RTM TECHNOLOGY IMPROVEMENT WITH TOOL SURFACE HEATING BY INDUCTION

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Abstract

With the goal of weight and cost reduction in the automotive industry, the need for a technology able to produce highly structural composite parts in a short cycle time is very important. That's why RocTool adapted its Tool Surface Heating Technology to the RTM process. The inductive phenomena allows this technology to heat fast and cool down quickly the tool surface leading to many advantages for the RTM process such as : overall cycle time reduction, filling time reduction and safer filling of the mould, injection time reduction, warpage reduction because of extraction of cold parts, surface quality improvement.

Background

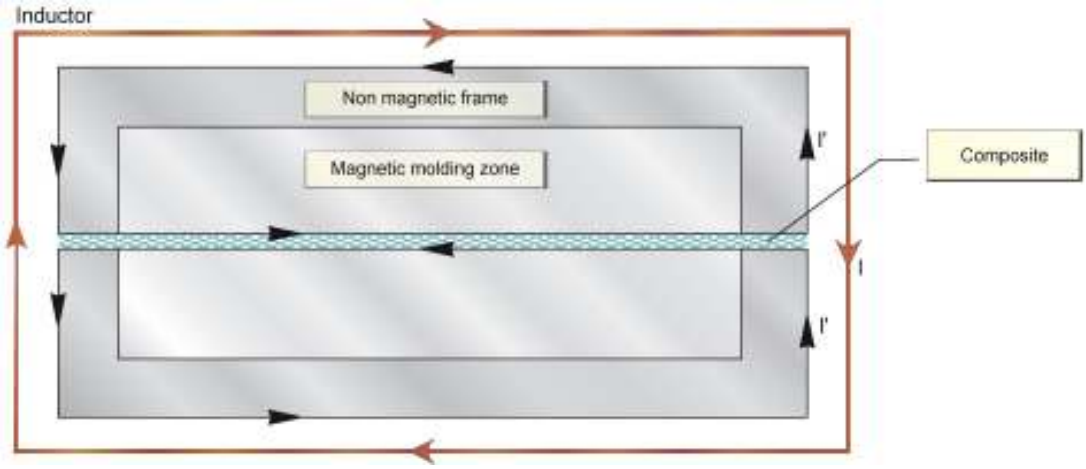
RTM process is well known to produce high mechanical properties composite parts. The resin is injected into a temperature controlled mould containing the fibrous reinforcement. Then the resin is cured into the mould and the part is finally taken out. This technology allows producing part with a high rate of reinforcement and thus high mechanical properties. But, one major drawback of this technology is the cycle time to produce a part which ranges from 10 minutes to several hours depending on the used resin and the mould temperature. This could be acceptable for some aircraft application but unfortunately not for the automotive market and its high production rate.

So the main work to carry on is to develop a technology able to really decrease this cycle time down to few minutes to be compatible with the automotive industry production requirements. The main time consuming phase is the curing of the resin because the mould temperature has to be compatible with part extraction leading to a quite low temperature and thus a long curing time. The idea of our technology is to get a temperature dynamic into the mould allowing high mould temperature to reduce curing time and low mould temperature during part extracting phase.

Tool Surface Heating technology (TSHT) key points

RocTool has developed the TSHT a core of technology declined in several processes which permits to transform plastics and composites very quickly. The THST uses an inductive phenomenon which heats instantaneously the tooling surface of the mould. Hence, it permits to decrease a lot the energy consumption compared to classical process which need to heat the whole mould, and abort all possibilities to cycle heating and cooling in an industrial configuration.

An electrical current ***I*** is sent through the inductor, surrounding the mould halves, and creates electromagnetic field and therefore two electrical loops of "eddy currents" in both parts of the mould. It generates induced currents ***I',*** localized in a thickness named EM skin depth δ, which loop around both mould half in opposite direction (governed by Lenz's law), alternately encountering a non-magnetic material and a magnetic material.



In fact, we generate a differential surface heating between the two different materials, by injecting a high quantity of energy (high magnetic output) into a small volume for the magnetic material (δ<<mm) compared with injecting a medium quantity of energy into a bigger volume (δ~$\forall$mm) for the non-magnetic frame.

Thus, controlled by different parameters like electrical and magnetic properties of the metals, frequency, the induce power is more important when ***I'*** is running through the surface of the magnetic insert than it is running through the non-magnetic frame.

