

## WHY CLOSED MOLD TECHNIQUES

- Laminate quality
- Safety / Environment & workforce
- Weight reduction
- New design possibilities
- Low capital investment
- Reduced secondary processes

## Injection techniques for Marine

### Light RTM

- Injection with use of standard female mould + extra flange to close both moulds halves.
- Male mould is laminate with  $\pm$  3-4 mm thickness.
- Injection via vacuum and sometimes some extra help of pressure ( $\pm$  0.5-1 bar) at 20-40°C.

### Vacuum injection

- Injection with standard female mould + extra flange to close both moulds halves.
- Male mould is a flexible film
- Injection via vacuum (20-40°C).

## D'Arcy's Law, the basis of all injection techniques

$$t = \frac{l^2 \cdot \eta}{2 \cdot k \cdot \Delta P}$$

$t$  = injection time

$l$  = injection length

$\eta$  = resin viscosity

$k$  = permeability

$\Delta P$  = pressure difference

# Injection - Influence of viscosity

- Viscosity of the resin
- Permeability
- Injection length
- Injection strategy

$$t = \frac{l^2 \cdot \eta}{2 \cdot k \cdot \Delta P}$$

A low viscosity gives a short injection time

Injection experiments with viscosity 180 – 750 mPa.s

# Injection - Demonstration influence of viscosity



730 mPa.s

350 mPa.s

180 mPa.s

**DSM Composite Resins**

*Unlimited.* **DSM**

# Injection – Influence of the permeability

- Viscosity of the resin
- Permeability
- Injection length
- Injection strategy

$$t = \frac{l^2 \cdot \eta}{2 \cdot k \cdot \Delta P}$$

A high permeability gives a short injection time.

- High permeability: CFM, Multimat, etc
- Low permeability: CSM, fabrics, etc

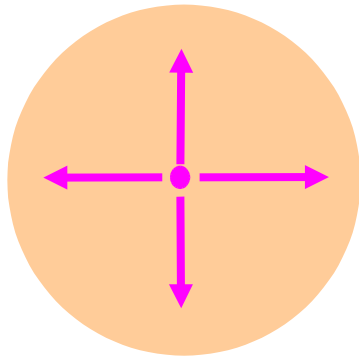
## Injection – Influence of the permeability



Injection experiments with materials with different permeability

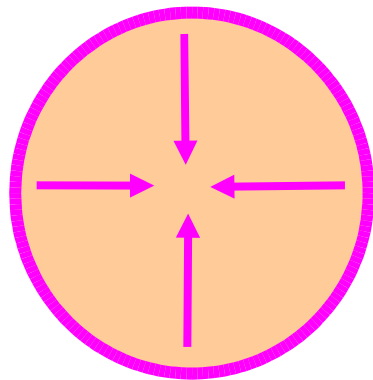
# Injection – Influence of strategy

- Example: Circular injection panel



60  
minutes

$$t = \frac{l^2 \cdot \eta}{2 \cdot k \cdot \Delta P}$$



15  
minutes



## Vacuum injection : Important practical topics

- Gelcoat and tiecoat steps follow same criteria as for HLU/SU
- Adapt curing system for different temperatures to avoid gelification before complete injection/infusion
- Ideally gel time  $\pm$  15 minutes longer than injection time
- Test resin flow on small pieces to design properly the curing system
- After peroxide mixing wait for air release
- System must be 100% leakage free and must be always tested before each infusion to avoid air entrapment

# Injection techniques – resins portfolio

## VE injection resins

	Viscosity (mPa.s)	VOC content (%)	Geltime (min)	Peak temperature (°C)
Atlac 580 AC 200	150	53	65 (1,5% but M50)	125
Atlac E-Nova 6215	90	41	46 (3% but M50)	120

# Injection techniques – resins portfolio

## DCDP injection resins

	Viscosity (mPa.s)	VOC content (%)	Gel time (min)	Peak Temperature (° C)
Syn 1967-G-3	290 - 330	33 - 36	45 (3%MEKP)	120 - 150
Syn 8488- G2/G4	80 – 90	38 – 43	45 – 65 (3% MEKP)	40 - 65

# Surface quality - Effect of curing

- Influence of post curing
  - Curing at room temperature = After cure after demoulding = shrinkage / shrink marks / fibre print
  - Post curing on mould (e.g. 5 hrs. 50°C) = After cure with support of mould = less shrinkage after demoulding



**Post curing on / in the mould gives the best surface quality!**

Test surface quality: [Diffracto.ppt](#)

# Important issues for high quality surface

Best surface quality can be reached by :

- good surface of mould
- thickness of gel coat > 500 micron cured
- use of barrier coat / tie-coat & degree of cure before applying next layers
- degree of cure of gel coat before applying next layers
- use of veils
- use of low TEX CSM p.b.
- no overlapping
- no resin rich spots etc
- use of stitched mats (no woven rovings)
- use of DCPD based resins or VE
- proper curing system with right peak exotherm
- (use of fillers)
- high degree of cure of gel coat + successive laminate layers before mould release
- (heated moulds?)