

# AN INTRODUCTION TO SHEET MOULDING COMPOUND (SMC)

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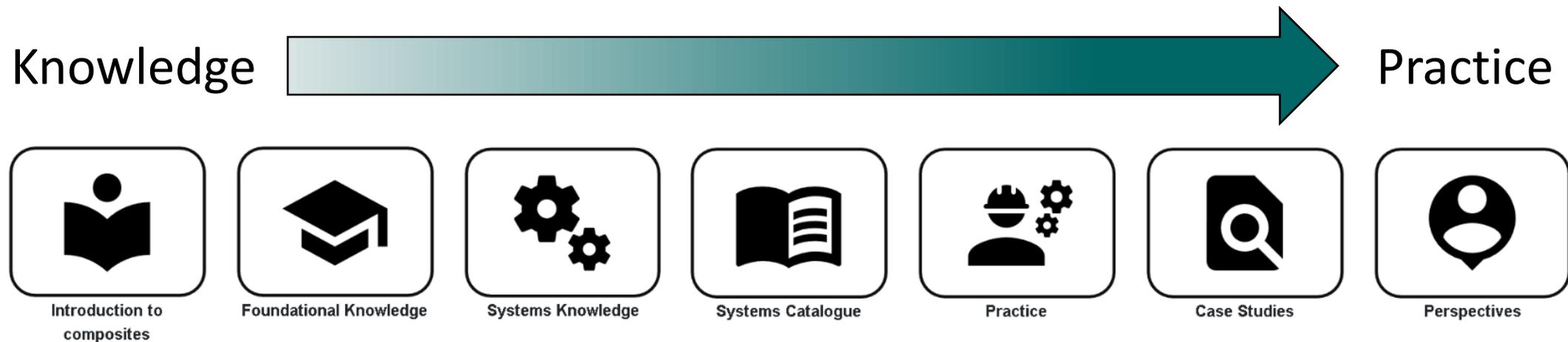
**Eric Martin, MEng.**

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Research @ Western University  
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- Masters of Engineering Science in Mechanical Engineering
- Sheet moulding compound (SMC) compounding and moulding
- High pressure resin transfer moulding (HP-RTM) and liquid compression moulding (LCM)
- Thermoset open bath pultrusion

## KNOWLEDGE IN PRACTICE CENTRE (KPC)

- A freely available online resource for composite materials engineering:  
[compositeskn.org/KPC](https://compositeskn.org/KPC)
- Focus on practice, guided by foundational knowledge and a systems-based approach to thinking about composites manufacturing



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**TODAY'S TOPIC:**

*An Introduction to Sheet Moulding  
Compound (SMC)*

## OUTLINE

- FIP @ Western Introduction
- What is SMC?
- What is SMC made of?
- How is SMC made?
- How are parts made with SMC?
- What are applications of SMC?
- Summary

## FIP @ Western Introduction

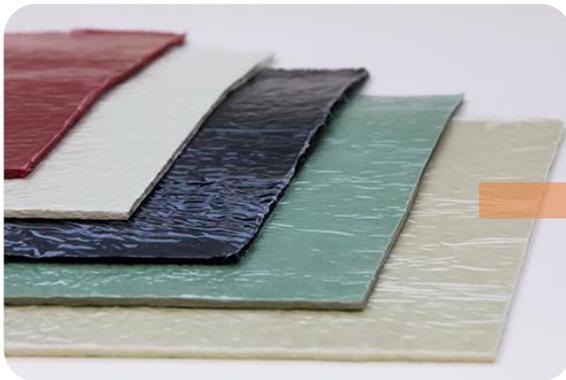
- Fraunhofer Innovation Platform for Composites Research at Western University (FIP-Composites@Western) in London, Ontario, Canada
- Industrial scale applied composites R&D (2500T Press and SMC Line)



## WHAT IS SMC?

### Sheet Moulding Compound

- **Sheet Moulding Compound (SMC)** is a semi-finished product consisting of a thermoset matrix, fillers and discontinuous (chopped) reinforcing fibres. This semi-finished product is moulded in a secondary operation.



SMC  
Sheet Moulding Compound

Source: astar SMC/BMC



SMC Automotive Fender  
Part

Source: Fritzmeier Composite



Painted and Assembled  
Automotive Fender

Source: Fritzmeier Composite

# WHAT IS SMC?

## Advantages and Disadvantages of SMC

Advantages	Disadvantages
<ul style="list-style-type: none"><li>• Class-A surfaces for automotive possible</li><li>• High thermal stability</li><li>• Good fire resistance with certain formulas</li><li>• Freedom of design (part consolidation, ribs, etc)</li><li>• Long term stability</li><li>• Good damping properties</li><li>• Electromagnetic permeability</li><li>• Chemical and corrosion resistant</li><li>• Does not rust compared to metals</li><li>• Low density compared to metals (<math>\rho \approx 1.9 \text{ g / cm}^3</math>)</li></ul>	<ul style="list-style-type: none"><li>• Relatively high cycle time compared to metal stamping</li><li>• Recycling more difficult than the case of thermoplastic composites and metals</li><li>• Fluctuating semi-finished quality</li></ul>

## WHAT IS SMC MADE OF?

### Composition of SMC

SMC can be any **combination of reinforcing fibre, solid additives and thermoset resin**. For exterior body panel applications SMC is typically a **highly filled glass reinforced polyester compound**.



Source: uLine

#### Liquid Thermoset Resin

- Unsaturated polyester
- Styrene
- Low profile additives
- Initiators
- Accelerators
- Inhibitors
- Thickeners



Source: allchemical

#### Solid Additives

- Calcium carbonate
- Mould release
- Density reducers
- Clays/mineral fillers
- FR additives
- Pigments



