

Bicomponent Fibers for Thermoplastic Composites: Towards a New Intermediate Material for Rapid Stamp Forming

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1 Stamp Forming of Thermoplastic Composites

Today, fiber-reinforced composites are broadly considered to be lightweight but labor intensive alternatives to conventional engineering materials and are thus seldom chosen for high volume production schemes. Let's change that!

Composites with thermoplastic matrix systems offer alternative processing routes and provide a higher potential for recyclability than those containing conventional thermosets. However, the desired low cycle times are currently only achievable in stamp forming using comparatively expensive organosheets. Stamp forming of thermoplastic composites is still a promising method for high volume production and facilitates the transition of using composite materials in existing sheet press plants. The issue at hand lies not with the process, but with the intermediate material.

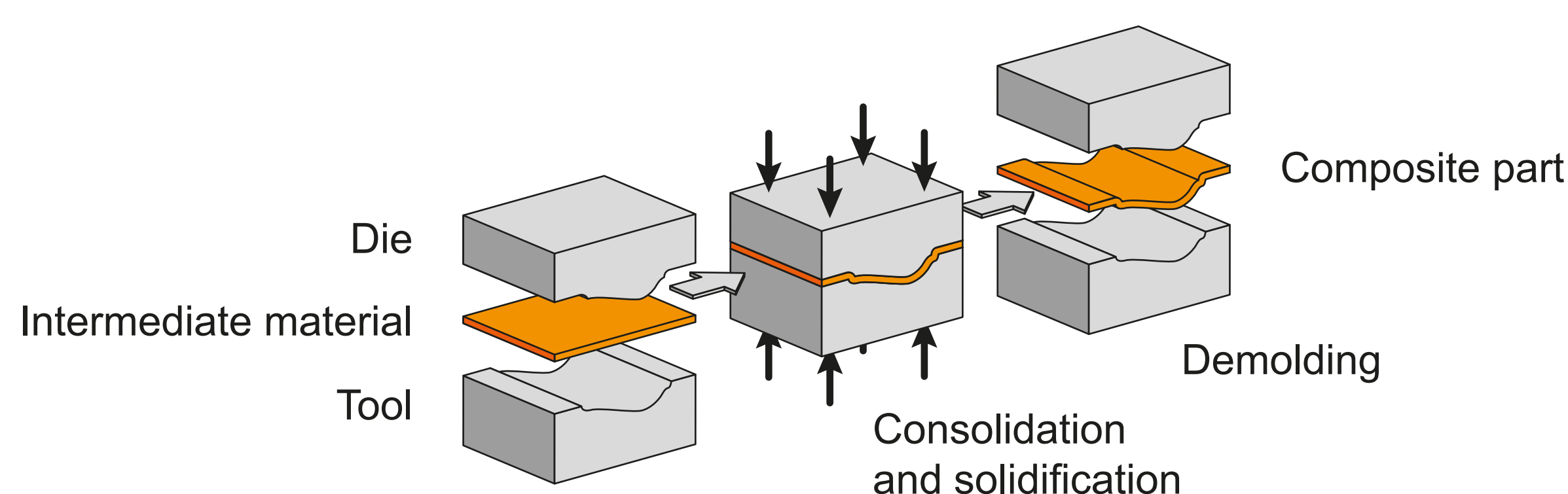


Figure 1 Principle of stamp forming of thermoplastic composites.

Known alternatives for intermediate materials provide different degrees of hybridization, meaning the intimacy of mixture between the reinforcing fibers and the matrix. Examples are hybrid weaves and commingled, powder coated or overjacketed yarns. But to achieve processing times under two minutes, which would be interesting for the automotive industry, a more intimate degree of hybridization is still needed.

