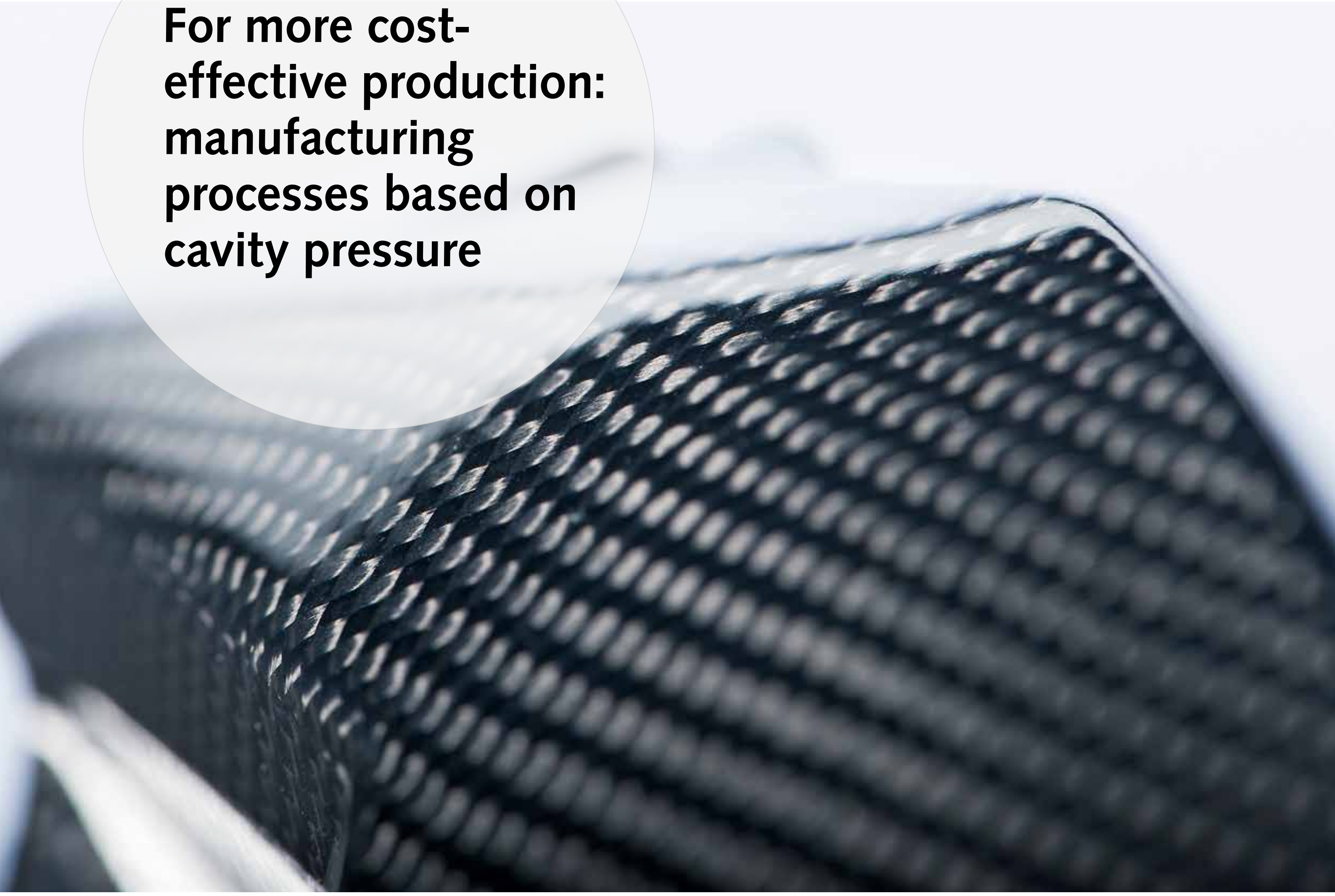
KISTLER
measure. analyze. innovate.

