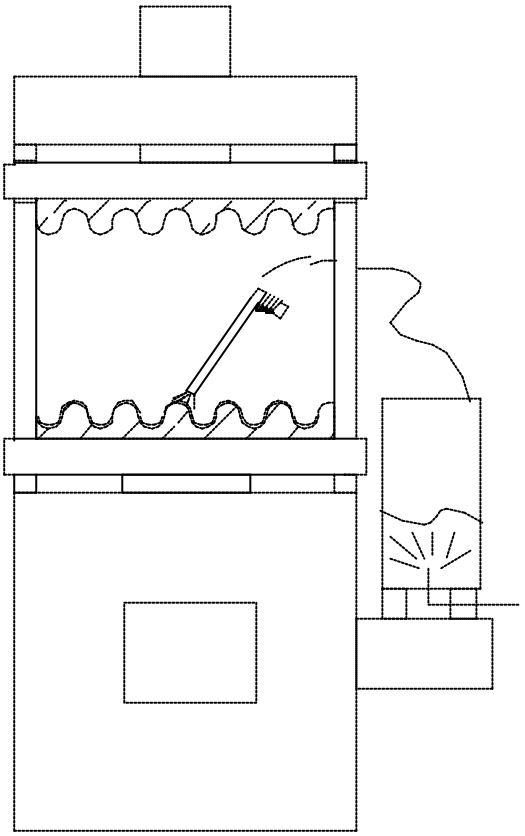
synres-almoco bv

Framework and process guidelines for Powder in-Mould Coating.



The contents of this brochure are aimed to assist the designers of moulds and the moulding-shop managers in their preparation for the use of PiMC as one step topcoat over SMC/BMC pressed parts.

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1. Introduction to PiMC.

Simple in its concept and a challenge to control.

Powder In-Mould Coating (PiMC) in its concept of just spraying a powder layer prior to moulding a part is an easy technology from the perspective of sophistication of equipment and control parameters. Still a good result is the balance of a mix of often counteractive dynamics in the in situ formation of the coating. The PiMC composition and the process circumstances are the parameters that need to play together to get that good result (appearance and low number of rejects).

What exactly is happening at the mould-surface?

- A homogeneously sprayed layer of un-reacted powder on the hot mould surface will become the robust topcoat of the SMC/BMC part by integrally reacting with the SMC/BMC during the press and cure step for the whole part. This PiMC layer is in between the mould surface and a highly viscous SMC/BMC mass that needs to flow over the back of this layer that is in the forming process.

Over the years Synres-Almoco's PiMC formulations have been carefully developed to ensure a good result when correctly applied.

Critical steps in this physical / chemical process are:

- Applying a powder-layer with a consistent and homogeneous thickness on a mould surface with the right temperature.
  The typical layer thickness of the PiMC is between 150 and 250 microns.
- Melting and partly curing of the powder into a film that can resist the next steps.
- Charging the SMC or BMC mass on the PiMC film.
- Controlling the speed of closure of the press in order to let the SMC or BMC flow over the film without rupturing it. (The film should adhere enough to the mould but come loose easily after the complete cycle.)
- Applying the right temperature and pressure cycle for full cure of PiMC and part.
- Controlling the speed of reopening of the mould.
- Controlling the releasing (or demoulding) of the coated part.

Managing these steps of the PiMC-technology involve investing in the right framework conditions and mastering the project-steps and production parameters.

This guideline is intended to instruct on these elements in order to enable a reliable and economical processing of PiMC.

For information on PiMC coating-characteristics and economics we refer to the relevant literature that can be obtained via our office.