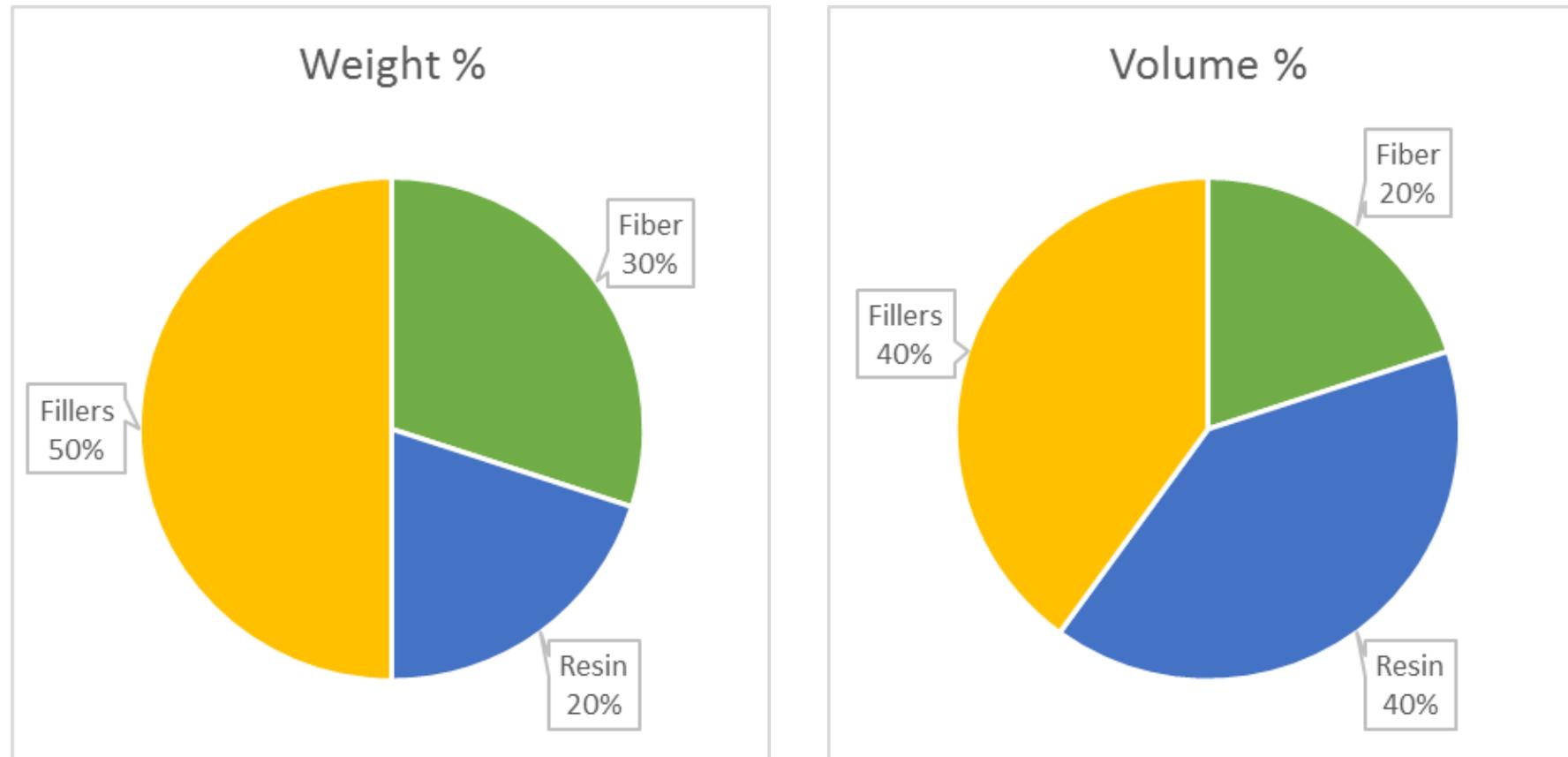
Source: Nippon Electric Glass

#### Reinforcing Fibre

- Glass fibre
- Carbon fibre
- 0.5", 1" or 2"

# WHAT IS SMC MADE OF?

## Composition of SMC (Generic Formula)



# WHAT IS SMC MADE OF?

## Function of components



Source: uLine

### Liquid Thermoset Resin

- The composite matrix
- Transfers load to the fibres
- Links the fibres to each other



Source: allchemical

### Solid Additives

- Imparts stiffness
- Reduces overall material cost
- Imparts good surface quality



Source: Nippon Electric Glass

### Reinforcing Fibre

- Main contributor to strength, stiffness and toughness

## WHAT IS SMC MADE OF?

### SMC Resins

- Unsaturated Polyester Resin (UPR)
  - Most popular
  - Low cost
  - Decent mechanical properties (not high performance)
  - High shrinkage (6-8%)
  - Good weatherability
  - Short curing time (addition polymerization)
  - Expires after 6 months (if refrigerated and protected from light)

## WHAT IS SMC MADE OF?

### SMC Resins

- Vinyl Ester Resin (VER)
  - High mechanical properties (structural applications)
  - Short curing times (radical polymerization)
  - Good chemical and hydrolysis resistance
  - Thermoforming resistant
  - Costly

## WHAT IS SMC MADE OF?

### SMC Resins

- Epoxy Resin
  - Highest mechanical properties
  - Most expensive
  - Most used resin for high-performance applications
  - Typically paired with high content of glass or carbon fibres to achieve high performance mechanical properties
  - Low shrinkage (2-4%) and low warpage
  - Longer cure (polycondensation or polyaddition)
  - Curing by reaction partner (hardener)
  - Operating temperature around 180 °C

## WHAT IS SMC MADE OF?

### SMC Resins

- Phenolic Resins
  - Good mechanical properties at elevated temperatures
  - Good chemical and fire resistance
  - Low shrinkage (0.05%)
  - Longer cure (polycondensation)
  - Operating temperature up to 220 °C

## WHAT IS SMC MADE OF?

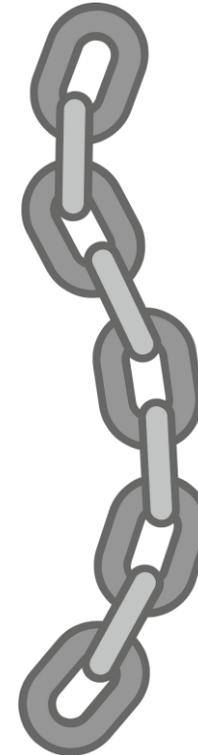
### Resin Summary

- Resin is the main component of the composite 'matrix', and transfers load to the fibres linking them to each other
- Each resin has its own specific properties which makes it the appropriate choice for specific applications
- Unsaturated polyester (low cost)
- Epoxy and Vinyl Ester (high mechanical properties)
- Phenolic (fire resistance)
- Several resins for SMC; unsaturated polyester most popular
- Different resins expected to become more popular to meet new vehicle needs (lightweighting and electrification)

# WHAT IS SMC MADE OF?

## SMC Additives

- Initiators
  - Initiate a curing reaction
  - Induce free radicals in resin
  - Reaction should only happen during moulding stage
  - Reaction happens between 80 C – 150 °C



## WHAT IS SMC MADE OF?

### SMC Additives

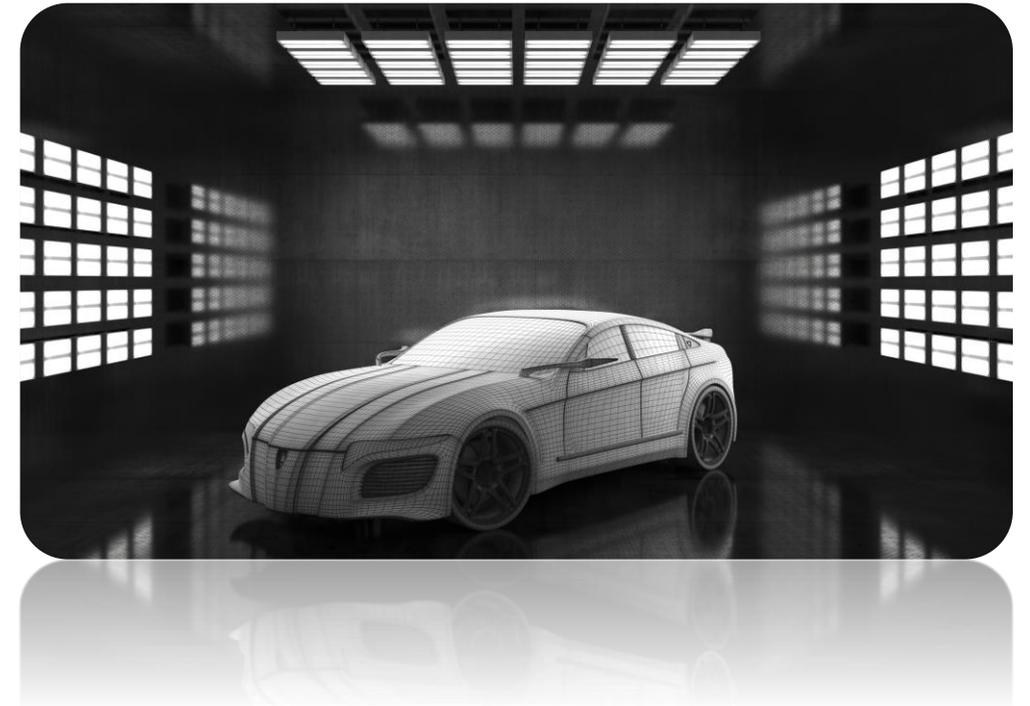
- Inhibitors
  - Used to control chemical cross-linking reaction
  - Eliminates undesirable gelation before the target curing time
  - Trap free radicals of the UP resin
  - Quinone and hydroquinone (and their derivatives) are most commonly used