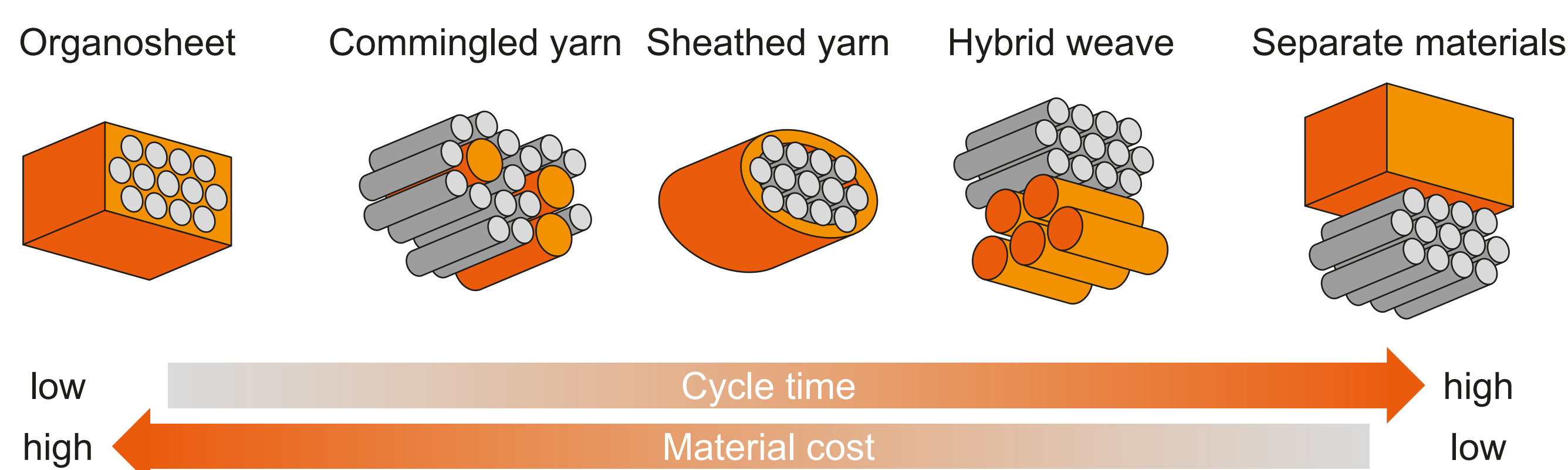


Figure 2 Morphologies of organosheets, cheaper intermediate materials and separate reinforcement and matrix materials.

3 Dip-Coating Trial

Small samples of bicomponent fibers have been successfully manufactured by dip-coating. Small strands of glass fibers were drawn by hand through solutions with varying concentrations of poly(ester-amide) (PEA, see info on the right) in chloroform.

SEM imaging revealed the surface topology of the coating and by concentrating the electron beam on the polymer sheath, it burned away locally, thus revealing the glass core and allowing to measure the sample's fiber volume content.

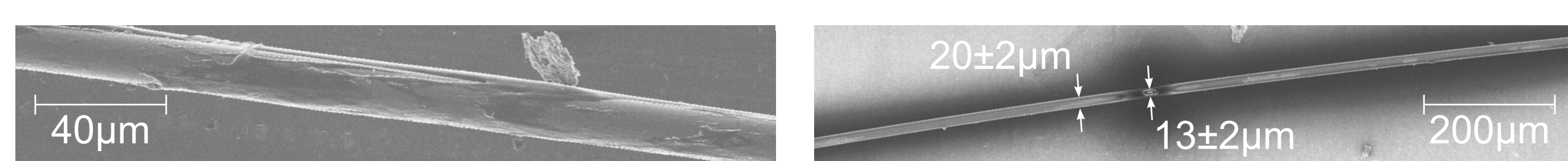


Figure 5 Micrographs of single glass fibers dip-coated with dissolved PEA. Right: The burnt polymer sheath reveals the diameter of the glass core, the coating results in a fiber volume content of 42%.

4 Challenges in the Production Process

Assuming that bicomponent fibers would perform equally well in rapid stamp forming as organosheets do, the material's competitiveness is dependent on its cost and therefore related to the output rate of production. Figure 6 shows achievable withdrawal velocities in dip-coating, calculated using three different models for the coating thickness.

