Light Solutions

The Crossfire vision for the future Automotive

Let's define them,
based on the final
applications

June 2016

Lightweight

- **The drivers for the future bodies**
  - Less energy required to move
  - Less CO2 emission
  - Equal or better safety (ductile crash)
  - High and very high productive throughput
  - On the overall investment, competitive with the current steel parts
  - Stress and vibrations resistant; noise dampening
  - Eco friendly (no VOCs , no Solvents)
  - Fire Resistant or Retardant
  - Recyclable
  - **Parts cost, competitive with the current**

The Costs question

- By **Finished Part** and not by RM Kg
- The Zero scraps policy to produce (re-use your cut-offs)
- The best the FEA design the lowest the weight
- The Lowest investments technology
- The Highest production rate
- The Minimum steps to a "ready to assemble" Part

THINK COMPOSITE !

The Crossfire vision
the new generation Composites

- The Fabric choice driven by the final mechanics
  - Glass; Carbon; Aramid; Basalt;
- The Resin choice driven by
  - The lowest viscosity at molten stage (impregnation by capillarity) to a complete impregnation
  - Tg, al least, over 100°C
- The process choice driven by
  - High speed (seconds to few minutes)
  - Possibility to over mould
  - Possibility to "In Mould Coating"
  - Possibility of "In Mould adding inserts"
    - To the "most finished" part to reduce the finishing costs
  - "No Glue" assembly by Stage B

The Key concepts

- Structurality
  - Defined by the application
- Isotropy/Anisotropy
  - Defined by the material

The structurality

- High Structural
  - Must resist to high, static and dynamic, stresses
    - Example: Body in white, Suspension arm, ….
- Medium Structural
  - Must resist to, mostly, static stresses
    - Example: Bonnet, Trunk floor, …
- Low Structural
  - Mostly is a static cover, to prevent from relative shocks and static loads
    - Example: Flat bottom, Fender, …

Isotropy/Anisotropy

- Isotropy:
  - Same performances in any direction of the space
    - Example: steel and any metal
- Anisotropy:
  - Different performances in different directions of the space
    - Example: bamboo cane

The Composites
Low Structural

- **Reinforced plastics made by:**

  Chopped fibers, SFT/LFT
  - Random, isotropic pattern

  Thermoplastic Resin (PP; PA; PC; PBT …)
  - Relatively low fibers wettability
  - Relatively high resin content
  - Injection Molding process
- Possible over molding to a Medium/High Structural Thermoplastic or Hybrid Composite fabric