For more cost-effective production: manufacturing processes based on cavity pressure



Composites

Process transparency and quality assurance in the production of fiber-reinforced composite parts

Lightweight construction: the dual benefits of efficiency and quality

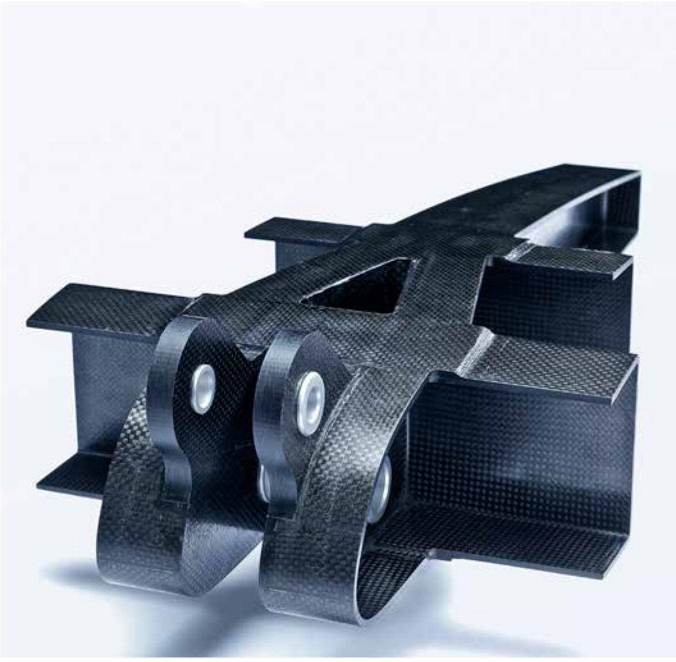
Increased mobility in every sector is boosting demand for lightweight designs that help to conserve energy and resources. Fiber-reinforced composites offer the ideal solution thanks to their high specific strength and excellent rigidity.

Composite materials are both lightweight and very strong. These impressive advantages account for their widespread use in plant and machinery that must meet high technical standards of efficiency and durability.

The aerospace industry has already been using composite parts for a long time. And now, the automotive sector too is using more of these materials to keep up with the trend towards enhanced efficiency and optimized use of resources. The changeover to renewables calls for more widespread use of CO_2-independent energy sources such as wind turbines. All of these developments are steadily boosting demand for composite parts.

Benefits of composite parts in the RTM process:

- Extremely lightweight components
- Shorter cycle times
- Low tolerances
- Class A surfaces are possible on both sides
- Defined wall thicknesses
- Guaranteed process reliability thanks to cavity pressure monitoring

Automated manufacturing processes for composite parts are being continuously developed and optimized to meet these growing requirements. Resin transfer molding (RTM) and wet molding are just two examples of processes that harbor vast potential for highly automated production.

With a range of sensors and systems specifically tailored to these methods, Kistler delivers individual solutions to optimize and automate manufacturing processes, including the related quality assurance activities.

With the mold cavity pressure sensor, you can virtually take a look inside the mold, so you can:

- Find the ideal settings for a reproducible process
- Drastically reduce set-up times
- Detect defects in the preform or mold
- Detect defects in the part that will be produced – online
- Control components such as the resin pump or press


Image source: Dow Automotive Systems

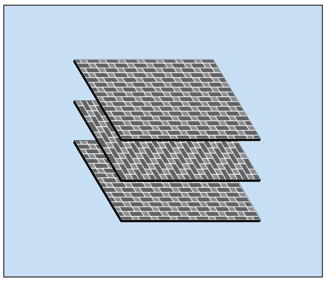
The composite process: state-of-the-art series production

Mass-produced composite parts must be increasingly lightweight, but also robust. Production has to be based on stable processes that are always reproducible so that dimensional and optical requirements for the parts are met.