## WHAT IS SMC MADE OF?

### SMC Additives

- Low Profile Additives
  - Thermal expansion and shrinkage
  - Warpage, poor surface appearance, and surface defects
  - Low profile additives can be added to combat this
  - Especially important for UP resin due to high shrinkage
  - LPA must be added in liquid state in order to ensure uniform mixture



## WHAT IS SMC MADE OF?

### SMC Additives

- Thickening Agent
  - SMC requires higher viscosity for handling
  - Higher viscosity also helps promote the flow of fibres
  - Several thickening agents exist to increase the viscosity for these reasons
  - Most commonly MgO thickener is used
  - Typically ranging between 0.5 – 3% of mixture



## WHAT IS SMC MADE OF?

### SMC Additives

- Internal Mould Release Agents
  - If a part sticks to the mould during demoulding it could damage the part
  - Mould release agents are added to prevent this
  - Typically, stearates, zinc, calcium or aluminum stearates
  - Usually do not exceed 3% of total compound



## WHAT IS SMC MADE OF?

### SMC Additives

- Fire Retardants
  - Most thermoset resins are combustible creating harmful fumes when burned
  - Flame retardant additives improve combustion resistance
  - Some examples are: Alumina Trihydrate (ATH), bromine, chlorine, borate, and phosphorus



# WHAT IS SMC MADE OF?

## SMC Additives

- Fillers
  - Calcium carbonate is the most widely used filler. It is low cost and has a variety of particle size and treatments
  - Kaolin is the second most commonly used filler (aka clay), a wide range of particle sizes are also available
  - Both calcium carbonate and kaolin are used to bring the cost of SMC material down, but increase the density of material
  - Glass bubbles are a lightweight filler which still allows for class A paintable surface, it is more expensive but reduces material density



Source: allchemical

## WHAT IS SMC MADE OF?

### SMC Additives

- Pigments
  - For applications which do not require painting operation
  - Typically 1 – 5% of total compound



Source: SpecialChem

## WHAT IS SMC MADE OF?

### Additives Summary

- Additives provide specific functions to the SMC material
- An additive is included in an SMC paste formulation depending on the intended application
- The most common additive are fillers, and their main functions are to reduce the cost of the SMC, provide good quality part surface, and allow SMC to be paintable
- Additives like initiators and inhibitors determine the cure characteristics of the thermoset matrix
- Thickening agents are responsible for the viscosity increase of the matrix which eases the material handling for moulding

## WHAT IS SMC MADE OF?

### SMC Fibres

- Glass Fibre
  - Most common fibre
  - Cheap
  - Low thermal expansion and electrical conductivity
  - Non-flammable
  - Chemical resistance
  - Operating temperatures up to 250 °C



Source: Nippon Electric Glass

## WHAT IS SMC MADE OF?

### SMC Fibres

- Carbon Fibre
  - Highest mechanical properties
  - Most expensive
  - High-performance applications
  - Good biocompatibility
  - Chemical resistant
  - Good electrical and thermal conductivity in in fibre direction



Source: Toray

## WHAT IS SMC MADE OF?

### SMC Fibres

- Aramid Fibre (aka Kevlar)
  - High mechanical properties
  - Very good impact behaviour
  - Low thermal conductivity (better insulation than glass)
  - Good chemical and temperature resistance
  - Good fatigue and damping behavior (ductile failure instead of brittle failure)
  - Lowest density of reinforcing fibres



Source: FIBER - LINE

## WHAT IS SMC MADE OF?

### SMC Fibres

- Natural Fibres
  - Sisal, flax, hemp, jute, cotton, lyocell, etc...
  - Green technology
  - Costly fibre treatment
  - Varying fibre properties due to varying harvest quality
  - Increased water absorption



Source: Alliance for European Flax-Linen & Hemp

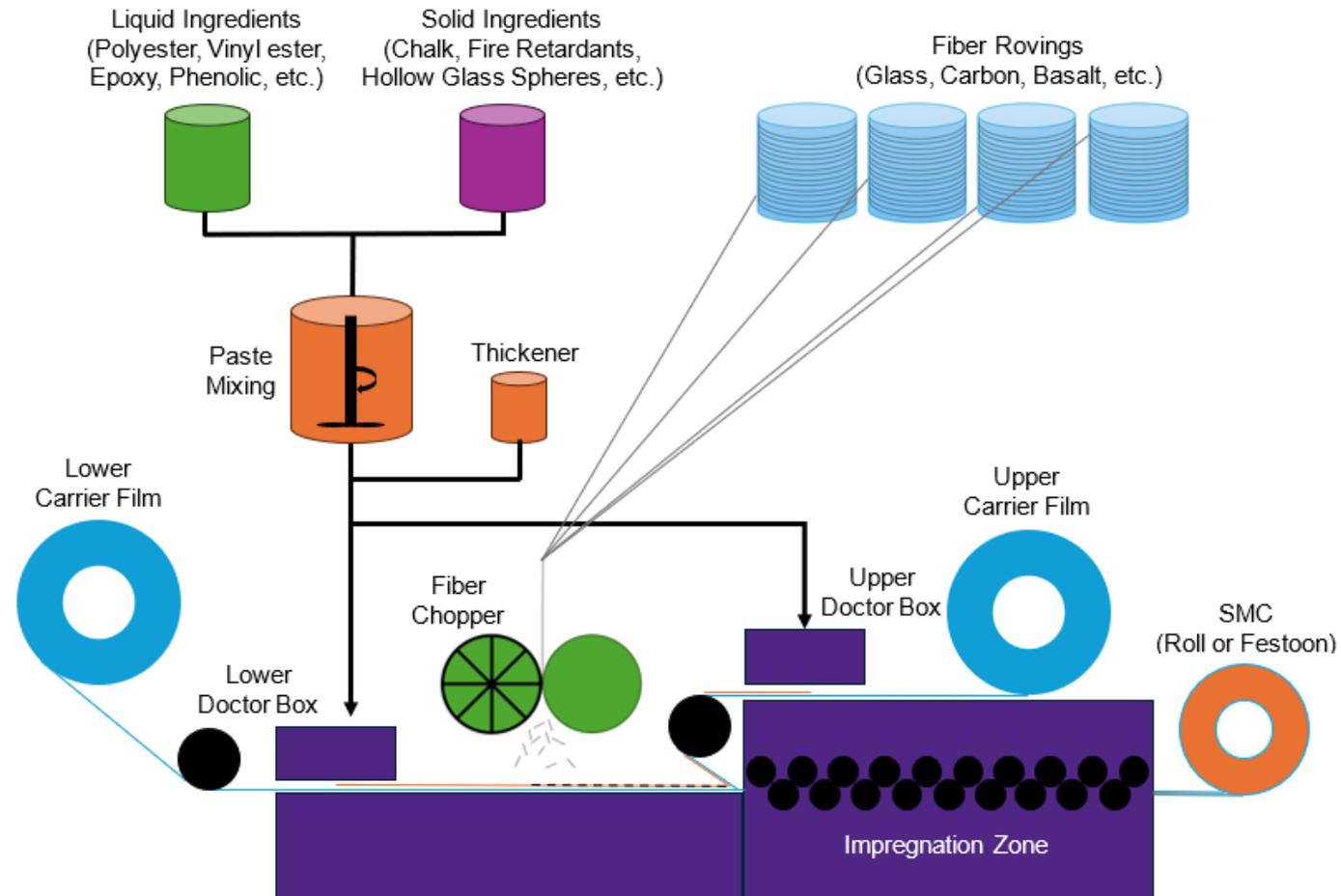
## WHAT IS SMC MADE OF?

