

EPOSIL® for Automotive Suspension Components, Coils Springs and High Pressure Vessels

Max Sardou
Sardou Societe Anonyme

Patricia Djomseu
Qip Sarl

ABSTRACT

SARDOU SAS has developed highly stressed composites parts for 35 years. SARDOU SAS and QUALITY INDUSTRIAL PRODUCT invented composite coils springs in 2002. Developing composite coils springs, we have faced a big challenge, how to increase the short life expectancy of this highly stressed structure?

We have identified that the weak point, in composite coils springs, is its epoxy matrix. In fact, during heavy loading, the matrix undergoes micro cracks. Then, during fatigue, micro cracks propagate and merge, transforming the matrix into a fine powder. The composite coil suspension springs, using, classic epoxy, were ruined after only 100,000 cycles in the best cases. The fact to integrate "functionalized silica aggregates", in the matrix, enable the springs to exceed 1,000,000 cycles, with the same spring design. In addition, the spring stiffness has increased by 6% and the thermal set has reduced by 1.6%. Based on these results we have worked, over 7 years, to develop, refine, and improve the efficiency and to reduce the cost of our technology.

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I. INTRODUCTION

Since 1980 SARDOU SAS has been involved in development of equipment for ground transportation. Nowadays the overall trend is to improve material mechanical performance, save weight, and increase the range of working temperatures.

Automotive: In order to save weight, many OEM's are considering replacing metal with composite parts, made of carbon fiber and epoxy. Replacing metal by composite is a smart solution for these reasons:

- It offers the potential to replace a number of metal parts on the automobile and, for example, to cut in half the weight of expensive aluminum forged suspension components (Fig 12).
- It offers the potential to produce light, high pressure storage vessels, for hydrogen and CNG (Fig 11).

Using carbon fiber and epoxy composite, OEM's [1] are planning to reduce weight of their vehicles by up to 350 kg. As a result, they expect to save:

- 1.2 liter/100 km fuel consumption,
- 3 g of CO₂/km emission.

Railways, especially subway: Reducing the weight of the unsprung structure provides significant energy savings and reduction in track damage.

Aircraft: The weight of the structure is an ongoing operational cost and performance issue. For instance, the structure of Tiger helicopters use 80% composites, and new aircraft like the Boeing 787, Airbus A350 and A400M are using composites for 53% of their structures [2].

Spacecraft: The weight and cost of the structure are the main drivers. New VEGA and future ARIANE VI rocket will use composite solid thruster elements. (Fig. 13)

Disadvantages

Classic epoxies are not tough enough in the following applications:

- When high levels of shear stress are applied to composites, especially in springs and suspension systems. This is specifically the case on composite coils springs.
- When parts, like suspension components, are exposed to road damage, such as high-energy impacts from stones (Fig 15).

- When high-pressure tanks exert a heavy outward load on the composite structure, there is a risk that the epoxy will be “cut” by carbon fiber tension effect (Fig 11).

Solutions = EPOSIL®

EPOSIL®

- Is a compound of classic “organic epoxy” and of “mineral epoxy”.
- Is REACH compliant.
- Can be implemented using techniques of standard composite manufacturing.
- Can be reinforced with all kind of fibers such as: glass, carbon, aramid, silica....
- Can be polymerized in the same way as standard organic epoxy resin.
- Can be used in temperatures from -40° to 150° C.
- Can be optimized for all composite techniques such as: prepreg, RTM, filament winding, BMC, XMC...

II. DEVELOPMENT MOTIVATIONS OF EPOSIL®

During the development of composite coils springs, it was found that a rapid degradation of the matrix, in the interface between two plies of UD fibers, was occurring. It was determined, that, under load, the degradation mechanism was the development of microcracks. With continued cycling, the microcracks propagated and merged, after a certain number of cycles, the matrix was transformed in powder and ruined the structure. Fig. 1 shows this mechanism, and the ultrasonic emission occurring during the first three first spring compressions.