Until recently, fiber-reinforced composite parts were manufactured using complex manual methods, but these have largely been replaced by processes that allow a high degree of automation. Automated processes guarantee maximum productivity and high volumes with consistent part quality.

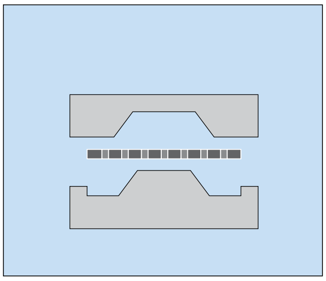
Injection processes (such as RTM) or depositing processes with pre-impregnated fiber fabrics (wet molding) are preferred. Based on a closed two-part mold, both processes deliver consistent part dimensions as well as high-quality optical surfaces.

The RTM process

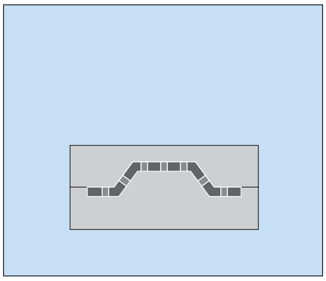


1 Manufacturing the preform

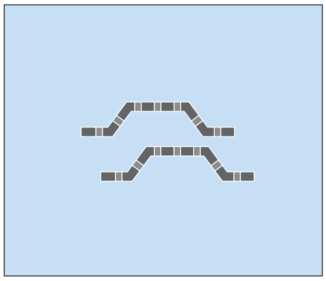
Fiber mats or fabrics are stacked in a defined sequence and fiber orientation.



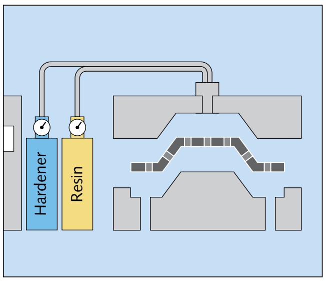
The package is molded into the required shape using a dedicated mold.



The binding powder added during stacking melts due to the heat impact and fixes the mats or fabrics in the correct shape.

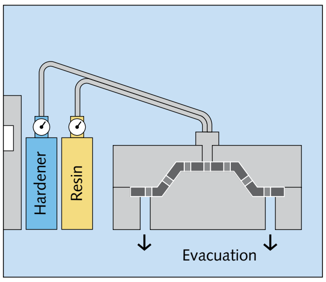


The resulting preform has the shape and contour of the injection mold, with dimensional stability for easy handling.

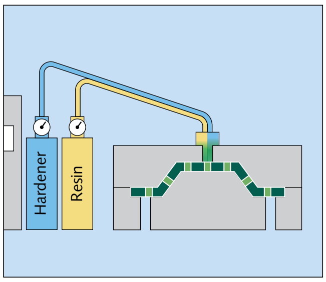


2 Injection

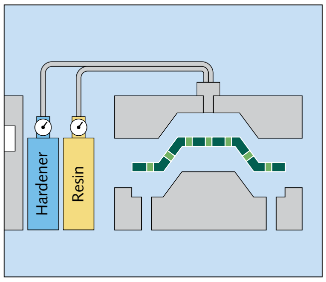
The preform is placed into the mold.



The cavity is evacuated after the mold is closed. This prevents air inclusions in the final product.

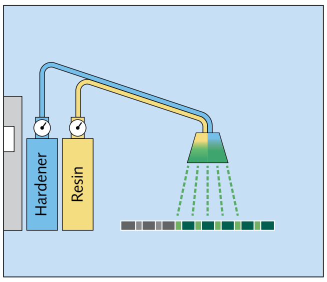


The resin/hardener mixture is injected into the cavity at a defined pressure, while the preform is impregnated with resin. Curing of the resin starts once the cavity is filled.

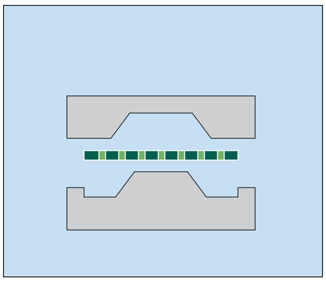


The part is demolded when it has been cured sufficiently.