### Fibre Summary

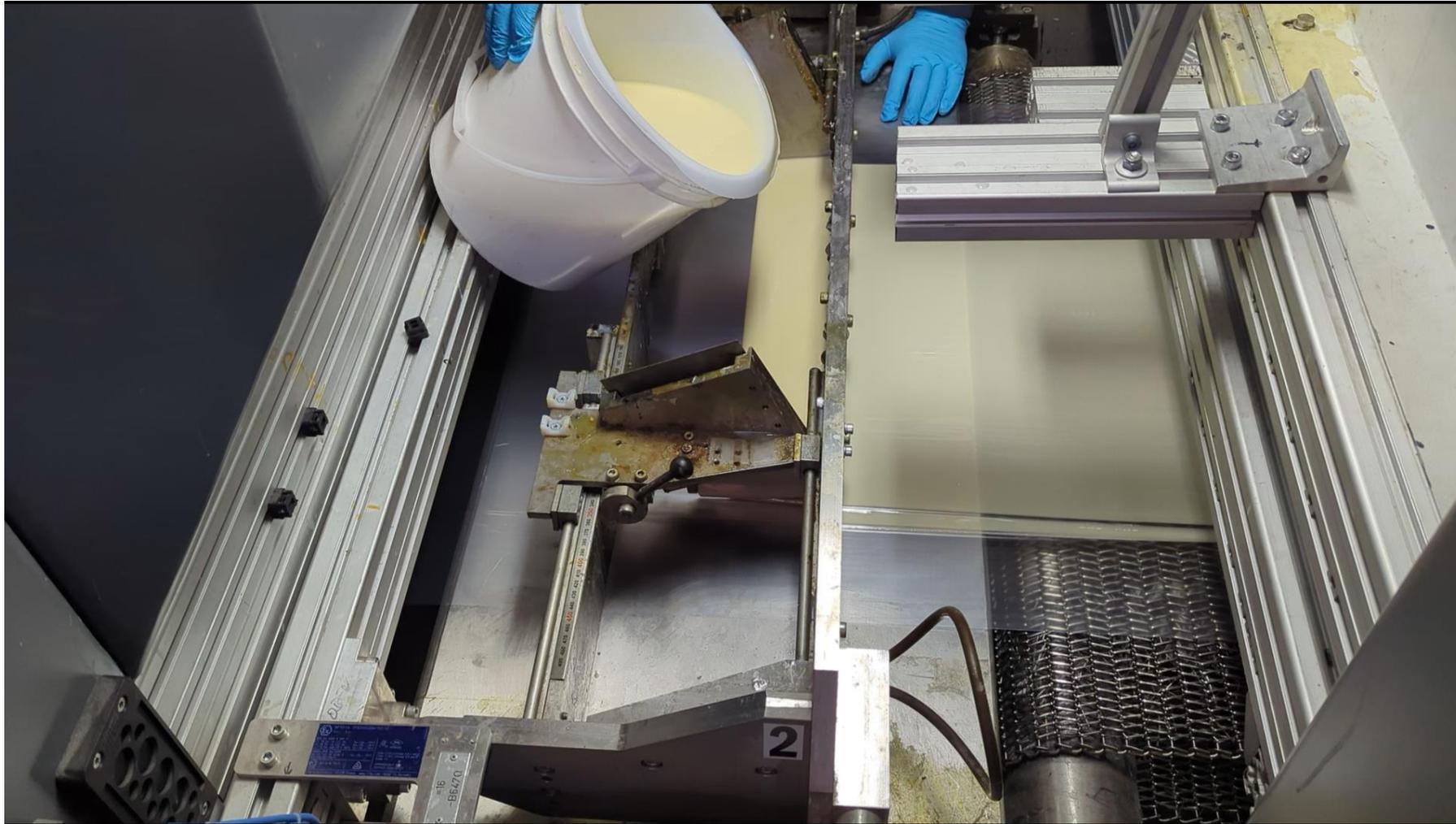
- Provides reinforcement
- Randomly dispersed in SMC
- Typically rovings chopped 1" in length
  - Fabric rolls can also be used but this is less common
- Wide range of reinforcing fibres, glass and carbon fibre (most common)
  - Glass fibre - more general use
  - Carbon fibre - high performance

# HOW IS SMC MADE?

## SMC Compounding Process



## HOW IS SMC MADE?



## HOW IS SMC MADE?

### SMC Compounding Summary

- Step 1: Blend liquid resin Components
- Step 2: Add fillers to make resin “A-paste”
- Step 3: Blend in a thickener to make resin “B-paste”
- Step 4: Dose the B-paste onto the SMC carrier film
- Step 5: Combine with and impregnate chopped fibreglass
- Step 6: Roll or Festoon material for storage and maturation

## HOW IS SMC MADE?

### SMC Paste Viscosity

Viscosity is an important material property for SMC compounding and Moulding. Thickening agents are used to take the low initial viscosity resin paste to a much higher viscosity to give SMC a leather like feel.