The Composites

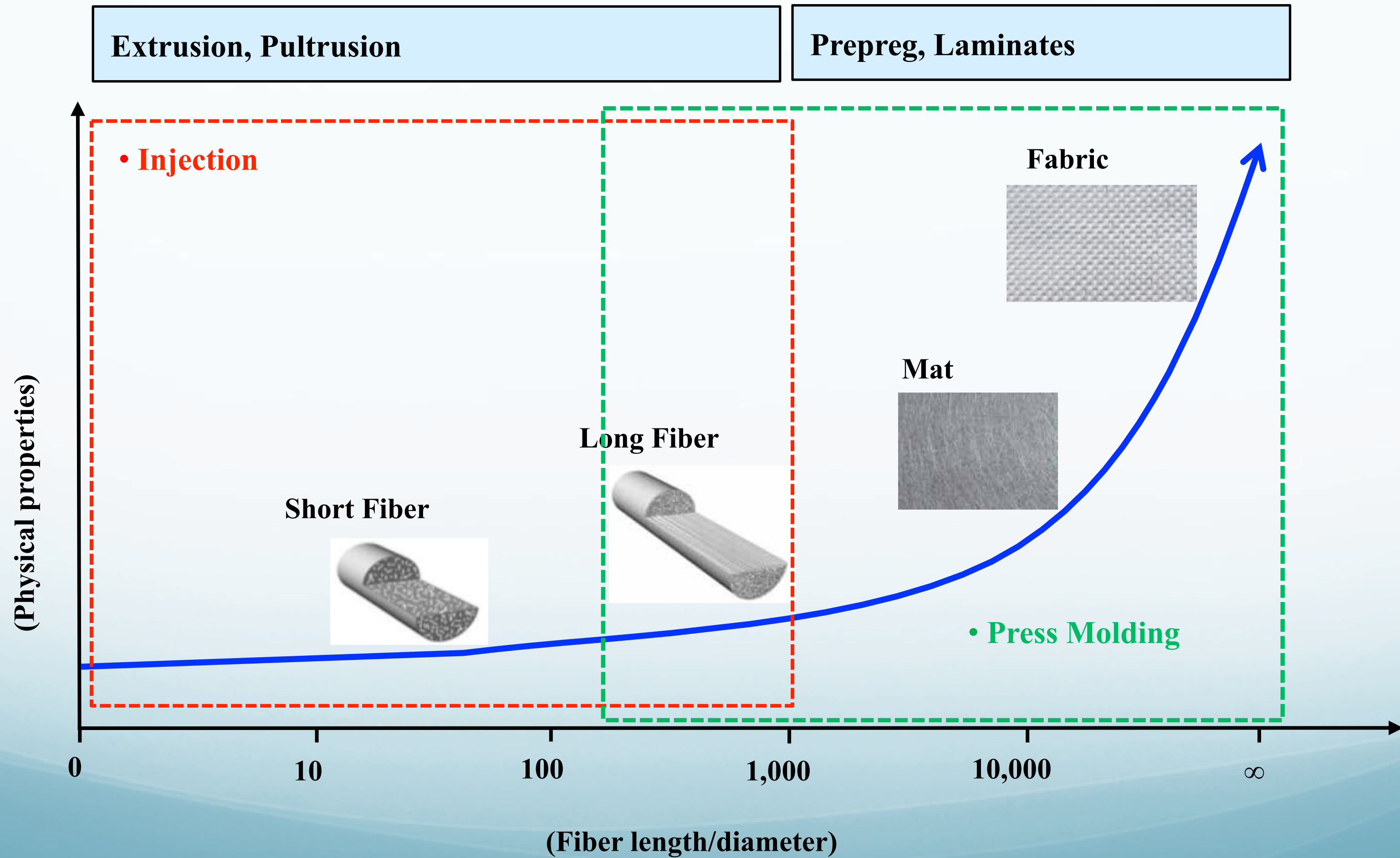
Medium Structural

- **Fabric, quasi isotropic/anisotropic**
  - Large network of the fabric/mat to facilitate the resin filling.
  - **Incomplete resin saturation** :
    - **By Thermoset resins**
      - Into a close mold impregnation/curing (RIM, RTM, SMC)
    - **By Thermoplastic resins**
      - Impregnation of the fabric by high Temp/Press technologies
      - Shaping by Press Thermo Forming
        - Tepex (Lanxess); Twintex ; Vizilon (Dupont) ; Tricap T (Samyang) …

The Composites
High Structural

- **Fabric, quasi isotropic/anisotropic**
  - Packed fabric by thin filaments/layers
- **Full saturation resins**
  - Impregnation by capillarity (Very low viscosity)
  - Impregnation by high pressure (low viscosity)
    - **Thermoset resins**
      - Autoclave process by PrePreg
    - **Reactive hybrid resin (thermoplastic behaving)**
      - **Hot Press molding process** (no size limits) by reactive laminate PrePreg
        - Tricap® P
      - **Cold press molding process after pre-heating** (dimensional limits) by hybrid cured laminate
        - Tricap® L
  - **"In situ" reactive chemistry (RTM)**
    - (PCL anionic, CBT oligomer) not industrial yet

The fiber length
reinforcement path



The impregnation

- Phisical phenomenon
  - The resin molecular size compared to the available space to enter = viscosity
  - Indicative rating of the molten resin categories:
    - Thermoplastic = abt. 2000 mP/sec
    - RTM and Autoclave = abt. 500 mP/sec
    - Hybrid reactive and Oligomers = below 100 mP/sec

- Chemical phenomenon
  - Capillarity
  - Surface tension and polarity
    - = wettability

The problems

- **Brittle brake**:
  - No plastic phase in the stress/strain but :
    - **Crossfire** can build an artificial plastic phase on the article by structural sandwiches
    - **Crossfire** can make ductile the composite laminate braking, by the introduction of property ductile films chemically bonded to the Hybrid resin
- **Fire resistance**:
  - Organic resins are easy to get on fire
  - The FR packages addition makes the impregnation even more difficult
    - **Crossfire** can protect by property FR film (V0 at UL) chemically bonded to the Hybrid resin