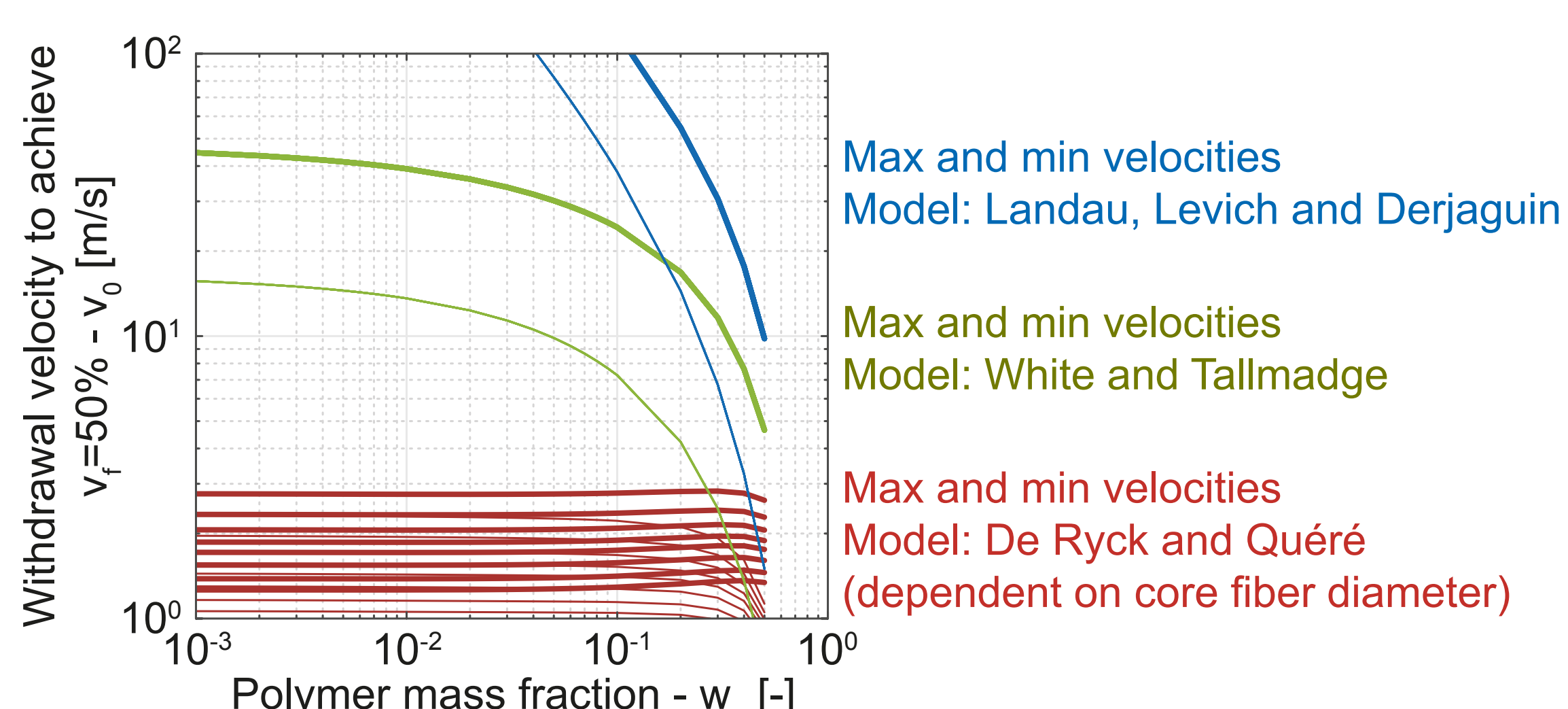


Figure 6 Necessary withdrawal velocities versus polymer concentration to achieve bicomponent fibers with a fiber volume content of 50% using dip-coating. Models reviewed in D. Quéré, Annual Review of Fluid Mechanics, 1999.

2 The Concept of Bicomponent Fibers

The time needed for consolidation of the preform before solidification (cooling) can be initiated due to local impregnation phenomena, where the highly viscous polymer melt needs to impregnate the dry regions of the textile.

The concept of providing sheath-core bicomponent fibers as an intermediate material for the preform eliminates this almost entirely, as all fibers are already fully wetted and local flows caused by the consolidation occur only over distances smaller than the diameter of a single filament.