### SMC Compounding

- Viscosity must remain low for to allow for good **fibre wet-out**

### SMC Moulding

- Viscosity must increase to provide a **tack-free** material for handling by operators and automated equipment. This **prevents sticking** to cutting equipment and **maintains a consolidated sheet** during charge preparation
- During moulding sufficient matrix viscosity is necessary to **prevent fibre-matrix separation**

## HOW IS SMC MADE?

### SMC Paste Viscosity Build Summary

Stage 1: After the MgO thickener is added the paste viscosity remains low during compounding to allow for fibre impregnation

Stage 2: Initial thickening begins rapidly increasing the viscosity 2 orders of magnitude over the first day

Stage 3: Final thickening begins and the SMC viscosity gradually increases into a mouldable range for compression moulding

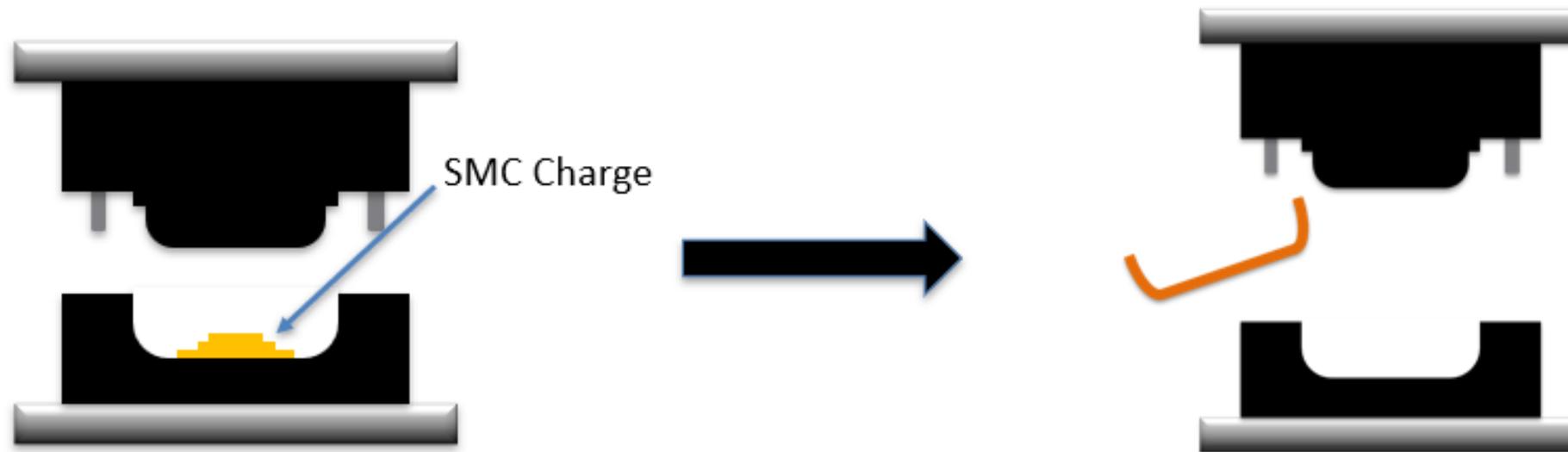
Stage 4: The SMC continues to thicken gradually over time until it becomes unusable

## HOW ARE PARTS MADE WITH SMC?

SMC Compression Moulding

### Purpose

To **flow a charge of SMC** into the part shape in a **closed mould** and **cure it under heat and pressure**

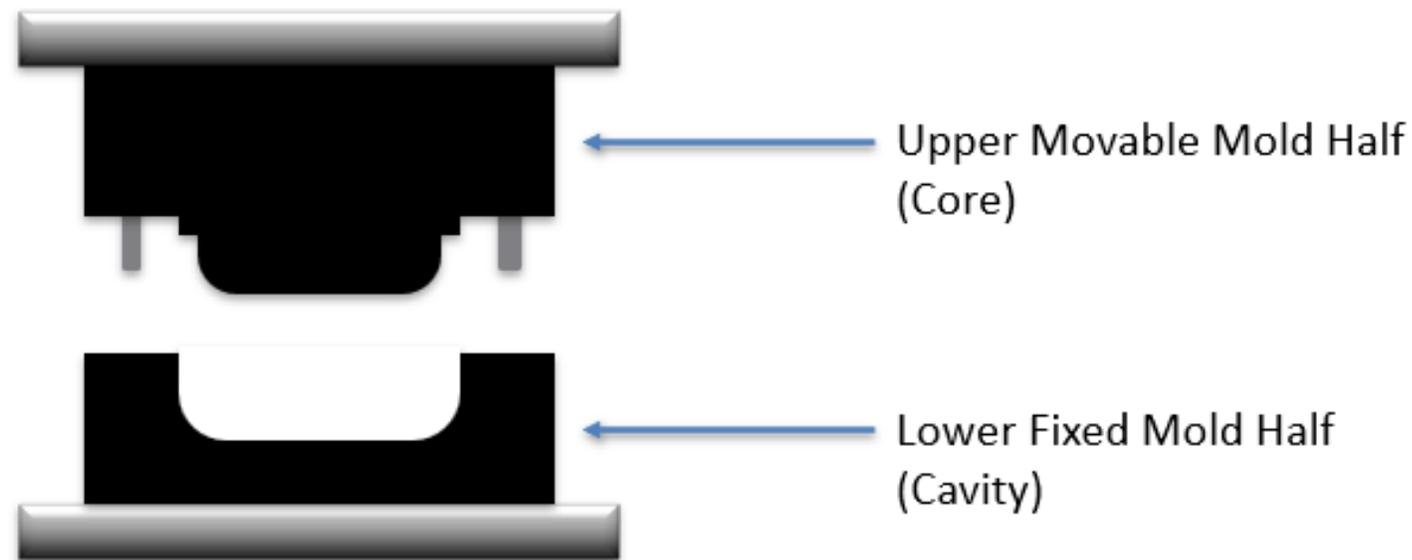


## HOW ARE PARTS MADE WITH SMC?

SMC Tooling

### Shear edge tooling

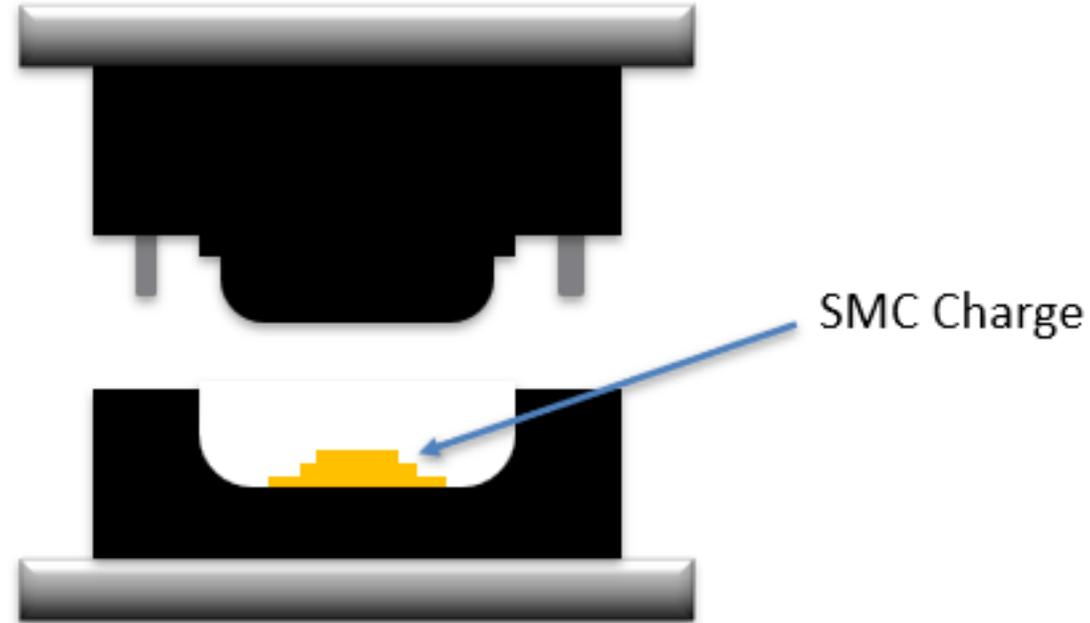
A closed mould design where the **parting line** of the mould is **variable** and the **thickness** of the part **depends on the amount of material** added to the mould