2. Frame work conditions for the PiMC technology.

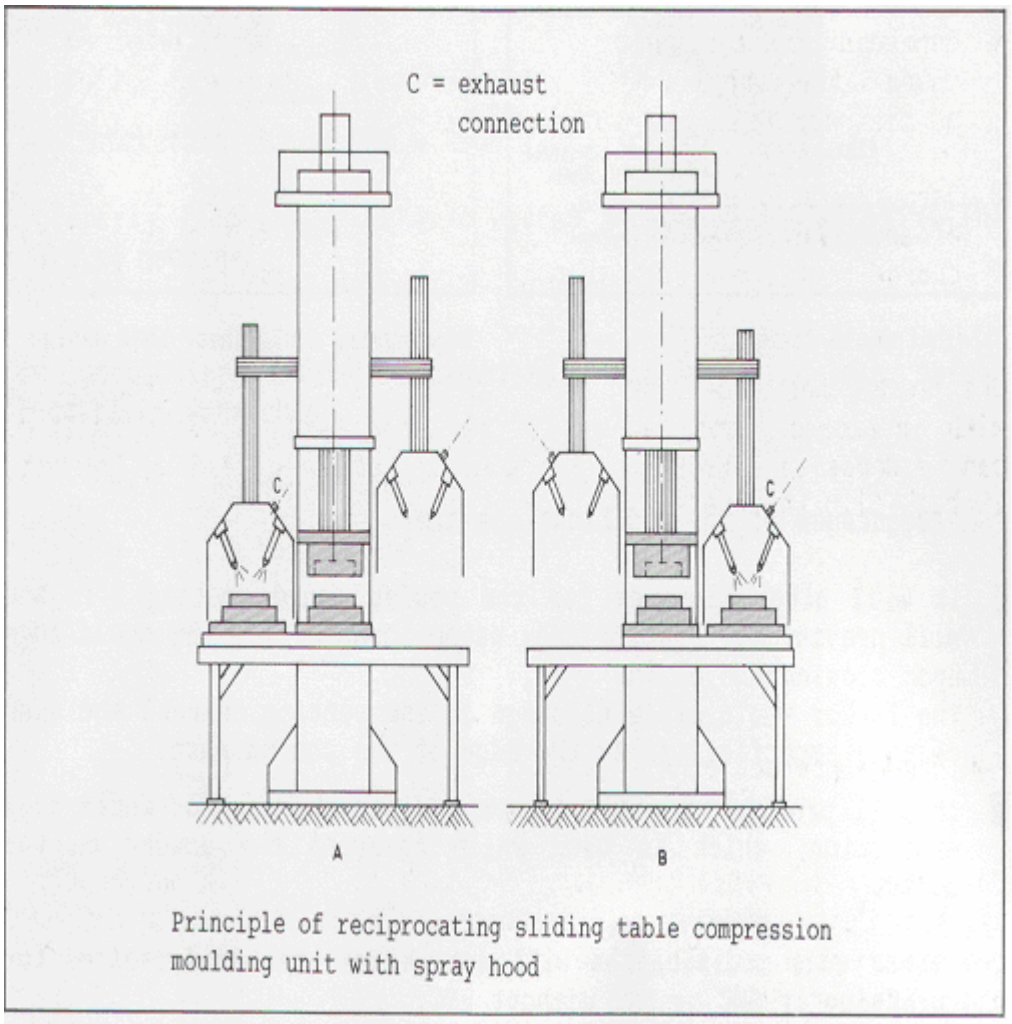
Thinking this through will benefit for all future jobs for PiMC.

2.1 Press.

- Space between upper- and lower mould half for the robot arm with the spray gun to move around. The press should have a large enough opening between the two mould halves.

- Adjustable speed for closing and opening of the mould. During the flow of the SMC/BMC the press should be closed at a low speed to avoid the risk of shifting of the PiMC layer due to the shear force of the flowing, highly filled, SMC/BMC. A slow opening speed of the mould prevents damage of the PiMC layer.

- A reciprocating sliding table compression moulding unit can be considered for large series to reduce cycle times. Using this sliding table enables you to coat the 2nd mould during the cure cycle of the first mould.