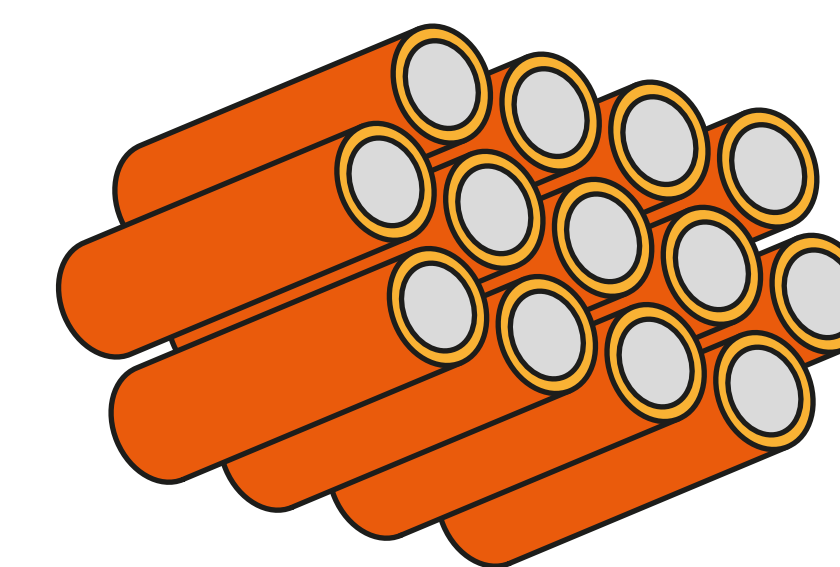


Figure 3 Morphology of an intermediate material made from bicomponent fibers.

But where lies the advantage over using organosheets?

- An organosheet is already fully impregnated and consolidated and thus provides resistance to draping deformations, which can result in wrinkling, fiber breakage and thus poorer mechanical properties. Preforms made from bicomponent fibers should provide the drapeability of a dry textile at room temperature.
- Organosheets are expensive due to the need for an extra preconsolidation step. In the case of glass fiber composites, bicomponent fibers have the potential to be manufactured directly at the spinning stage of the glass filaments and thus eliminate the need for additional processing before the material is provided to a textile manufacturer or directly to the press plant.
- Continuous bicomponent fiber yarns open up more possibilities for different manufacturing routes, such as extrusion, pultrusion, tape-laying, filament winding or fused deposition molding (additive manufacturing).

Segmented Block Poly(ester-amide)

Dow Europe GmbH supplies the project with a new segmented block poly(ester-amide) copolymer (PEA). Due to its ability to spontaneously organize into a semi-crystalline structure by forming hydrogen bonds, it behaves as a thermoplastic. In its molten state it possesses an unusually low viscosity of 1-5 Pa·s and behaves as a Newtonian fluid. It is therefore suitable for coating processes where a low melt viscosity is needed. Additionally, it adheres well to glass, providing the potential to lose the sizing stage in the fiber production process.

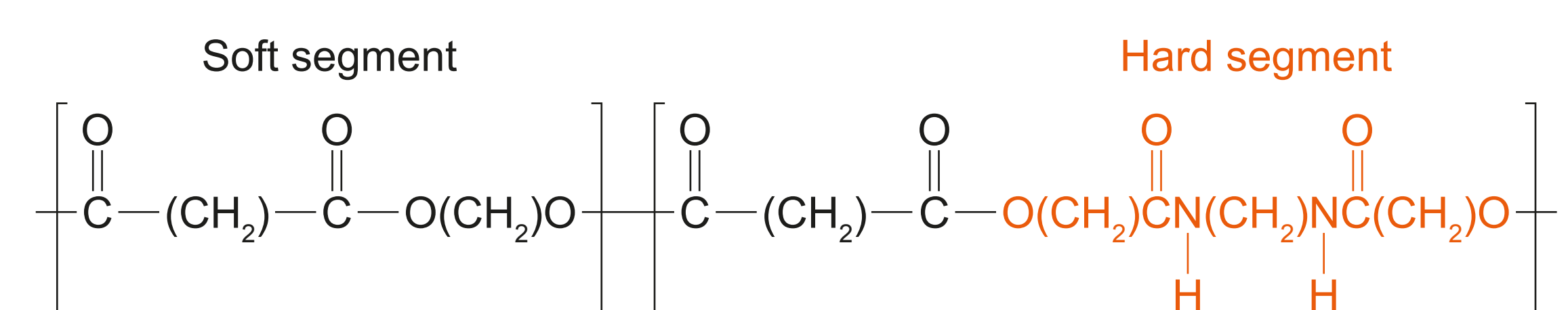


Figure 4 Chemical formula of the segmented block poly(ester-amide) copolymer. Source: R. Koopmans, Dow

