GLATFELTER

The use of scrim is known to increase cycle life in flooded batteries. But as these results — validated by the world-famous IEES — show, getting the composite mix right is the key to success. Glatfelter's Brendan Naughton reports the results.

How a composite scrim laminate can reduce degradation of PAM and so extend EFB cycle life

The development and use of enhanced flooded batteries (EFB) in stop-start systems is progressing at rapid pace. One of the key improvements required to make EFB viable is increased cycle life, particularly of the positive plate.

Any claim to improve such a property must first pass the litmus test of cost-effectiveness. Seen in that light one of the promising routes is to apply a scrim material to the surface of the plate in order to reduce the degradation rate of the positive active material during cycling.

This particular approach to enhancing battery cycle life is, from a cost point of view, especially attractive. It makes it possible for one product to play two crucial roles: as pasting paper during the production on the pasting line, and then as a retainer scrim significantly increasing battery cycle life once in operation.

Glatfelter has developed a unique composite scrim Dynagrid® NG328 which performs both these functions exceptionally well. The product is a composite laminate made up of two layers, one layer of cellulose fibres adjacent to a layer of polyester (PET) fibres.

The unique Glatfelter inclined-wire paper making technology ensures a laminated product with a perfect interface between the two layers of the above mentioned cellulose and PET.

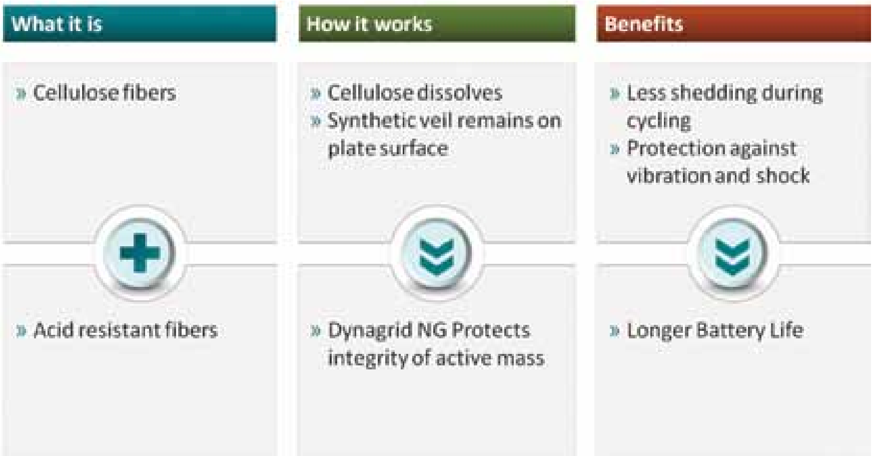

Figure 1: Schematic overview of the manner in which the Dynagrid® NG328 extends battery cycle life

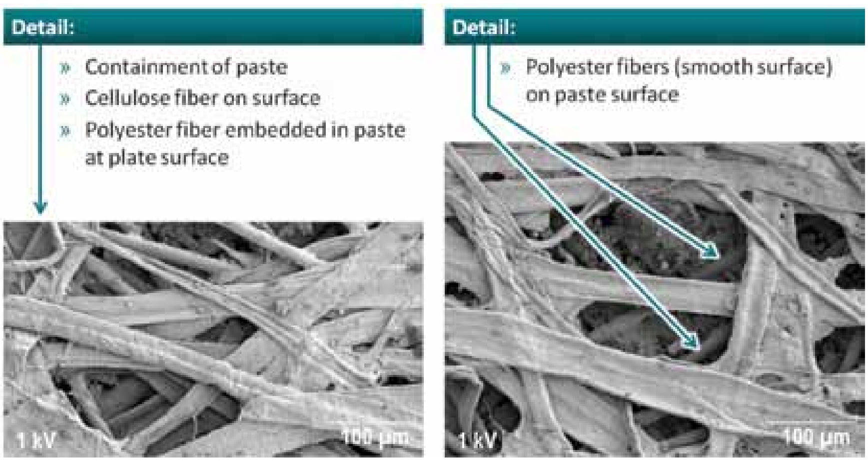

Figure 2: Micrograph of Dynagrid® NG328 in position of lead plate

The IEES study

In order to evaluate the ability of Dynagrid® NG328 to increase the discharge-charge cycle life a study was performed at the Institute of Electrochemistry and Energy Systems (IEES), a department of the Bulgarian Academy of Sciences. The investigation was carried out under supervision of Dr Stefan Ruevski with Professor Detchko Pavlov as project adviser. In this article a brief overview is given of the results.

Dynagrid® NG328 scrim (PET based) increased the DOD 50% cycle life at 40°C by more than 40%. This increase is comparable with glass scrim: Dynagrid® NG328 gave an increase of 43%, glass scrim 44%.