Principle of reciprocating sliding table compression moulding unit with spray hood

2.2 Powder spray equipment.

- Any commercially available corona type spray gun for electrostatic powder spraying will do the job.
Well known and reputed suppliers are i.e. (in alphabetic order):
- ITW Gema.
- Larius.
- Sames.
- Spray S.A.
- Wagner.

- Care has to be taken that the powder transport line (the hoses from powder hopper to the spray gun) should be as short as possible, whereby we found out in practice that 7 metres are the absolute maximum.
Too long hoses may result in inhomogeneous and not constant powder clouds, resulting in varying layer thicknesses on your component. For speckled colours too long hoses may even result in separation or disintegration of the mixed colours.

- In order to avoid contamination, each colour of PiMC should preferably be used which its own dedicated hose. Hoses should be cleaned regularly in order to avoid that residues of powder remain in the hose, which can easily turn lumpy when the hose is not used for a while. This “lump” will in time be set free and blown onto the mould surface resulting in defects and a “reject-part”.

As indicative price one should consider € 5000 per spray gun, including control unit. (Price 2004)

2.3 Compressed air.

For spraying of the powder compressed air must be available. This is usually available in every mould shop, but for proper spraying of the PiMC, the compressed air should be cooled and dried and free from oil. To obtain this a freeze drier and an oil separator should be incorporated in the air line.

The temperature setting of the drier should preferably be set at 5 ºC, but never lower than 0 ºC to prevent ice formation and inclusion of moisture into the powder (see also the remarks made in paragraph 2.8 under “Storage of the PiMC powder”)

Necessary equipment can be obtained from i.e.:
Ingersol Rand
Productieweg 10
2382 PB Zoeterwoude
The Netherlands
Phone +31 71 5452200
Fax +31 71 5452202

Other companies certainly exist but with this company we have good experience in our own factory.

2.4 Exhaust system.

A good exhaust system is essential when you realize that you work with very fine powder. Not only will it keep your work shop clean, but it also contributes to proper health & safety conditions for your operators.
An exhaust can be mounted on or around the mould half that has to be coated.

2.5 Robot.

Here one should opt for a so called Point-To-Point robot, for easy programming.

Reputed suppliers of robots are i.e.:

- ABB Robotics Ltd.
- Atlas Copco.
- Hitachi.

Having installed a robot one should realise that this will enable you to also make use of this robot for additional jobs at the press, like:

- Placing and removing the protective mask.
- Taking out the product after moulding.
- Machining the moulded part.

For cost planning one should consider an indicative price of € 100.000 up to € 200.000 depending whether this robot is non explosion proof resp. explosion proof.

2.6 Operators, accurate and responsible.

For producing SMC/BMC parts with PiMC the operators should be specially trained. Besides the usual preparation of the mould, cutting and weighing of the SMC, demoulding and trimming of the part the operators have to fulfil the additional task of controlling the spray equipment and robot.
We advice our customers to train the shift leaders in programming the spray equipment and robot. The operators should check each moulded part on quality and respond quickly to failures.

2.7 A cutter for trimming the part.

As will be explained in detail in section 3.1, the pinch off area of the mould has to be changed in order to maintain the venting of the mould. This will however result in a thicker bur (approx. 0.6 mm.) than the usual 50-100 microns of uncoated SMC products.

Because of the thicker burr a knife and sand paper cannot be used anymore to remove the burr and one should use a saw cutter instead. The cutter may preferably be of hard metal with diamond grit.

2.8 Storage of the PiMC powder.

Storing the PiMC in a refrigerated room (< 15 ºC) provides you with a Shelf Life of over 6 Months.
When stored in a refrigerated room it is recommended to take the cartons out of the refrigerated room several hours prior to start working with it. This will enable the powder to gradually adapt to the ambient temperature and prevents condensation of moisture due to temperature shock. This is the more important since absorbed moisture in the powder may cause delayed polymerization, but also surface defects in the form of small blisters.