## HOW ARE PARTS MADE WITH SMC?

SMC Compression Moulding

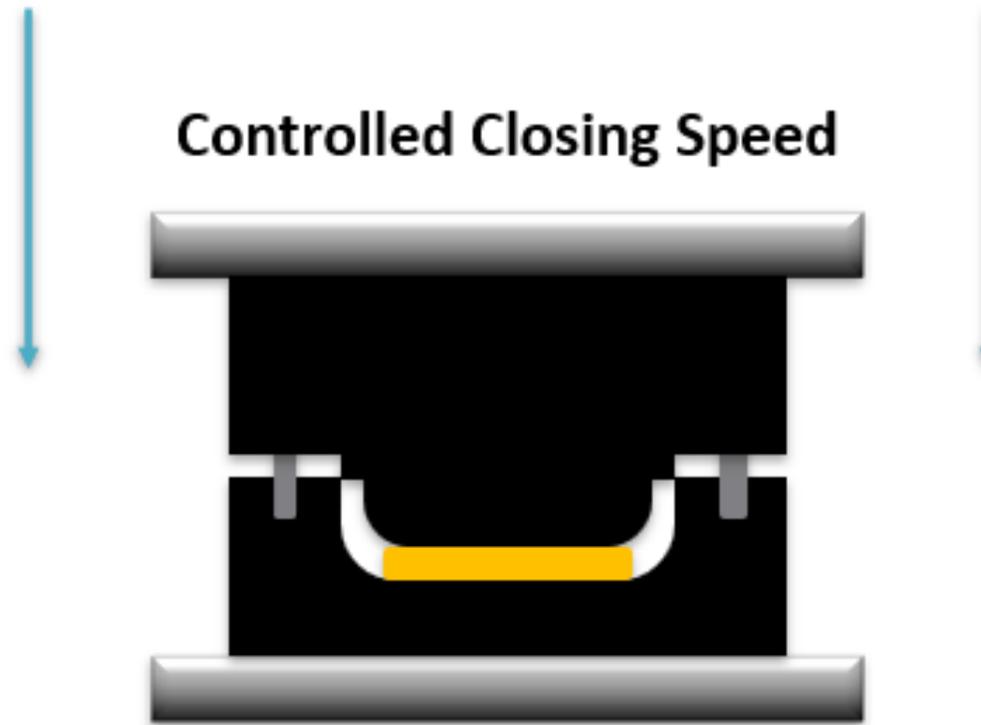
**Step 1:** Place an SMC charge in the heated tool



## HOW ARE PARTS MADE WITH SMC?

SMC Compression Moulding

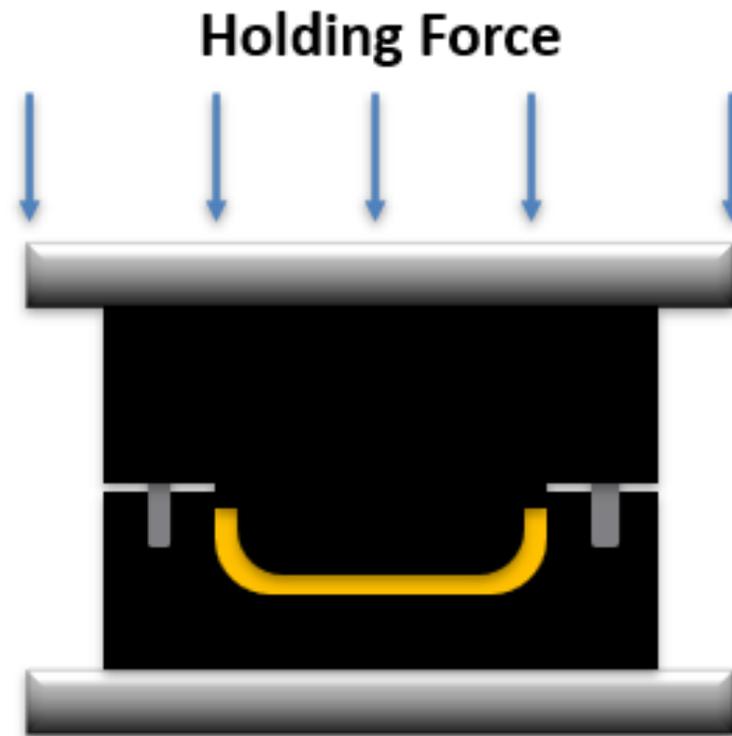
**Step 2:** Close the mould under controlled speed filling the cavity



## HOW ARE PARTS MADE WITH SMC?

SMC Compression Moulding

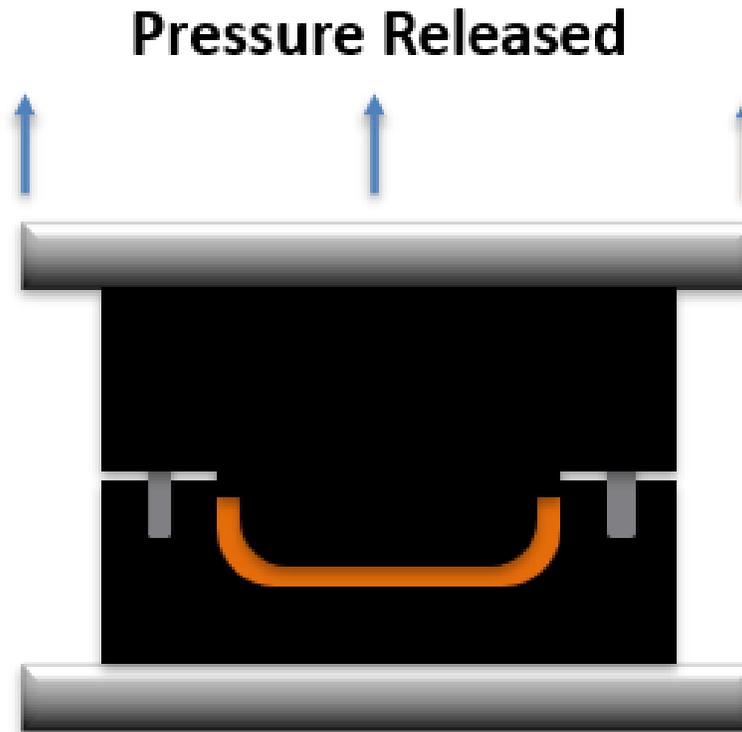
**Step 3:** Once the material has filled the cavity, it is held under controlled pressure



