Rubber Mixing Equipment; Past, Present, and Future

ITEC Akron, OH USA September 2014
**The Quality Objective**

**QUALITY PRODUCT**

**PRODUCT POTENTIAL**

When properly fabricated the part must meet all physical requirements

**PROCESSABILITY**

The product mix must easily be formed & cured into the final product shape
Productivity and Quality Conundrum

Quality

Productivity
"PROCESS TECHNOLOGY"

Compound Ingredients

Compounding Machinery
THE MIXING TASK

- POLYMER
- FILLER
- MISCELLANEOUS

Resulting mixture
BASIC TYPES OF MACHINERY MIXING

TYPES OF MIXING

- REACTIVE
- DISPERSIVE
  - High shear
- DISTRIBUTIVE
<table>
<thead>
<tr>
<th>Type</th>
<th>General</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Mills                 | First Rubber compounding machine (not generally a primary mixer. They are used as a post mixer forming device) | - Very versatile  
- Broad range of shear capability  
- Accepts all feed forms  
- Good for short production runs | - Difficult to control  
- Difficult to automate  
- Batch to batch variation (due to weighments, feeding, and heat & shear history)  
- Dirty operation  
- Safety considerations  
- Low output  
- Varying power demand  
- Labor intensive |
| Batch Mixers          | Most common Rubber compounding Machinery      | - Accepts all feed forms  
- High output  
- Can be automated  
- Good for short production runs  
- Long life expectancy  
- Broad range of shear capability | - Varying power demand  
- Batch to batch variation (mixer control & weighments)  
- Post mixer variable product heat history  
- Capital intensive  
- Need post mixer forming  
- Can be labor intensive |
| Continuous Mixers     | Specialty applications                        | - High output  
- Energy efficient  
- Ease of process optimization  
- Easily automated  
- Uniform product shear & heat history | - Need free flowing feed (particulate rubber)  
- Require sophisticated weigh & feed systems  
- Not applicable for short runs  
- Capital intensive  
- May need post mixer forming |
| Twin Screw Extruders  | Specialty applications                        | - Newer technology  
- Specialty applications | - Energy efficient  
- Ease of process optimization  
- Easily automated  
- Geometry optimized for use  
- Uniform product shear & heat history |
The Mill

Dispersive and distributive Mixing
The Batch Mixer

HOPPER ASSEMBLY

HOPPER COVER

RAM or WEIGHT

ROTORS (Tangential or Intermeshing)

AIR or HYDRAULIC CYLINDER (s) (ram actuator)

Batch discharging mechanism

THERMOCOUPLE IN DROP DOOR OR END FRAME (indicated mix temperature)

Mixer motor drive & reduction set

Drop door or WEIGHT (Tangential or Intermeshing)

HOPPER COVER

MIXER MOTOR DRIVE & REDUCTION SET

HOPPER COVER
THE WORLD’S FIRST
BANBURY®
1916

THE WORLD’S FIRST
INTERMIX®
1932
Popular Batch Mixing Technologies

Intermeshing
- "Intermix®"
  - "E" series
- "GKE"
- "VIC"
  - "VIC" series
  - Banbury®

Tangential
- "GKN" & "P" "Banbury®" Mixers
- "N" series
INTERMESHING

Intermix ®

TANGENTIAL

Banbury ®
Batch Mixing Technologies

Intermeshing

“E” series Intermix®

Tangential

“N” series Banbury®
AREAS OF MIXER APPLICATION

**Intermix ®**
- specialty rubber and plastic (low temperature compounding)
- extreme quality applications
- reactive mixing applications
- single step rubber mixing applications

**Banbury®**
- high volume application
- sticky materials
- multiple step rubber mixing applications (especially final mix of high viscosity compounds)

**Intermix ®** & **Banbury®**
- medium viscosity rubber & plastic formulations
- general rubber goods
Intermix® / Tangential comparison

Shear regions in the Tangential

Dispersion

Shear regions in the Intermix®
Regarding the DISTRIBUTION, the movement of the compound in Banbury, the long wings push Compound in the axial direction, or from end to end. The ram enhances Flow from one chamber to the other.
Regarding the DISTRIBUTION, the movement of the compound in Intermix has no stagnation point. The long wings push the material in axial direction (axial flow). The two "nogs" push the material in the other chamber (rotor to rotor flow).

This way the compound can reach every point of the mixing chamber for the best homogeneity.
Intermix® / Tangential comparison

- Mixing Power
- Distribution
- Dispersion
- Viscosity reduction
- Fillers incorporation

Time
FEEDING EFFICIENCY - INTERMESHING VS. TANGENTIAL MIXERS
VIC™ SERIES INTERMIX® BATCH MIXER

Adjustable Rotor to Rotor Clearance
TEMPERATURE CONTROLLED SURFACE COMPARISON

![Graph showing temperature controlled surface comparison between Tangential Internal Mixer and Intermeshing Internal Mixer. The graph plots empty volume [dm³] against temperature controlled surface [m²]. The Tangential Internal Mixer has a line starting from the origin and increasing linearly, while the Intermeshing Internal Mixer has a line that starts from a point and decreases linearly.]