The Structural sandwich

- **Sandwich** is a great engineered solution to give very high structural solutions without increasing the mass weight
- The sandwich thickness is the driver to define a deflection, under a given load, value
- The type of core material is either the reason or the consequence of the given thickness/deflection
  - At equal thickness, a honeycomb core will offer higher rigidity (less shear) than the obtainable by a structural foam
  - But the higher shear by the foam compressibility will offer a certain % of plastic elongation before of the break
- Sandwiches made by Tricap®P will avoid any glue ; the extremely low viscosity of the reactive resin, will act like a perfect glue by capillarity

Structural cores

not a complete list but the most used

- **Nomex (Dupont)** ; very light and strong Polyaramide HC; variable thicknesses are obtained by tooling in advance of the press operation; the highest rigidity obtainable
- **Soric (Lantor)** ; A HC like, pre-marked, Polyester matt; weight about 70Kg/m3, It allows the creation of a Tricap®P resin made HC structure and total freedom of variable thicknesses without pre tooling; within a max 6mm thickness, it allows a wide variety of rigid/flexible solutions
- **PET (various)** ; PET foams (even by recycling sources) at variable specific weight (60-80Kg/m3 minimum); does not allow any HC like cross-section, but offers an interesting resistance to squeezing loads and enough shear to give a certain elongation before of the break at thicknesses even largely over 6 mm
- **Paper HC (various)** ; very light and very cheap; ideal for medium/low structural panelling
- **Aluminium HC (various)** ; very light and FR

Process Conditions

The differences

- **Full Thermoplastic and Reacted Hybrid Composites**
  - Mold at lower than the resin crystallization point (as cold as possible) after an external heat up
    - Aesthetic layers; gluing; inserts positioning; … possible only in second later stage
- **Reactive Hybrid Composites**
  - Hot mold operations (reacts and pickup at constant high T°C)
    - Possible external pre-heat of the components
    - Reactivity and chemistry strictly driven by the temperature
    - Easy integration of further processes into the same molding operation (sandwich; inserts; in mold coating; …)

The driving Laws

- **Darcy's law (speed e quality of the impregnation)**
  - low viscosity = fast
  - high pressure = fast
  - high permeability = fast