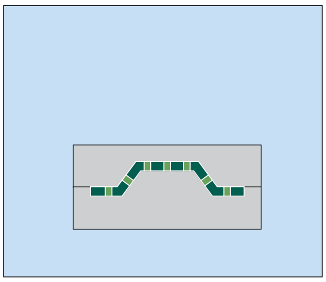
Wet molding



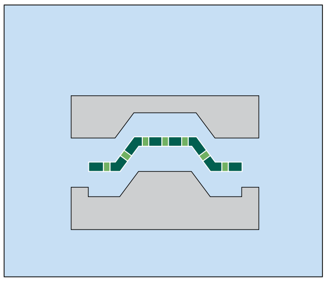
Dry fiber mats or fabrics are impregnated with the resin/hardener mixture.



The impregnated fiber mats are placed into the mold. The time factor is relevant here because the reaction has already started. This is why robots are often used to perform this step.



The resin continues to disperse as the mold closes, and the entire cavity is filled after complete closure.



After curing, the mold is opened and the part can be demolded.

Cavity pressure measurement delivers optimum results

As for other filling processes such as injection molding, the pressure curve is a key factor in optimizing these processes and monitoring production. Characteristic process phases such as evacuation, filling and curing can easily be identified from the pressure curve – so process parameters can be optimized to make production more cost-effective.

The pressure signal can also be used as a control variable for individual process steps, so online process control becomes possible. Anomalies in the pressure curve show whether defects can be expected in the final part and if so, which ones.

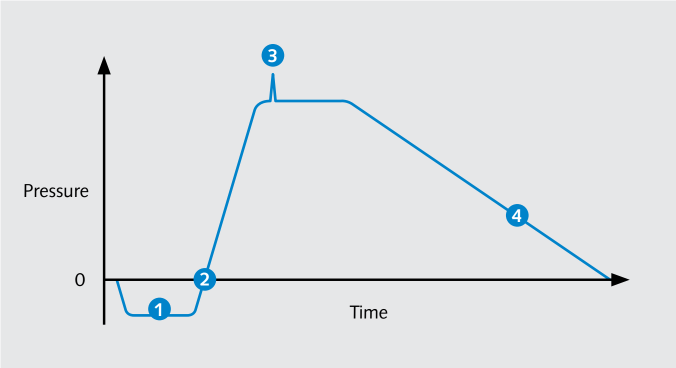
The pressure signal is also captured and recorded to allow traceability of individual process steps. For all these reasons, the pressure curve is an essential tool for quality assurance.

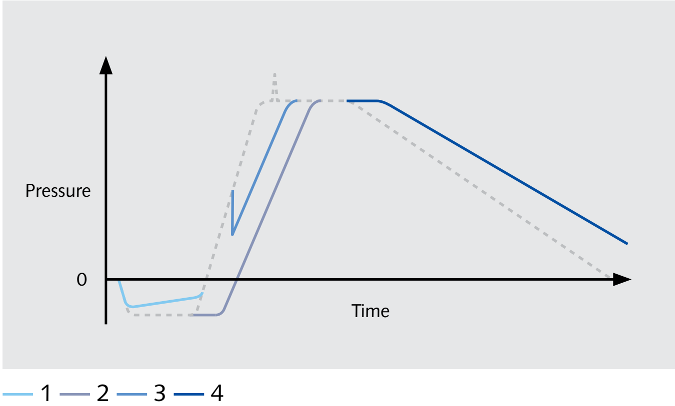
Using the pressure curve to identify defects:
Vacuum is too weak or intermittent:

Causes:	Faulty mold sealing Vacuum pump failure
Consequence:	Air bubbles and imperfections in the part

Irregularities in the injection phase:

Causes:	Dislocation of the preform Preform defect/incorrect orientation of a layer
Consequence:	Incorrect fiber content Dry spots





Reference pressure curve: RTM

1. Cavity evacuation begins after the mold is closed. The level and consistency of the vacuum are critical to prevent air inclusions in the part.