PUTTING IT ALL TOGETHER

Four major conclusions can be reached from this study.

- Dynagrid® NG328 scrim (PET based) increased the DOD 50% cycle life at 40°C by more than 40%. This increase is comparable with glass scrim: Dynagrid® NG328 gave an increase of 43%, glass scrim 44%.
- Neither scrim is the cause of ultimate battery failure. Both were still functional at the end of the battery cycle life and capable of functioning to a greater number of cycles.
- Visual and SEM analysis of scrim materials show:
  In the case of Dynagrid® NG 328 the individual fibres are in good condition as evidenced by unchanged fibre diameter. Also fibre to fibre adhesion is still clearly evident at the thermally bonded fibre intersections. This despite the highly oxidative test charging at 16V, 40°C.
  In the case of glass scrim, the individual fibres are likewise in good condition; however the binder dependent fibre-to-fibre adhesion is no longer present as the binder dissolves during the course of cycle testing.
- The Dynagrid® NG328 scrim reduces the rate of deterioration of electrical properties during discharge-charge cycling. This results in: better C20 capacity retention, improved cold start properties and lower increase of internal resistance during cycling. In all of these properties the effect of Dynagrid® NG 328 was moderately superior to glass scrim.

The evaluation was carried out using batteries made under carefully controlled conditions at IEES.

Four battery configurations were tested; these were:

1) a reference without pasting paper applied;
2) standard pasting paper Dynagrid® 313;
3) composite scrim Dynagrid® NG328; and,
4) a glass-fiber based scrim.

Two batteries were produced per configuration, giving a total of eight.

A 12V, 44Ah battery, L1 container was chosen for the evaluation program. To evaluate unambiguously the impact of the various pasting papers on the cycle life it is important to ensure that failure of the positive plate is the determining factor. (After all, premature failure of the negative plate would obviously invalidate the experiment.)

To achieve the desired designed redundancy of the negative plate, each cell was made using a five negative/four positive plate cell configuration. Additionally, a conservative utilization factor of 40% was used when calculating the quantity of dry active material needed for the negative plate.

IEES performed the manufacture of; lead paste, positive and negative plates and their dry-curing. Production of lead-oxide, the cast lead grids and battery assembly were carried out externally by a commercial battery producer. Battery filling with electrolyte, formation and final concentration adjustment of the electrolyte were performed by IEES.

Neither scrim is the cause of ultimate battery failure. Both were still functional at the end of the battery cycle life and capable of functioning to a greater number of cycles.

Some results from the IEES study

The test used to evaluate battery performance was based on the 50% DOD at 40°C as specified in the Volkswagen VE 75073 test protocol. This is a popular test used by many battery producers for doing a first screening of candidate materials prior to performing a full-scale qualification test program when evaluating new battery designs.

In addition to the cycle-life determination, C20 capacity, internal resistance and cold start properties were measured initially, (after battery formation), and at the end of each unit of 120 cycles. Here we report the cycle life data, the C20 capacities and some cold start properties.

Table 1 illustrates cycle life as measured using the specified DOD 50% at 40°C test. Both Dynagrid® NG328 and the glass scrim evaluated give comparable improvements in cycle life, 43% and 44% respectively.

Hence, it is seems reasonable to speculate that both PET scrim of Dynagrid® NG328 and the glass scrim functioned well in containing the

The Dynagrid® NG328 scrim reduces the rate of deterioration of electrical properties during discharge-charge cycling. This results in: better C20 capacity retention, improved cold start properties and lower increase of internal resistance during cycling.

	Reference		Dynagrid® 313		Dynagrid® NG 328		Glass-scrim	
Max. no. of cycles	229	218	224	268	324	313	307	336
Ave. no. of cycles	223.5		246		318.5		321.5	
Change per battery	-	-	0%	20%	45%	40%	37%	50%
Change ave.			10%		43%		44%	

Table 1: DOD 50% tests at 40°C and schedule of electrical properties tested during cycling test.

positive active mass and that ultimate battery failure is due to a progressive degradation of active material.

The C20 capacity numbers as in figure 3 exhibit a number of striking features.

Firstly, the initial capacities of the eight batteries are very close, which argues for a high uniformity in the manufacture of the battery achieved by IEES. This is an important result for the evaluation as we need to avoid production issues determining the outcome of the investigation.

Secondly, the impact of applying a composite scrim such as Dynagrid® NG328 on capacity is immediately visible, the C20 capacity of the reference batteries quickly drops off while the rate of reduction in C20 of the "328" batteries is the lowest.

Cold start performance is summarized graphically in figure 4. Clearly cold start performance at -18°C is dependent on the number of cycles. Also, the rate in which the CCA values decrease is dependent on whether or not a scrim was applied. Consequently, the ranking of CCA values changes as the DOD 50% cycle test progresses.

