











DARAMIC®

Innovations in Enhanced Flooded Lead-Acid Batteries

Daramic's new lineup of separators are specifically designed to support start-stop vehicle battery work requirements, enabling enhanced flooded lead-acid batteries to deliver reliable battery power in start-stop vehicle applications.

As a result of innovative design and development, the Daramic® EFS™ line of separators* offer solutions that withstand voltage drop, decrease electrical resistance, and increase cycle life in enhanced flooded lead-acid batteries.

	Daramic EFS	Daramic EFS ENHANCEMENT 1	Daramic EFS ENHANCEMENT 2	Daramic EFS ENHANCEMENT 3
DARAMIC SOLUTIONS	Daramic® EFS™*	Acid Mixing Solution*	Cycling Solution*	Charging Solution*
MARKET NEEDS	Power Output	Cycling in Partial State of Charge		Dynamic Charge Acceptance
FEATURES	 Low Electrical Resistance	 Patented Rib Design for Mixing	 Special Material Reduces Shedding	 Increase Amount & Speed of Electrification
CAR & BATTERY BENEFITS	 Improved Battery/Vehicle Perception – no dimming lights, major systems remain on		 Longer Battery Life  Fuel Economy Saving  Less CO ₂ Emission	 Fuel Economy Saving  Less CO ₂ Emission

* Daramic Proprietary IP



market need
POWER OUTPUT

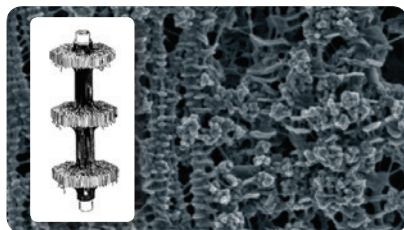
PROBLEM

- Start-stop vehicles can experience up to 70 restart events during a single commute. Each event creates voltage drops in the battery. If the voltage drops below a certain level, adverse effects, including dimming of lights and loss of power to the radio and other accessories, can occur, leading to poor vehicle perception.

SOLUTION – DARAMIC® EFS™

- Daramic® EFS™ separators* implement a unique shish-kebab polymer network that improves puncture resistance at higher porosity, lowers separator electrical resistance, and extends the operational duration of the battery by up to 44% before reaching minimum voltage.

Mechanical properties can be maintained at a higher porosity by using a shish-kebab polymer structure



market need
CYCLING IN A PARTIAL STATE OF CHARGE (PSoC)

PROBLEM

- Acid stratification causes poor charge acceptance, shorter life and higher internal resistance, limiting the useable energy and durability of the battery. Other battery designs that limit acid stratification have high cost implications.
- In flooded lead-acid batteries, limited mixing of acid requires costly equipment in order to increase electrolyte uniformity.

SOLUTION – ACID MIXING SOLUTION

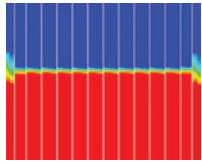
- By simulating the start-stop motion resulting from vehicle acceleration and braking, computational fluid dynamic (CFD) modeling has enabled Daramic to design a separator that promotes electrolyte mixing, providing better utilization of electrodes. These factors reduce acid stratification and improve Partial State of Charge (PSoC) performance in enhanced flooded lead-acid batteries.

continued on reverse

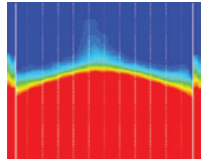
ACID MIXING SOLUTION DEVELOPMENT PROCESS
CYCLING IN PARTIAL STATE OF CHARGE (PSoC)



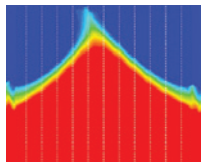
market need
DYNAMIC CHARGE ACCEPTANCE



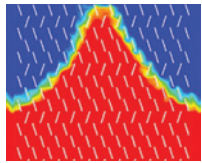
**DESIGN 1
STANDARD SOLID RIB SEPARATOR**
With a standard PE separator, the solid ribs act as baffles which contain the lateral movement of acid only yielding marginal (5%) improvement in acid mixing.



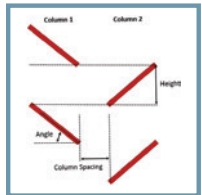
**DESIGN 2
SERRATED RIB SEPARATOR***
A serrated rib separator design expanded the mixing interface and allowed localized mixing to occur. Combined with the start-stop motion, a 10% improvement in acid mixing was achieved.



**DESIGN 3
SERRATED RIB SEPARATOR* WITH NEGATIVE ENVELOPING**
Utilizing negative enveloping allows for greater mixing while the serrated rib profile enables acid to move across the surface of the plate. Used in combination, acid mixing can be improved by 18%.



**DESIGN 4
OPTIMIZED SERRATED RIB DESIGN* WITH NEGATIVE ENVELOPING**
Finally, the design of the separator profile was optimized with the goal of converting start-stop motion into vertical acid mixing. By changing the angle, column space and height of the serration, substantial improvements in acid mixing were observed, leading to a combined improvement of 23% in mixing uniformity.



* Daramic Proprietary IP

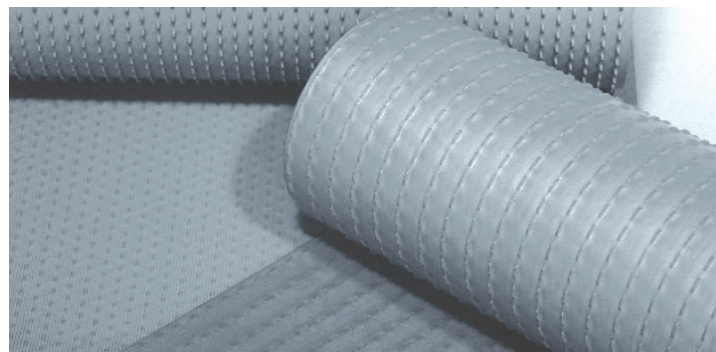
PROBLEM

- Rate limiting factors of charge acceptance have been identified, which include:
 - 1 Localized high density of lead sulfate crystals
 - 2 Poor conductance of electrons to lead sulfate layer exposed to bulk electrolyte
 - 3 Large lead sulfate crystals that limit electrode surface

SOLUTION – CHARGING SOLUTION

- Means of mitigation of these rate limiting factors continue to be explored with expected solutions using the following methods:
 - 1 Preventing acid stratification
 - 2 Improving charge acceptance & maintaining small lead sulfate crystals with carbon

Daramic is leading enhanced flooded lead-acid battery separator innovations



MIXING UNIFORMITY SCORECARD

DESIGN 1 – START-STOP MOTION	+5%
DESIGN 2 – SERRATED RIB*	+5%
DESIGN 3 – CHANGE TO NEG ENVELOPE	+8%
DESIGN 4 – OPTIMIZED SERRATED PROFILE*	+5%
TOTAL	+23%



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