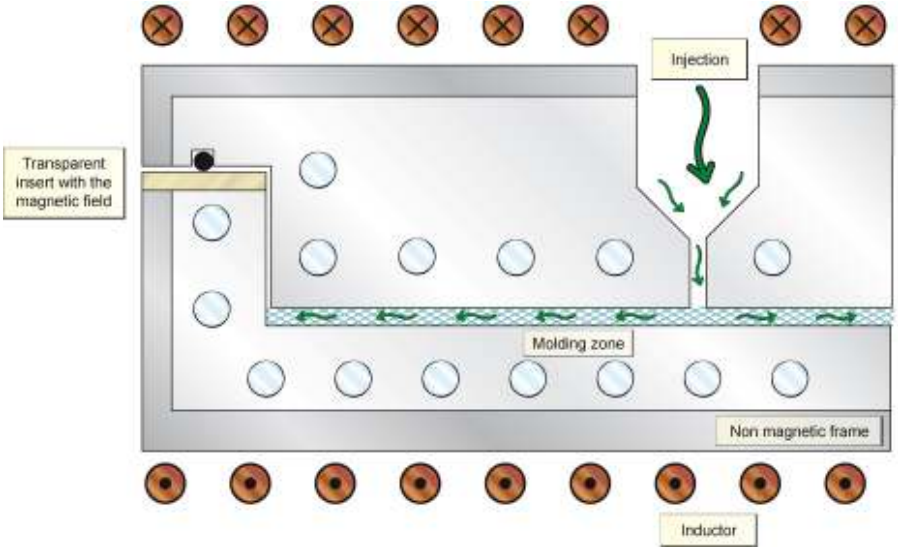
Induction… for RTM process

Presenting the specific features of the process set-up can help to identify the differences and, especially, the advantages that can be drawn from this technology.

The inductor surrounds the mould, forming the coil (represented below in cross-section) which generates induced currents simultaneously with the magnetic field. The non-magnetic frame assembled mechanically around the moulding area acts as a magnetic shield that keeps the entire mould from heating up.

The moulding area is made of magnetic steel that meets the requirements of the inductive process, even tough it comes from one of the more standard range of tooling steels.

A composite or ceramic magnetic-transparent pad conveys the magnetic flow into the air gap, while preserving the closing of the mould for the resin.



The main advantage of this technology is to have the possibility to reach almost instantaneously different levels of temperature on the mould surface, to optimize the three main phases:

⇒ Resin injection,

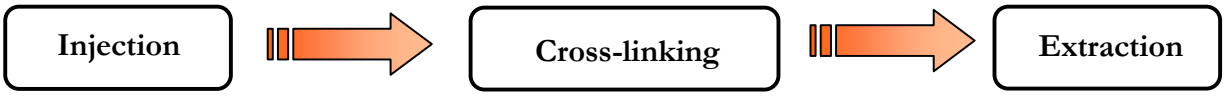
⇒ Cross-linking,

⇒ Part extraction.

Current RTM process limits

Currently, the RTM process is mainly driven by the injection and extraction temperatures. In fact one has to find a compromise between the highest temperature acceptable to extract parts, the highest temperature acceptable for the resin injection and the lower one acceptable to reach a decent curing time for the resin. This statement leads to have thermally regulated mould at a medium temperature around 100°C. Then the process is facing some difficulties as follows:

- ⇒ Mould filling difficulties, because the mould is already hot when injecting the resin what could create some pre-curing problems and blocking the injection system
- ⇒ Long cycle time due to low curing temperature and then low curing speed
- ⇒ Part wrapping when extracted due to high extracting temperature leading to a complex conformer step after part extraction
- ⇒ Low surface quality because of difference in the curing rate and also not good filling of the mould before curing starts.



Medium Temp.

These difficulties could now be overridden by the use of the induction for the tool's surface heating.

RTM Process improvements by the mean of THST technology

As seen previously, the lower the injection and extraction temperature and the higher the curing temperature, the better the RTM process would perform.

THST with its ability of heating and cooling the mould surface instantaneously allows having different temperature steps during the whole molding process.

Thus

Resin injection is carried out at a quite low temperature:

- ⇒ No risk for resin pre-curing and injection system blocking
- ⇒ Resin rheology optimization : better and faster filling of the mould
- ⇒ Enabling the use of very reactive resins

Once the mould is filled with the resin, then thanks to the THST, the mould is heated up at high temperature to cure the resin:

⇒ Fast resin curing due to high mould temperature

⇒ Homogeneous curing

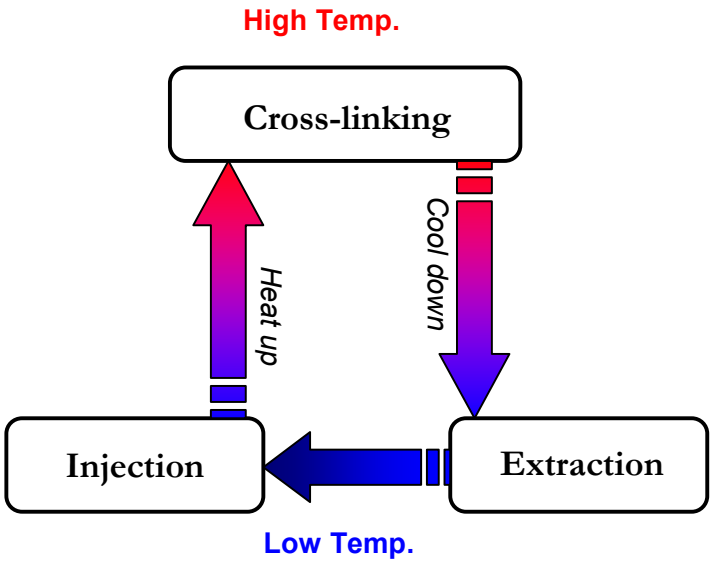
Then the mould is cooled down using water channels closed to the mould surface:

⇒ No more warpage as the part is cooled down into the mould

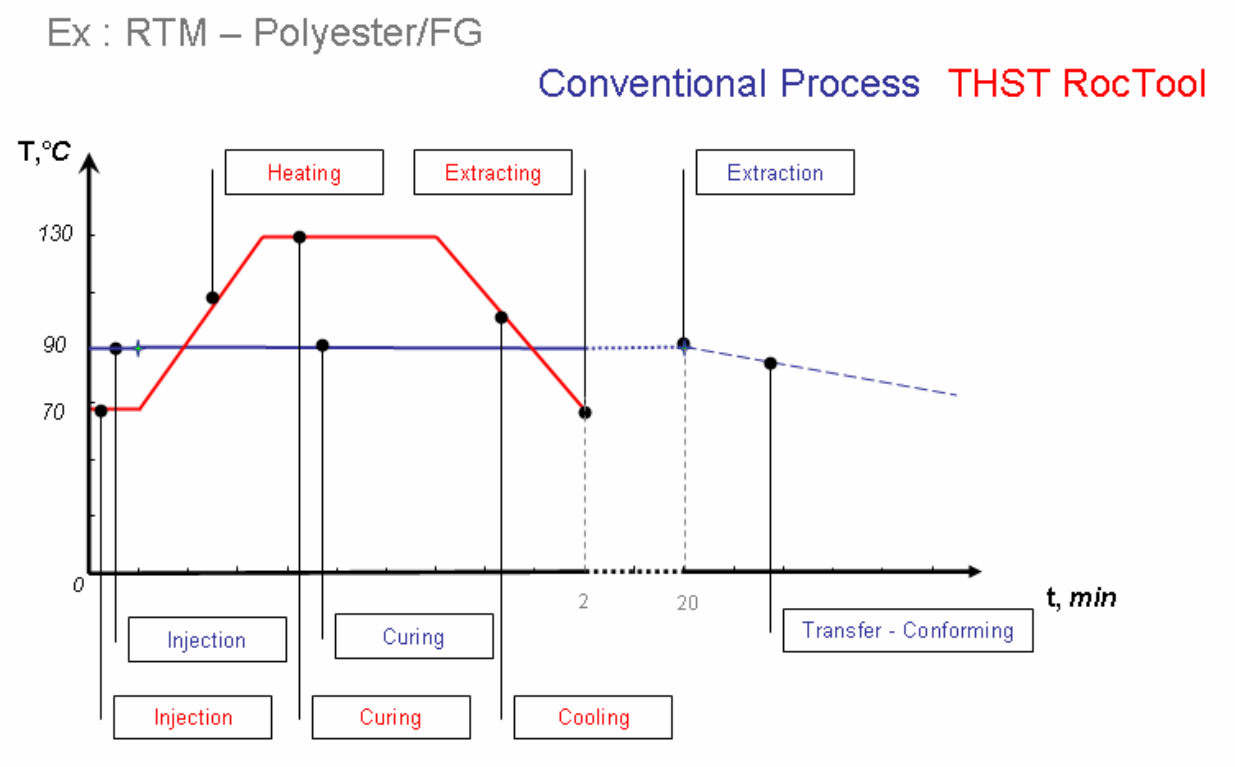
⇒ No need for expensive post conforming machine