The reference batteries show the best initial cold start properties. However, after 120 and 240 cycles it is the batteries with Dynagrid® NG328 which show the best CCA values, this applies both for CCA at EN current of 300A and at CCA DIN current 180A (not reported here).

Table 3 illustrates the change in ranking as DOD 50% cycling progresses.

Teardown investigation

On completion of the cycling tests, the condition of plates was examined, here we limit ourselves to reporting the findings concerning the positive plate.

As a first step the separator was carefully slit open along each side and folded back to reveal the grid and

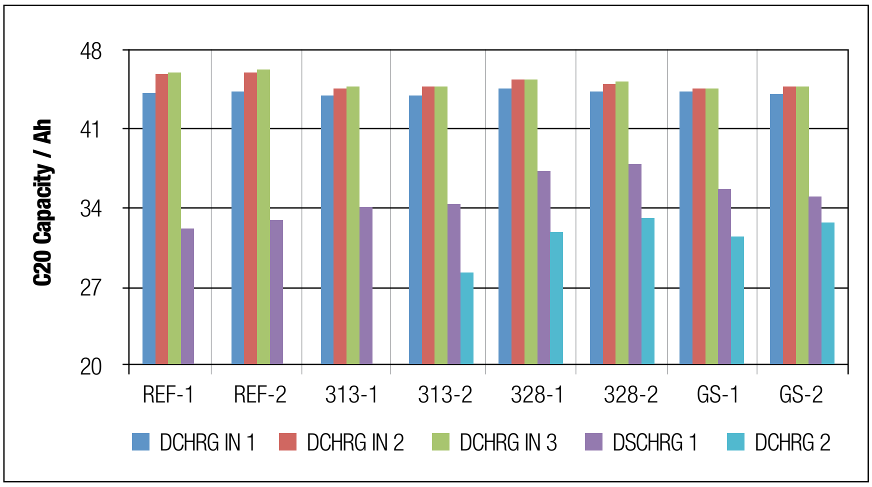

Figure 3: The development of the C_{20} capacity as cycling progresses.
Notes: • Prior to cycling indicated by DCHRG IN1, DCHRG IN2 and DCHRG IN3 • After first unit of 120 cycles indicated by DCHRG1 • After second unit of 120 cycles indicated by DCHRG2

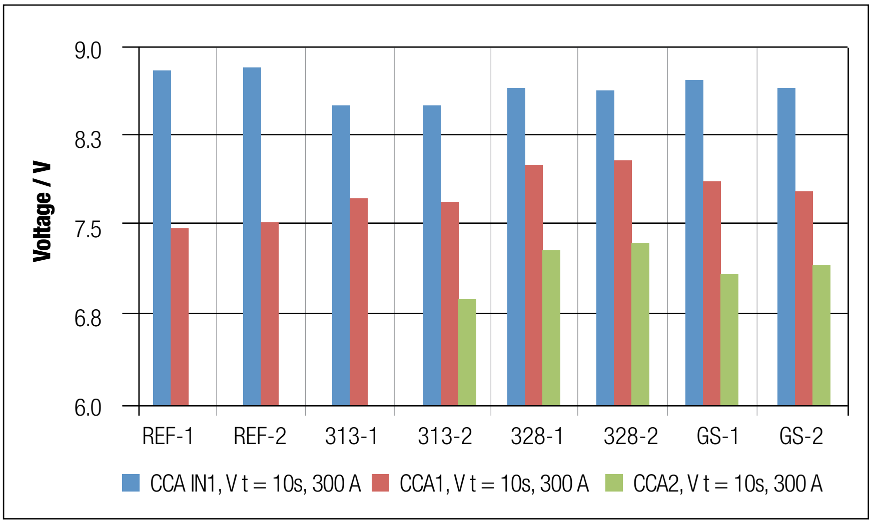

Figure 4: Cold cranking ability, EN current
Notes: CCA at -18°C • Prior to cycling indicated by CCA IN1 • After first unit of 120 cycles indicated by CCA1 • After second unit of 120 cycles indicated by CCA2

The reference batteries show the best initial cold start properties. However, after 120 and 240 cycles it is the batteries with Dynagrid® NG328 which show the best CCA values

Initial	C_{20} (Ref)	=	C_{20} (313)	=	C_{20} (NG328)	=	C_{20} (GS)
After 120 cycles	C_{20} (NG328)	>	C_{20} (GS)	>	C_{20} (313)	>	C_{20} (Ref)
After 240 cycles	C_{20} (NG328)	>	C_{20} (GS)	>	C_{20} (313)		

Table 2: Changes in the ranking of C20 capacity values as cycling test progresses.