2. As soon as the resin reaches the sensor position, there is a linear increase in cavity pressure. This reflects the continuous increase in flow resistance that the resin must overcome while the preform is impregnated.

3. When the cavity is completely filled, any possible overflows and risers can be closed and the resin pump can be switched off. The pressure now settles at the maximum level, equivalent to the pressure set on the resin pump.

4. The resin volume shrinks during the reaction, causing pressure to decrease continuously until it reaches atmospheric pressure levels.

Monitoring composite processes with Kistler
View our animation to experience convincing, first-class Kistler solutions – the sure way to achieve 100% quality in your production:
www.kistler.com/Composites

Causes and consequences of deviations

1. A vacuum that is too weak or intermittent suggests that the mold sealing function is inadequate. This leaves a high residual air volume in the mold, which can cause air inclusions in the finished part. The pressure curve shows whether evacuation of the mold is insufficient. Injection can be stopped at the outset before a low-quality part is produced.

2. The gradient of the pressure signal during the injection phase depends on the permeability of the preform. Deviations from the normal pressure gradient may therefore indicate differences in the preform composition or in the orientation of individual layers, or foreign objects in the mold.

3. Major pressure variations during the injection phase indicate dislocation of the preform, or of individual layers. An increase in pressure therefore serves as a reference for the preform's quality.

4. A falling pressure curve during the reaction phase indicates that the volume is starting to decrease, and curing of the resin system is beginning. As in the injection phase, the gelation speed can be deduced from the timing and gradient of the decrease. This makes it possible to determine the time still needed for sufficient curing of the part, allowing calculation of the optimal time for demolding.

Sensors, connection technology and analysis systems

Sensors
Precise, reproducible pressure measurements can only be obtained with reliable sensors that measure accurately. Kistler offers the right solution for all molded part geometries and all installation conditions. Sensors from Kistler have virtually unlimited service lifetimes; they deliver highly linear measuring results and operate independently of temperature. They offer high-resolution measurement of the smallest pressure variations up to 200 bar and/or temperature changes up to 275°C.

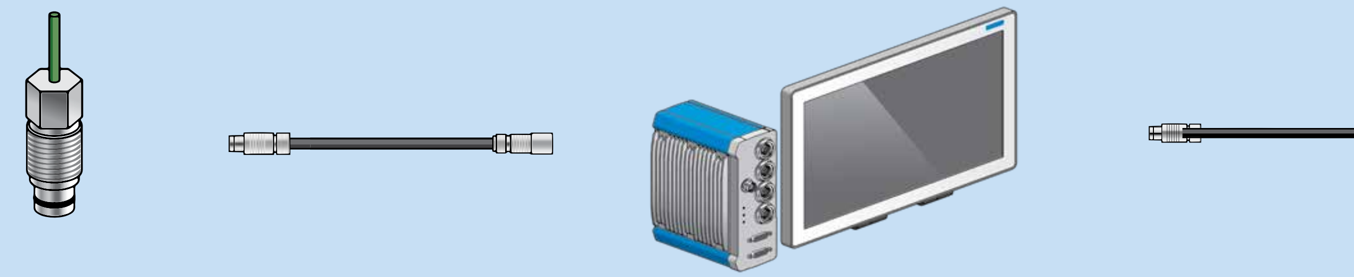
Kistler also offers a wide variety of temperature sensors for specific customer solutions.

ComoNeo
ComoNeo is Kistler's process monitoring system for cavity pressure-based optimization, control, monitoring and documentation of injection molding, with separation of good and bad parts. The system is suitable for every application and it cuts quality costs because faulty parts are detected automatically.