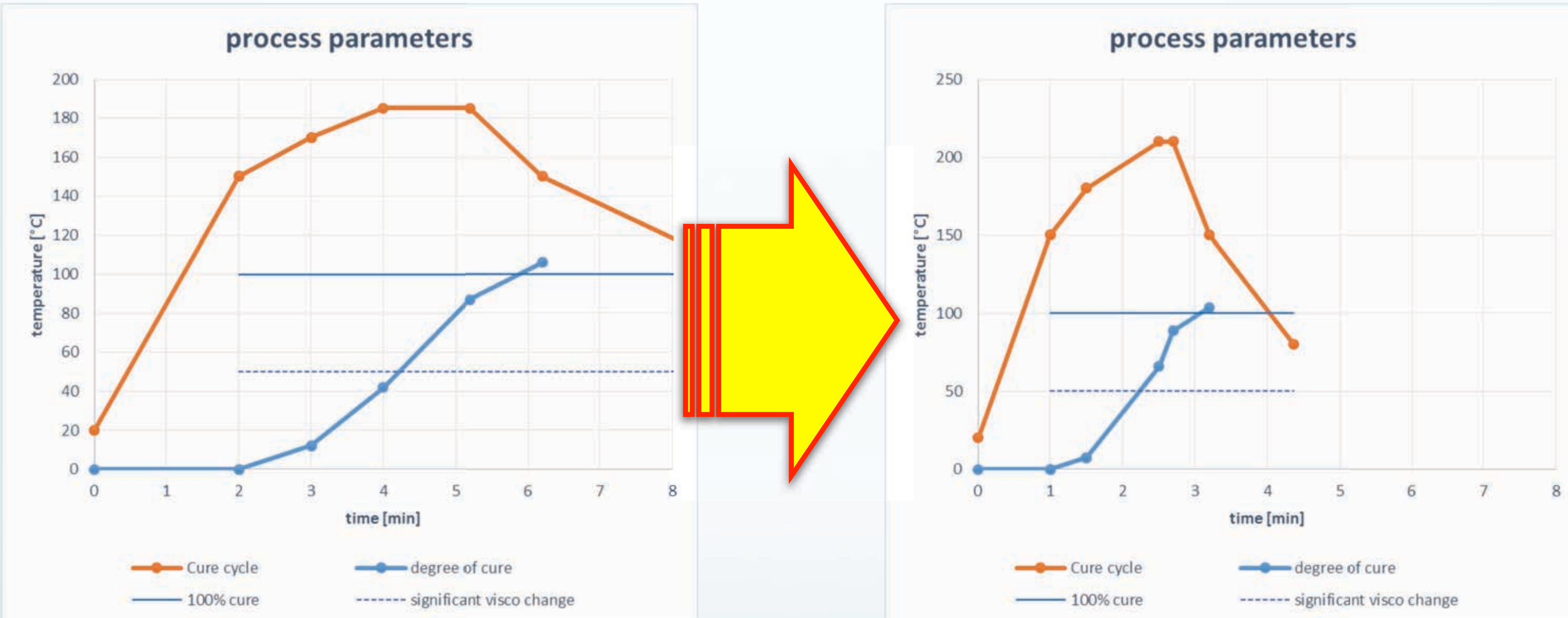
$v = |k(p).\Delta p / \mu|$

- **bending stiffness & deflection**
  - high Modulus = less deflection
  - high I_y = less deflection
  - thick = less deflection

$f = Fl3 / 3EIy$

$Ibeam = b.h3/12$

The Hybrid reactive system



- **Key parameters:**
  - **Physics**: heat ramp up(= minimum viscosity), max temp,
  - **Chemicals**: reaction time, viscosity change, “gel time”,…

In Mold coating

- **PIMC (Powder In Mold Coating)**
  - solvent free (no VOC's)
  - Includes release agents
  - base coat and/or top coat
  - "all" colors possible (even transparent)
  - Minimum Post processing

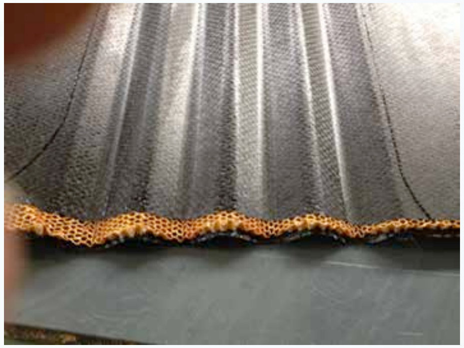
Inserts addition
(by direct resin gluing)

- integration
  - various inserts (bolts,…)
  - distance calibrations
  - profiles
  - core materials
  - bonding
  - b-stage assembly

The project of a part.......

- When a solid ?
  - The highest rigidity and stiffness
  - Constant thickness
  - Limited size
  - No further surface finishing
  - Easy over moulding at the part forming
  - The highest productive throughput

The project of a part.......



- When a sandwich ?
  - The lightest solution
  - Variable thickness
  - Any size and dimension (no limits)
    - Out of the Press Technology Available (ex.. wind blades)
  - Additional surface finishing
  - "Powder In Mould Coating" finishing
  - Inserts positioning in the mould
  - Noise dampening and thermal insulation
  - A certain elongation % before of the break
    - **All in a single shot process**

Providing full solutions

- Crossfire is your Partner to develop and make real your lightweight solutions
  - Listen and understand your Light-Weighing need
  - Address your FEM Modelling or bring you a FEM Modelling proposal on your Specs
  - Propose you the Composite technological solution by an economical pre-evaluation (RM + Investments) by selecting with you the most suitable RM
  - Makes the Pre-Series and can make small serial productions (up to a few thousand parts/y)
  - Drives the Build up of your large scale production line and brings you the full technological package and know how

Crossfire Srl

via Corona 1, 48027 Solarolo (RA)
Italy

Swiss CMT

Bahnofstrasse 35, 8854 Siebnen
(CH)

- "always ahead in technology"