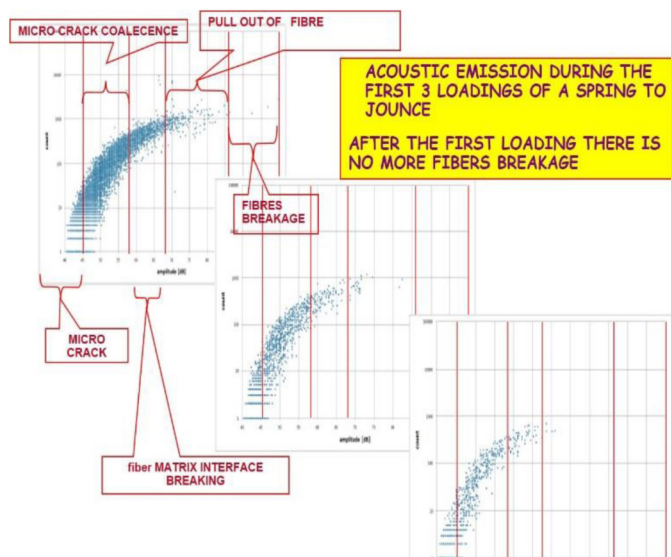


Figure 1. Composite coil spring “US” monitoring during “three first loadings”

In order to reinforce a matrix, current state-of-the-art is to add “little loading particles”. Fig. 2 shows that the Composite life expectancy, versus composite loading, reaches an optimum at 50 %, by volume, of fibers loading. As can be seen in Fig. 2, it is clear that to improve mechanical performance of the structure, all available strength in the form of “UD” working fibers needs to be used.

Conclusion: if we want to reinforce the matrix, we have to find a solution which is not a “classic loading” solution.

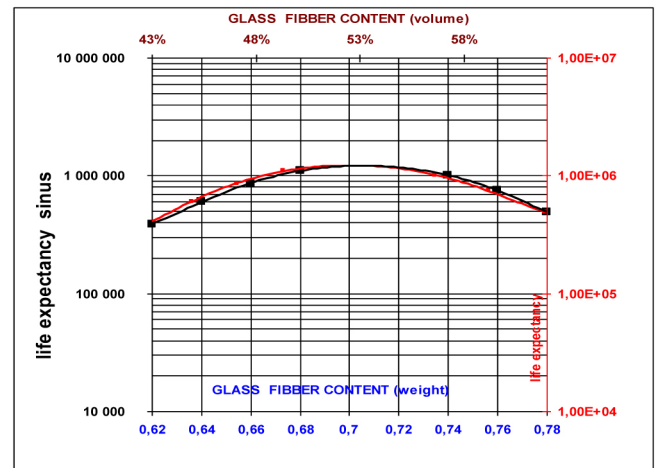


Figure 2. Composite fatigue potential versus “UD” loading [3]

III. DEVELOPMENT OF EPOSIL®

After evaluating a wide variety of potential loading particle candidates, we have selected a dendritic silica micro particle, shown in Fig 3. This silica is the aggregate, by covalent bonding, of a number of silica nano-pearls of around $0.020\ \mu\text{m}$ diameter. The typical aggregate length is around $0.200\ \mu\text{m}$ to $1\ \mu\text{m}$.

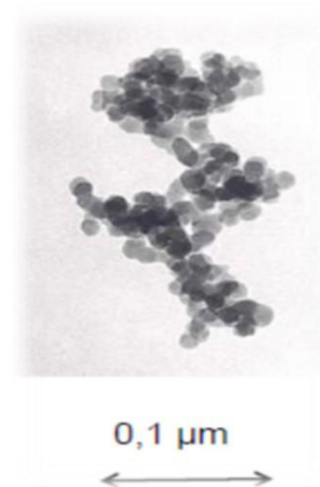


Figure 3. SEM “Staple morphology” of the selected silica aggregate.

It has been necessary to develop a unique solution in order to transform this silica in an “epoxy with silica aggregate structure”. Using a patented process, we apply, a perfectly controlled monomolecular surfactant layer to the silica aggregate surface. This monomolecular surfactant layer offers “epoxy functions” on the outer surface of the silica. With this, on a single silica aggregate epoxy, it is possible to gang up to 100,000 active epoxy functions.