**Tangential Internal Mixer**

**Intermeshing Internal Mixer**
Intermix® / Tangential comparison

GEOMETRY COMPARISON AT EQUAL BATCH SIZE

Heat Exchange Surface > 20%
TEMPERATURE CONTROLLED SURFACE COMPARISON

Surface-to-Volume Ratio vs. Machine Size

Area/Volume vs. Machine Size

Small

Large
GEOMETRY COMPARISON AT EQUAL BATCH SIZE

The surface of Intermeshing rotors is greater than tangential.

- greater cooling efficiency
- greater energy transfer to the compound (related to the total skin friction between rubber and rotors)
- higher surface area to volume ratio
Intermix® / Tangential comparison

Filler - Phase

Rubber - Phase

DISTRIBUTION
# Intermix® / Tangential comparison

## Pros & Cons summary

<table>
<thead>
<tr>
<th></th>
<th><strong>Tangential</strong></th>
<th><strong>Intermix®</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading behaviour</td>
<td>★★★★☆</td>
<td>★★★☆</td>
</tr>
<tr>
<td>Dispersion</td>
<td>★★★★☆</td>
<td>★★★★★☆</td>
</tr>
<tr>
<td>Viscosity reduction</td>
<td>★★★★☆</td>
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</tr>
<tr>
<td>Distribution</td>
<td>★★</td>
<td>★★★★★☆</td>
</tr>
<tr>
<td>Temperature control</td>
<td>★★</td>
<td>★★★★★☆</td>
</tr>
</tbody>
</table>
Pneumatic & Hydraulic Hopper
The Batch Mixer

AIR or HYDRAULIC CYLINDER (s)
(ram actuator)

HOPPER COVER

RAM or WEIGHT

HOPPER ASSEMBLY

ROTORS
(Tangential or Intermeshing)

CHAMBER

Batch discharging mechanism

THERMOCOUPLE IN DROP DOOR OR END FRAME
(indicated mix temperature)

Mixer motor drive & reduction set
Hydraulic Ram

Potential Benefits

• Eliminates compressed air requirements

• Efficient application of high batch pressure

• Increase of process repeatability due to the elimination of the variations in the plant air supply

• Potential reduction in plant operating expenses

• Ram speed, speed profiling and position control
Conventional Batch Mixing Mill Room Machinery

Mixer & Mill (s)

Mixer & single screw extruders with pushers (roller, pork chop or pellet head)

Mixer & twin screw extruder/ sheeter
The Tandem Mixer Concept

Primary Mixer (with ram)

Secondary Mixer (without ram)

Post Mixer forming
The Tandem technology

- The primary ram type mixer has to incorporate and disperse ingredients rubber, fillers and chemicals
- For Master-batch (1 stage) or dispersive mixing prior to reactive compounding (silica incorporation)
  (Dispersive mixing must be completed in the upper machine)
- The secondary ramless mixer has to mix fed chemicals and/or complete any chemical reaction
The tandem concept

Low Viscosity Silica Tread Compound

**task sharing**

Cycle Time

Temperature curve

Primary mixer

Tandem mixer

- temp. drive side °C
- Temp. water side °C
- Drop door temp. °C
- Ram position (mm)

- Mixer RPM
- Mixer power (KW)
- Mixer motor amps
Continuous Mixers for Rubber Applications

Uni-drive continuous Mixer

MVX

CP compounder

FTX twin screw
The Continuous Mixer

1. feeding & conveying (starve fed)
2. particle size reduction
3. mastication
4. dispersive mixing
5. distributive mixing
6. venting
Multiple step compounding system

First stage (masterbatch):
Batch mixer-convex with pellet head
Followed by dewatering / drying conveyor and storing bin/drum

Second Stage (re-mill or final mix):
Continuous mixer followed by mills or convex with roller head then mill or convex with pellet head

High pressure twin screw with pelletizing head (up to 200 Bar (2900 psi))
**Power Considerations**

**Batch Mixer (Banbury)**

- Ram Position
- Power Draw
- Rotor Speed
- Melt Temp

**Continuous Mixer (FCM)**

- Melt Temp
- Rotor Speed
- Orifice Position
- Mixer Load
- Specific Energy

**Cyclic demand**

**Constant demand**

Batch Mixing requires higher duty cycle which could lead to higher drive costs
Thank you for your attention

Questions?

bob.mcnabb@us.hf-group.com