5 Integration in Fiber Spinning Plant

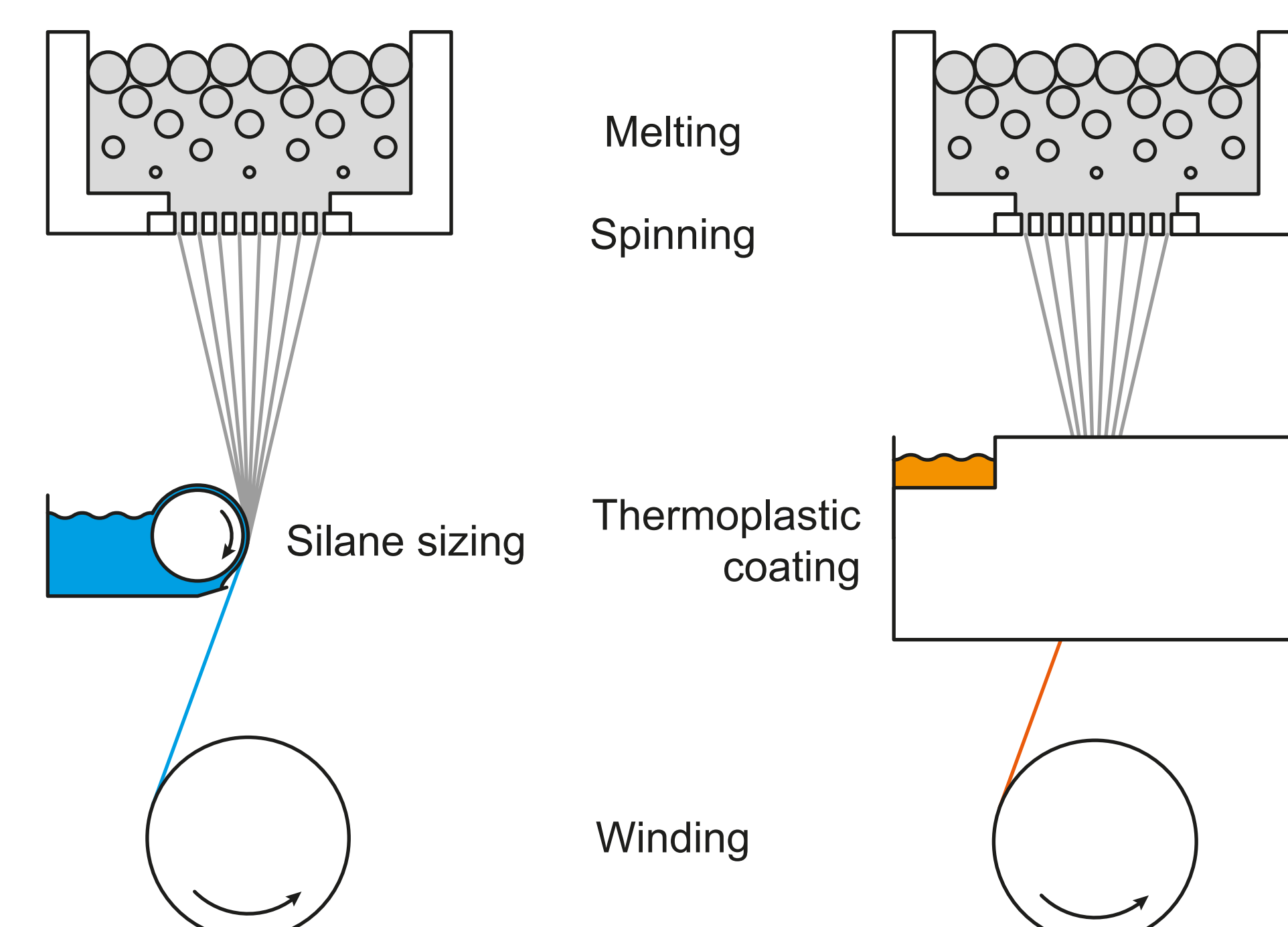


Figure 7 Left: Typical melt spinning of glass fibers with sizing process. Right: Integration of fiber coating stage in the spinning plant, while filaments are still separate.

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