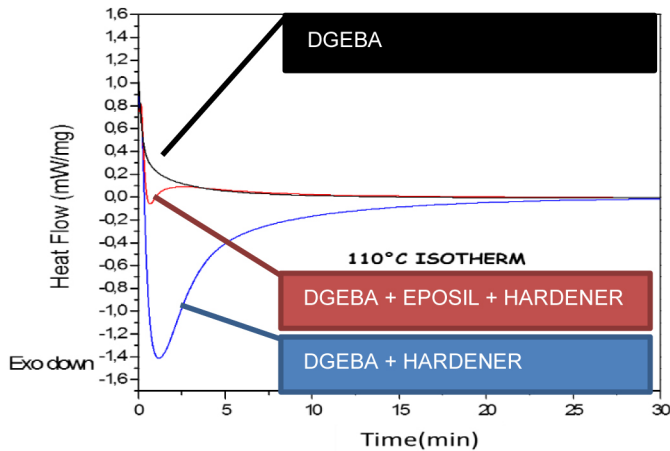


Figure 4. DGEBA + EPOSIL + hardener behavior–

This big number of epoxy functions, when reacted with the hardener molecules, provides a high density crosslinking. Moreover [Fig 4](#) shows that a compound using EPOSIL[®] reacts 155% more rapidly than pure organic epoxy. So EPOSIL[®] is acting like a “polymerization precursor”. We obtain, thanks to the “silica epoxy”, a huge reinforcing potential of the surrounding organic network. The Young's modulus of the silica, being 30 times the modulus of the organic epoxy, acts as a matrix reinforcing agent. The dendritic topology of the silica provides a powerful microcracks blocking mechanism, as illustrated in [Fig. 5A](#).

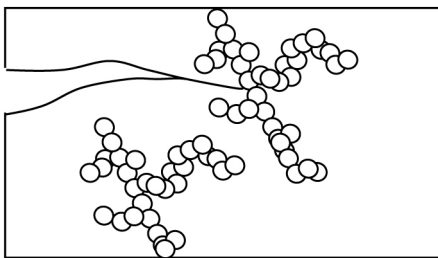


Figure 5 A. Illustrates the micro-cracks blocking mechanism, “silica aggregate epoxy” acts as a micro reinforcing staple.

Thanks to EPOSIL[®] composite coils springs life expectancy was increased by more than ten times. As illustrated in [Fig. 5B](#), using EPOSIL[®], we end up with a “three-stage composite structure arrangement” made of an organic matrix containing functionalized micro-reinforcing particles and macro reinforcing structure, like yarn or UD fibers. It is possible to disperse in any organic resin the “silica aggregate epoxy”, in order to achieve the level of concentration needed to match performance and viscosity requirements.

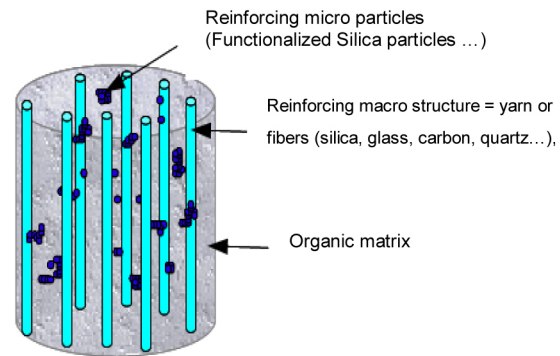


Figure 5 B. Three stage composite structure arrangement

The organic resin can be any kind of structural resin such as: epoxy bisphenol A, epoxy bisphenol F, epoxy Novolac, Cyanate esters, aeronautic 3 or 4 functions, etc.

If a high concentration, of “silica aggregate epoxy”, dispersed in a matrix, is used, the result is a relatively high viscosity, analogous to a thermoplastic material.

If chopped glass or carbon fibers are added to the system, the chopped fibers will be trapped in the dense compound matrix.

Because of this high viscosity, it is possible to inject the compound, into a mold, as if it was a reinforced thermoplastic or a high pressure metal molding process. It is also possible to add inserts, dry fibers, or dry yarn into the mold. The fibers will be impregnated by the excess resin from the compound during the injection process.

Doing so, we can get XMC and BMC ready-to-use, reinforced structural parts. Parts produced by this technique, at ultra-low processing cost, offer high stiffness and half the weight of aluminum counterparts. [Fig. 6](#) shows an example of a feasible part, a V8 engine block, using the XMC process.



Figure 6. Xmc ready to use reinforced structural parts can replace aluminum casting saving 50% weight as well as machining.