of the mixture (total 8 positions) and (R) example of an extracted core sample. Sample is approximately 10 mm in length

- A statistical approach using the standard deviation of the concentration of the dye inside each mixing trial was then used to quantify the degree of mixing uniformity. The concentration of the dye in each sample is obtained via solvent-water separation and UV-Vis spectrometry.

4. Results and Discussion

4.1 Effect of Mixing Time on Mixing Uniformity

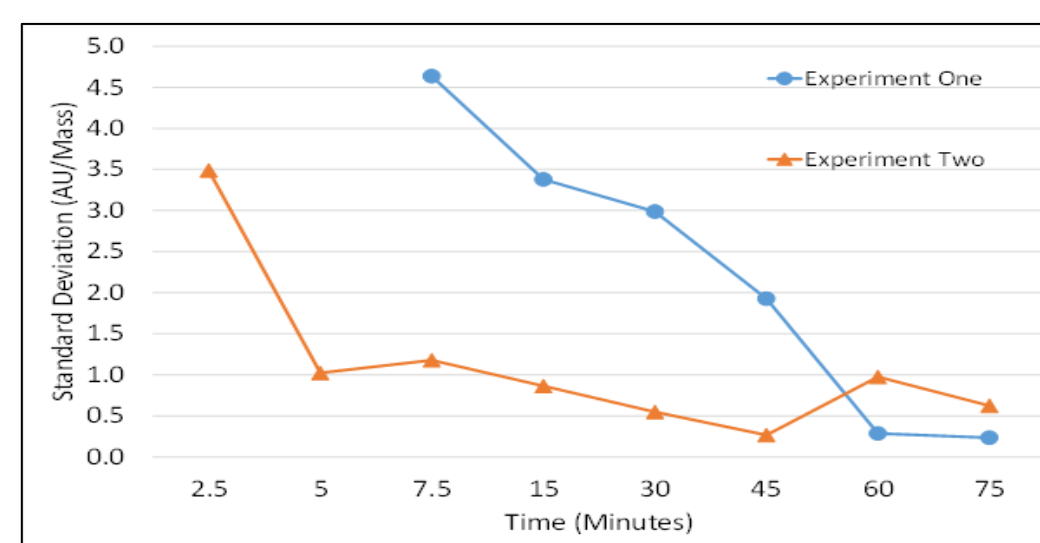
- The ingredients were loaded in the following sequence: (1) Binder; (2) Plasticizer; (3) Filler (248 µm particle size); (4) Dye and (5) Filler (16 µm particle size).



- On top: (L) The effect of mixing time on mixing uniformity (variation of the standard deviation vs. mixing time). (R) Dye concentrations at various depths (variation of the concentration vs. mixing time +/- 1SD).
- The relative viscosity affected the rate of uniform mixing. The fine and coarse sugars at the top quickly normalized after 15 min of mixing time until complete mixing at 60 min. The concentration increased at a slower rate for the plasticizer-coarse sugar boundary (C). At the bottom layer where the viscous HTPB was, the concentration stayed relatively inconsistent until complete mixing.

4.2 Effect of Pre-mixing Binder and Plasticizer on Mixing Times

- The binder and plasticizer were pre-mixed for 5 min until a single phase liquid was obtained.

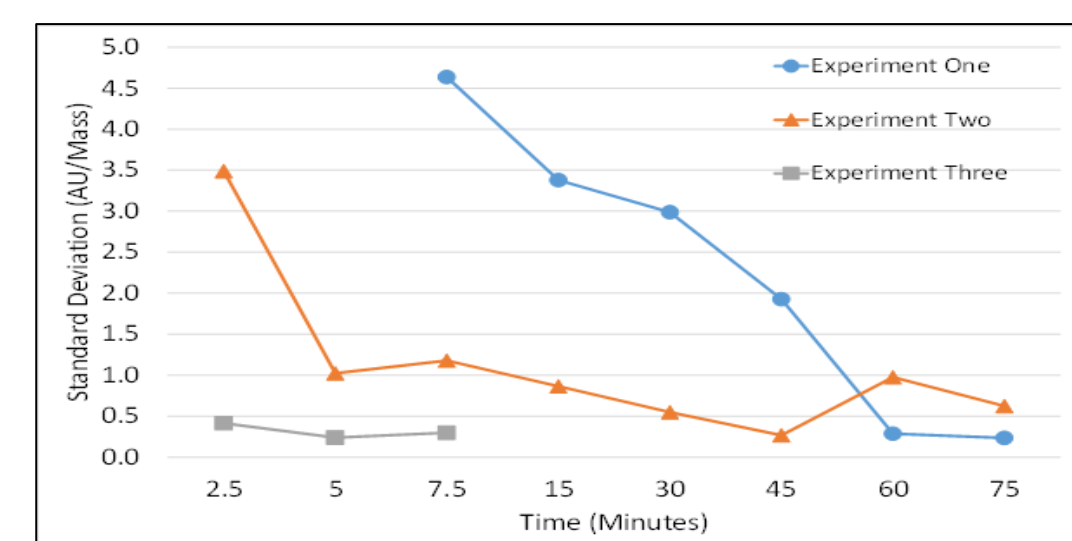


(L) Two-phase followed by (R) single phase liquid after 5 min of pre-mixing

- The time to obtain a uniform mix depends on the most viscous ingredients, the energy needed to move the viscous material is greater; a reduction in the starting viscosities of the ingredients was proposed. A faster optimal mixing time was reached after 45 min (with possible process variation).

4.3 Effect of Applying Vacuum on Mixing Times

- The vacuum system was switched on after 1 min of mixing. The vacuum reading was maintained at 91500 Pa.



- Mixing uniformity was reached after only 2.5 min. This is a huge improvement in mixing times.

4. Conclusions

- Pre-mixing and applying vacuum are both practical and feasible improvements that can be made for small scale process development.
- To enable energetic work to be performed, safety considerations such as temperature monitoring and electrostatic discharge (ESD) studies must be carried out.
- Inert materials such as sugar has a different material property and morphology compared to ammonium perchlorate (AP). Differences in particle mobility.

¹Advanced Material Engineering Pte Ltd
Singapore Technologies Kinetics
Email: yewtg@stengg.com

²Cranfield Defence and Security
Cranfield University
Shrivenham, Swindon SN6 8LA,
United Kingdom
Email: p.p.gill@cranfield.ac.uk