Initial	CCA (Ref)	>	CCA (GS)	>	CCA (NG328)	>	CCA (313)
After 120 cycles	CCA (NG328)	>	CCA (GS)	>	CCA (313)	>	CCA (Ref)
After 240 cycles	CCA (NG328)	>	CCA (GS)	>	CCA (313)		

Table 3: Changes in the ranking of CCA as cycling test progresses

Figure 5: (a) Positive plate from the reference battery after removing the separator, shedding is clearly visible (b) Positive plate from Dynagrid® NG328 battery after removing separator, active mass is held in place with material loss through shedding being prevented.

Figure 6: (a) the PET scrim after removal from the positive plate with its structure intact. (b) shows part of the glass scrim, removal was problematic as the fibres have lost their mutual cohesion

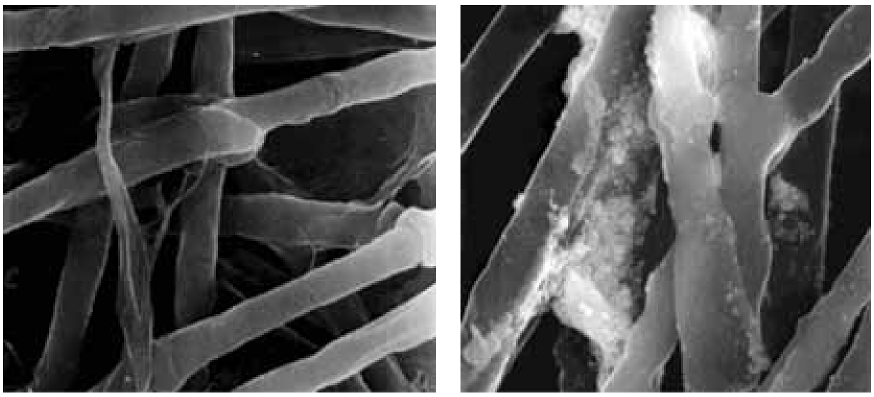

Figure 7 (a) SEM image of the PET fibre side of Dynagrid® NG328 before use, (b) image of PET fibres' after discharge-charge cycling to end of battery life, magnification 500x

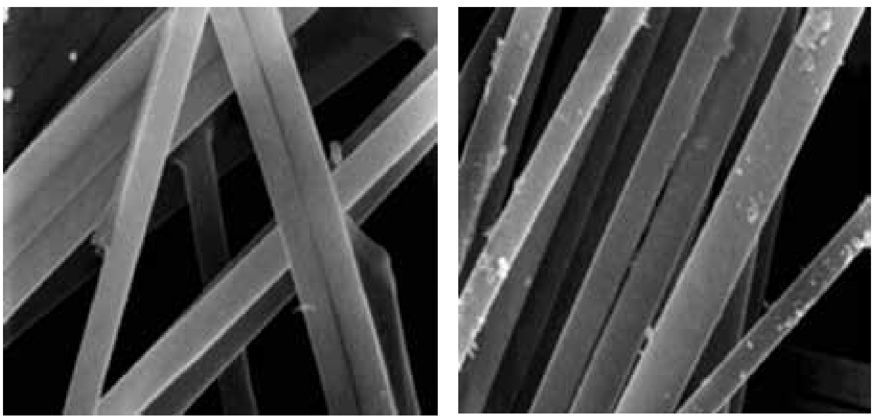

Figure 8: SEM image of the glass fibre scrim before (a) and after (b) testing, magnification 1000x

positive active mass. From the visual inspection the following observations could be made:

- The positive plate of the batteries manufactured without scrim shows extensive disintegration. The PAM has lost its adhesion with the grid, is loose and tends to fall out of the grid on handling.
- Positive plate of batteries manufactured with either PET or glass scrim are visually intact. The scrim is in place and supports the PAM in the grid.
- On removing the scrim from the surface of the plate the PAM comes loose.

These observations are further illustrated in the two images in figure 5.

As a second step the scrim itself was examined. On removal of the scrim the following was observed:

• The PET scrim is intact; individual fibres appear sound and bonded to each other. This meant that removal of the scrim from the plate surface was easy to do.

• Glass scrim is also intact on the plate; however the fibre to fibre adhesion was significantly reduced. Removal of the glass scrim from the plate surface was problematic with the scrim disintegrating once subjected to gentle pulling force.

These two observations are illustrated in the pictures in figure 6.

Figure 7 shows show the PET fibres to be intact with their diameters unchanged.

Also thermal bonding between fibres at their intersection points is clearly evident.

Dynagrid® is a registered trademark of Glatfelter

Brendan Naughton has been business development manager for the past three years at Glatfelter for electrical markets where his primary focus is on energy storage and transmission. He says: "I delight in the opportunity to explore the many battery chemistries out there and find novel ways to improve performance which we can exploit together with our customers."