## HOW ARE PARTS MADE WITH SMC?

SMC Compression Moulding

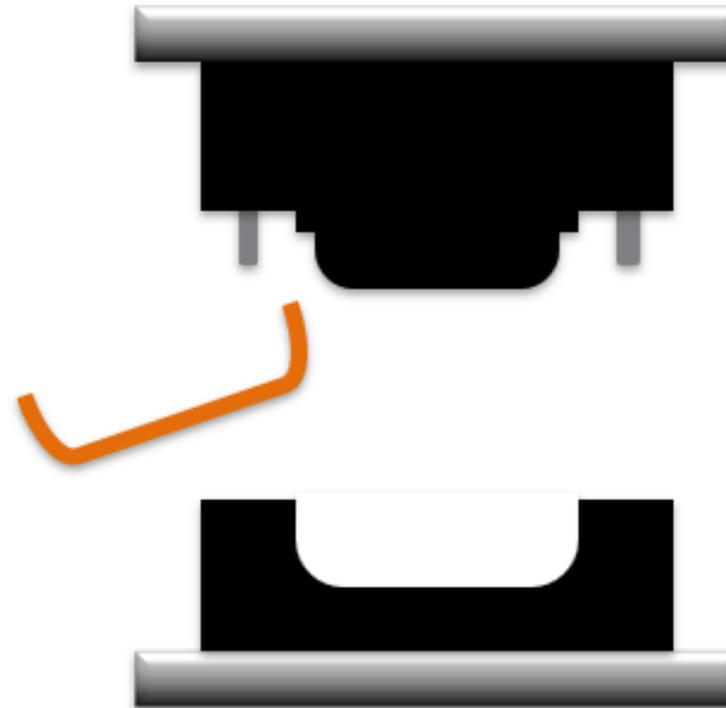
**Step 4:** Pressure is released once the part has cured



## HOW ARE PARTS MADE WITH SMC?

SMC Compression Moulding

**Step 5:** The part is removed from the mould, typically assisted by hydraulic ejector pins

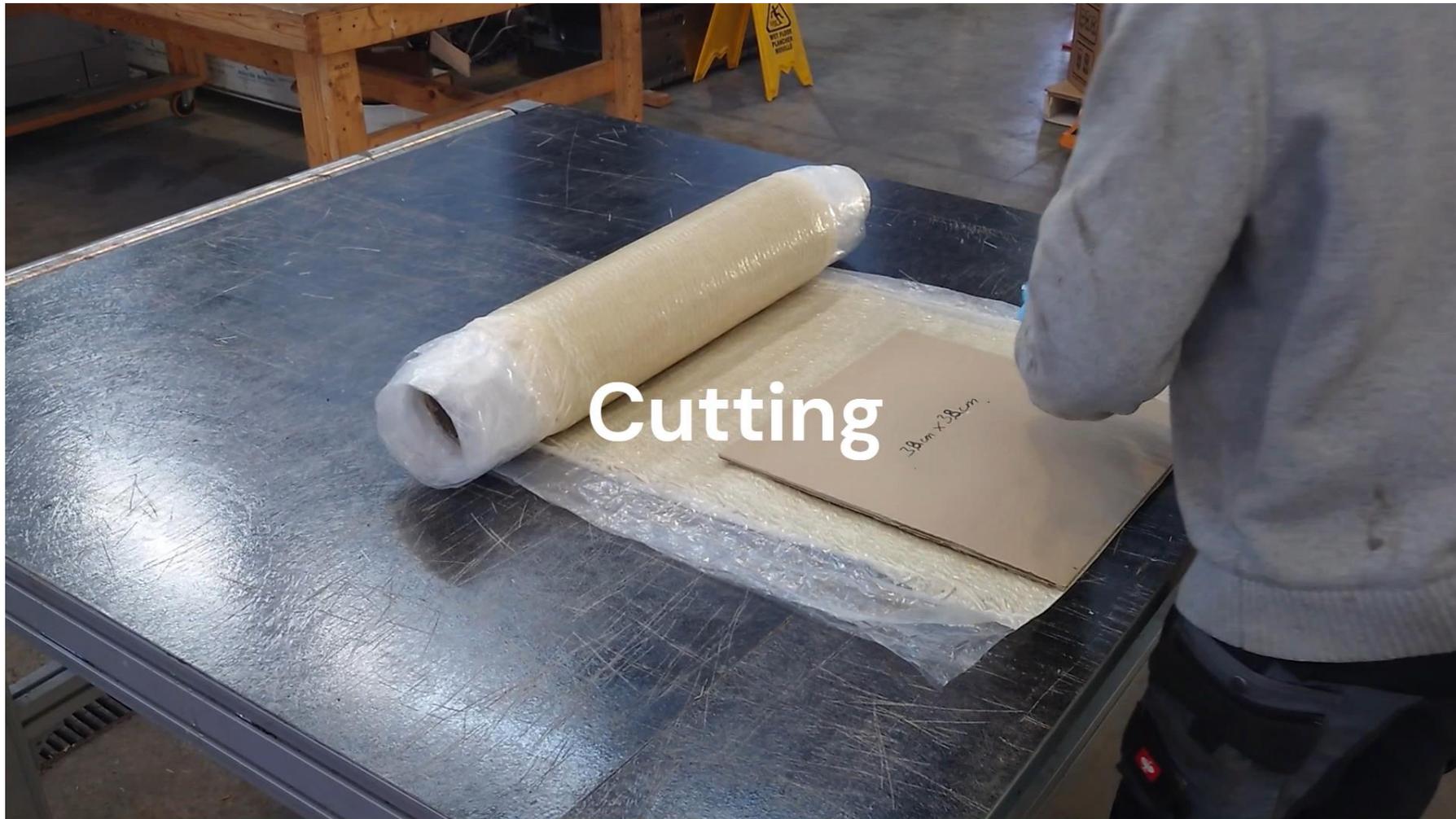


## HOW ARE PARTS MADE WITH SMC?

### SMC Curing

- Solidification of SMC
- Irreversible process (cross linking of polymer chains)
- Condensation Polymerization vs Addition Polymerization
- Three Stages: Viscous Liquid, Gel, and Solid

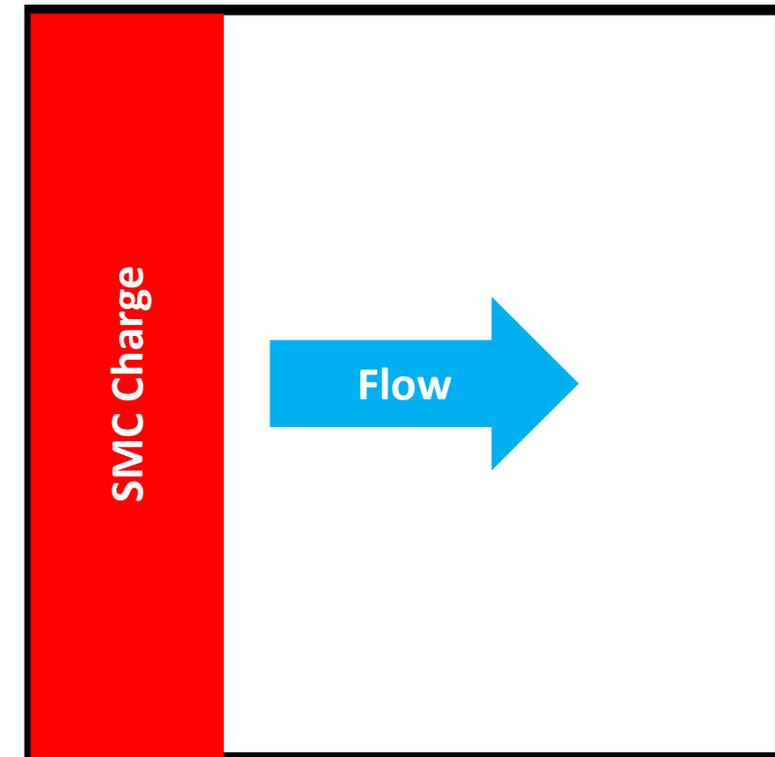
## HOW ARE PARTS MADE WITH SMC?