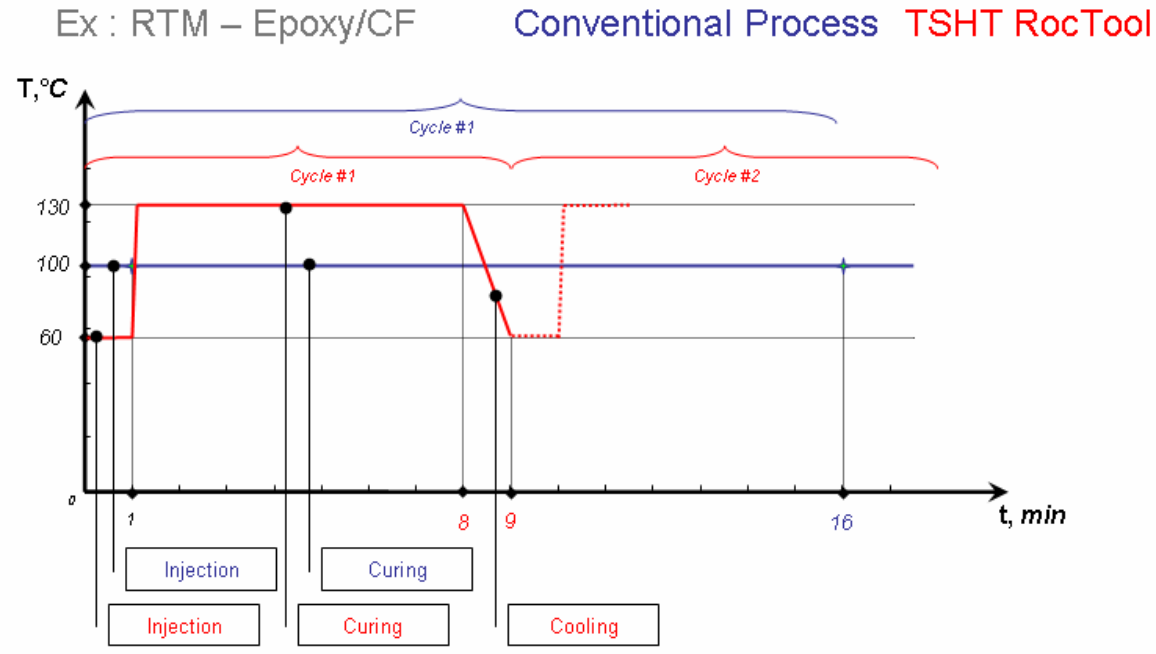
⇒ Safe extraction of the part as it is cold when the mould opens

⇒ Good surface quality allowed by cold part extraction. No sticking to the mould. No deformation. No fibbers coming on the surface.



In the scheme below, you will find two examples of processes carried out on a polyester / FG part and an epoxy / CF part using conventional and TSHT.





It is also to be noticed that having a fast changing temperature does not impact badly on the mechanical properties of the produced parts, and even give some mechanical and quality improvements.

On the previous example with the polyester / fibber glass part (40% wt reinforcement), we carried out a first testing session on parts molded with the conventional process and also with the TSHT. The results are as follows:

Conventional way of moulding : mould regulated at 90°C, cycle time 20 minutes

TSHT way of moulding : mould temperature ranging 70°C→130°C→ 70°C, cycle time 2 minutes

⇒ Reduction of residual styrene content: from 3,3% (conventional process) to 1,7% (TSHT process)

- Less residual styrene leads to better curing rate
- Less residual styrene leads to lower odor emission

⇒ No mechanical properties modification:

- Flexural strain 195 Mpa with conventional process
- Flexural strain 230 Mpa with TSHT process

Conclusion

So, tool surface heating technology allows a better process in terms of part quality, a safer process in term of blocking the machines but also regarding the operator who is no more in contact with a hot tool. Then the main advantage is for sure an economic one in term of cycle time reduction but also in term of lower investments.

As we already mention, one major drawback concerning RTM process is its long cycle to produce a part. It is becoming a real big issue when looking at the automotive market and its low costs requirements. To reach the high production rate and the automotive target, there are only two ways, either using a conventional process and multiplying the number of installations, or highly reducing the cycle time to produce a part. We choose to work on the second solution for economic reasons: lower investment and lower labor cost per part.

Then when using the TSHT you reach a better process control, a higher quality part but also a very cheaper part:

- ⇒ The labor cost is really decreased as the cycle time is
- ⇒ The investment cost is much more lower as only one installation running with one shift a day can produce the same number of parts as three installation running three shifts a day using the conventional RTM process
- ⇒ No more need for expensive cooling device (conformers) as the parts are extracted when cold