ComoNeo is compact, meets industry standards and is easily configurable. It features a process-oriented operating philosophy and integrates flexibly into various production environments. The system has up to 32 inputs for piezoelectric cavity pressure sensors, up to 16 inputs for temperature measurements and four analog voltage inputs for machine signals (screw drive, machine pressure, etc).

Measure and connect

Monitor and control

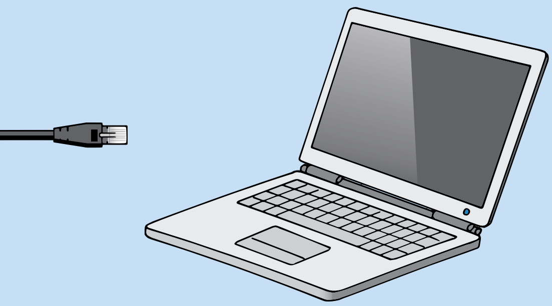


Charge amplifiers
Product range from Kistler also includes charge amplifiers specially adapted to composite processes. Charge amplifiers convert the sensor signal into an analog 0-10 V signal. This signal can then be visualized and processed with a suitable data acquisition system. Charge amplifiers for use with composites offer special amplification ranges that optimally support relatively low pressures.

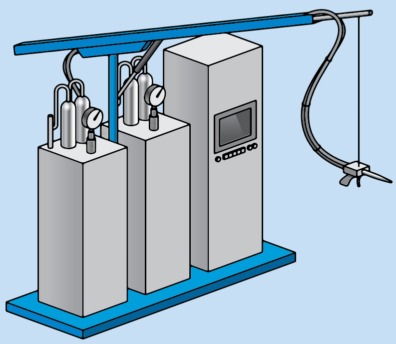
Software
The basic ComoNeo package can be expanded with the ComoDataCenter from Kistler. All ComoNeo devices can be linked in the ComoDataCenter. Live and historical data views are available.

Control
The pressure signal is fed back to production plant components, so active process control is also possible. For example, the resin pump's feed pressure can be controlled. Without pump control, there is a risk that the mold halves could be pressed open by the feeding pressure after the cavity is completely filled. This feature prevents incorrect part dimensions and damage to the mold.

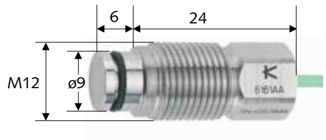
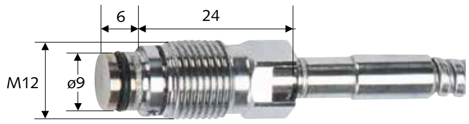
Document and analyze



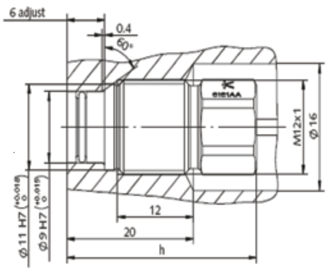
Regulate and control



Sensors

Front diameter		9 mm	9 mm
Measurands (p: pressure; T: temperature)		p	p+T
Technical data	**Type**	**6161A**	**4001A**
			

Installation sketch



Measuring range			
Temperature	mV/K	–	10
Pressure	bar	–1 … 200	–1 … 2, 5, 10 or 50
Sensitivity		18.5 pC/bar	0.2 V/bar
Operating temperature			
Mold temperature	°C	–40 ... 200	20 ... 275

Applications + characteristics		Automotive (fast-curing resins) HP RTM SMC Wet molding	Aerospace (slow-curing resins) LP RTM Resin infusion Unlimited measuring time Temperature-compensated pressure signal for processes with changing temperature conditions
Accessories			
Minimum overall height	mm	35	90
Data sheet: see www.kistler.com		**6161A (003-053)**	**4001A (003-248)**

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Thanks to Kistler's global sales and service network, we are always close to our customers. Some 2,200 employees at more than 60 locations are dedicated to the development of new measurement solutions, and they offer customized on-site support for individual applications.

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Find out more about our applications:
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