## HOW ARE PARTS MADE WITH SMC?

### SMC Flow Characteristics

- An SMC charge has randomly oriented fibres.
- During compression moulding the fibres start to align in the flow direction.
- This fibre alignment can significantly impact the mechanical properties of the final part (stronger in the direction of flow and weaker perpendicular to it).
- The more the charge flows, the stronger the fibre alignment will be.
- Increasing mould coverage can maintain isotropic material properties.



## HOW ARE PARTS MADE WITH SMC?

### Moulding Process Conditions

**Temperature:** The fixed and movable tool halves can be controlled independently. Usually movable tool half is set to a higher surface temperature because the SMC charge is in contact with the lower side for a longer period of time. For SMC this range is typically 130 – 150 C.

**Pressure:** The moulding pressure can be varied throughout the cycle and can have drastic impacts on part appearance. For SMC this range is typically 50 – 100 bar (~750 – 1500 psi).

**Closing Profile:** The speed at which the tool is closed may not be constant. Ramping the speed down for a constant flow velocity is common. For SMC the typical speed range is 1-20 mm/s.

**Charge Pattern:** Every mould/material combination will require determination of a charge pattern. Pyramid charges, multiple charges and jelly rolls are some of the common configurations.

**Mould Coverage:** The amount of projected area covered by the initial charge. Some flow is needed, and can vary from ~ 20 – 80 %.

## HOW ARE PARTS MADE WITH SMC?

### SMC Moulding Summary

Stage 1: A charge of SMC of the correct weight is prepared and transferred into an open tool

Stage 2: The movable half of the mould is lowered at a controlled speed flowing the SMC charge and filling the mould cavity.

Stage 3: After the mould is filled clamping force is built up to hold the uncured material under pressure in the mould cavity

Stage 4: Part way through the cure cycle the clamping force is partially reduced for the remainder of the cure time to allow the low profile additives to level the surface of the part.

Stage 5: The movable half of the mould is raised and the part is demoulded.

## WHAT ARE SOME APPLICATIONS OF SMC?

### SMC Formulations

SMC is a broad category of materials which include the use of different resins, additives, and fibre reinforcements.

The ingredients which are used to make SMC allow the material to be 'tunable' and made with specific applications in mind.

Generally, there are four main categories of SMC formulation which can be used to ensure the material meets the requirements of many applications.

1. Class A SMC
2. Structural SMC
3. Lightweight SMC
4. Fire Retardant SMC

## WHAT ARE SOME APPLICATIONS OF SMC?

### Class A SMC

- Defining Characteristics
  - Designed to be used as aesthetic body panels (automotive industry)
  - Can be painted
  - Provide smooth and high-quality surface finish (Class A)
  - Traditionally made using unsaturated polyester, low profile additive, chalk, and some glass fibre
- Applications
  - Automotive and heavy truck body panels



Source: Fritzmeier Composite

## WHAT ARE SOME APPLICATIONS OF SMC?

### Structural SMC

- Defining Characteristics
  - Designed to be used as semi-structural components
  - Surface quality not as important
  - Made with a variety of resins depending on application (unsaturated polyester, vinyl ester, and epoxy)
  - Low filler content and high reinforcement content
- Applications
  - Automotive body panels
  - Seat structures
  - Infrastructure components



Source: Hubbell

## WHAT ARE SOME APPLICATIONS OF SMC?

### Lightweight SMC

- Defining Characteristics
  - Similar to Class A SMC
  - Typically used for automotive body panels
  - Use lightweight fillers (hollow glass spheres) to reduce mixture SMC density
  - Used for specialty applications where weight savings is important
- Applications
  - Automotive body panels for high performance cars

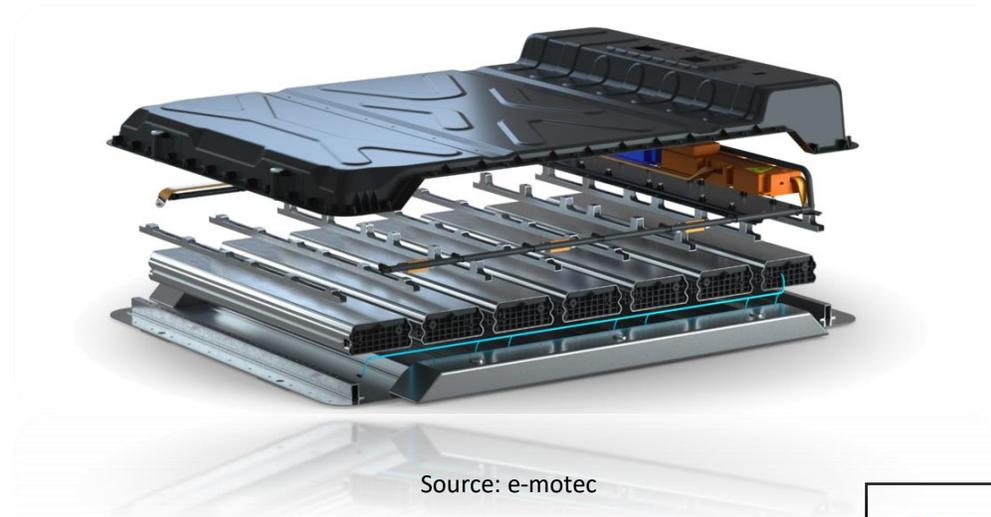


Source: General Motors

## WHAT ARE SOME APPLICATIONS OF SMC?

### Fire Retardant SMC

- Defining Characteristics
  - Reduces flammability of composite material
  - Reduces toxic smoke generated in the event of a fire
  - Suppresses the spread of fire
  - Provides barrier between passengers and flame
  - Typically uses ATH filler SMC formulations or phenolic resin SMC
- Applications
  - Transportation applications
    - Train/subway interiors
    - Electric vehicle battery enclosures



Source: e-motec

## SUMMARY

- Sheet moulding compound (SMC) is a semi-finished product consisting of a thermoset matrix and discontinuous (chopped) reinforcing fibres.
- The ingredients which are used to make SMC allow the material to be 'tunable' and made with specific applications in mind.
- SMC is used to produce parts via a compression moulding process.
- SMC offers manufacturers several benefits including: design freedom (integration of ribs, large complex parts, over-moulding inserts, etc...), low scrap rate, chemical/corrosion resistance, and good damping properties (among many other benefits).
- SMC is well established in industry and is used in many products we interact with on a daily basis.

**Thank you for joining us!**

***Keep an eye out for upcoming AIM events:***

*Continuous Welding of Thermoplastic Composites*

*Presented by Romain Martin, PhD*

*February 25, 2026*

<https://compositeskn.org/KPC/A398>

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