The Powder Stability is over 8 hours at 30 ºC, giving you ample time to have the powder in your mould shop at ambient temperatures.

2.9 Measurement equipment.

- A helpful tool during programming of the robot and for in-line quality inspection is an instrument with which one can check the layer thickness of the PiMC on the mould surface, prior to applying the SMC.
This can be done using an Elcometer, supplied by:
Elcometer Instruments Ltd
Edge Lane, Droylsden
Manchester M35 6 BU
Phone 061 370 7611
Fax 061 370 4999

- A thermometer for measuring the actual mould surface temperature before start-up of the production or for trouble shooting should be at hand.

3. Prior to a project for a specific SMC/BMC part.

The check to be made with each new job.

3.1 Mould design.

The mould surface should be in a perfect condition with respect to surface quality (bear in mind: PiMC will act as a “mirror”. Any defect on the mould surface will show on the moulded component).
Preferably the mould should be chrome plated and highly polished unless a low gloss or textured surface is required.
Due to the electrostatic spraying the mould should be earthed, enabling the powder to “discharge”, but also for safety reasons for the operator.

Special care has to be taken to the design of the mould with respect to the venting channels, especially in cases where powder is going to be applied in already existing moulds so far only used to mould uncoated products. One should bear in mind that the PiMC coating in general will be approx. 200 µm thick and, when not adapting the venting section at the pinch off area, the venting channel will be blocked by the layer of powder and the air cannot get out anymore.
The principle on how to change the pinch off area is explained in figures 1, 2 and 3 on the next pages.

The mould should have ejectors, preferably in combination with compressed air, the so called air valves. Air valves are less sensitive to leaving marks on the products. Should one only have pneumatic ejectors, these should be carefully positioned, because they may leave a mark on the product.
Using air valves is also preferred, because they can help to overcome release problems. Should the product not release, just open the mould for a little bit, open the air valves and bring in air. Close the mould again, thereby distributing the air over the full surface of the product. Then open the mould again and introduce more air. This should normally solve the release problem.

In the design phase of a project one should be aware that when spraying in small and deep cavities one has to deal with the so called Faraday-effect. The Faraday-effect can be overcome by reducing the high voltage setting to approx. 10 kVolt. Of course it is obvious that when the cavities get that small that the spray gun cannot penetrate, it will virtually become impossible to apply PiMC in that section.

3.2 Mask.

A mask is a helpful tool to keep the table of your press clean from powder dust and molten powder and will (if properly designed), also cover the venting channels of your mould, thereby preventing that these venting channels will be blocked by the cured film of PiMC.
In figures 1, 2 and 3 these masks are also shown.
Masks can be simply made from cardboard or wood, but also more sophisticated masks do exist in our industry, for example:

- Teflon coated wood.
- Aluminum, double walled enabling cooling by water.

Warning: do not use steel or any other material that can be electro-statically charged.

3.3 The right quality of SMC/BMC.

Despite the fact that PiMC will improve the aesthetic appearance of the final part the quality of the SMC/BMC also determines the surface quality. Properties such as waviness and orange peel are determined by the SMC/BMC type.

The SMC or BMC used should be based on Tert.-butyl-perbenzoate as a catalyst. Tert.-butyl-peroctoate is too reactive compared to the PiMC and may cause cracks in the coating or shear-off of the coating.

The SMC/BMC used should not be dried out, because this will lead to too high shear forces during the melting/flowing of the substrate, resulting again in shear-off of the coating.

Due to the shrinkage characteristics of our PiMC (2% linear shrinkage) the SMC/BMC should preferably not have too low shrinkage in order to avoid your product to bend during cooling off.
This warpage can be reduced/overcome in the design phase of your product by applying reinforcement ribs at the uncoated side of the part.
Putting the part in a clamping device during cooling off will also reduce the warpage.

Flame retardant SMC grades are typically highly ATH filled compounds. These compound types are usually difficult to process. Here PiMC can assist in hiding and reducing the surface defects.

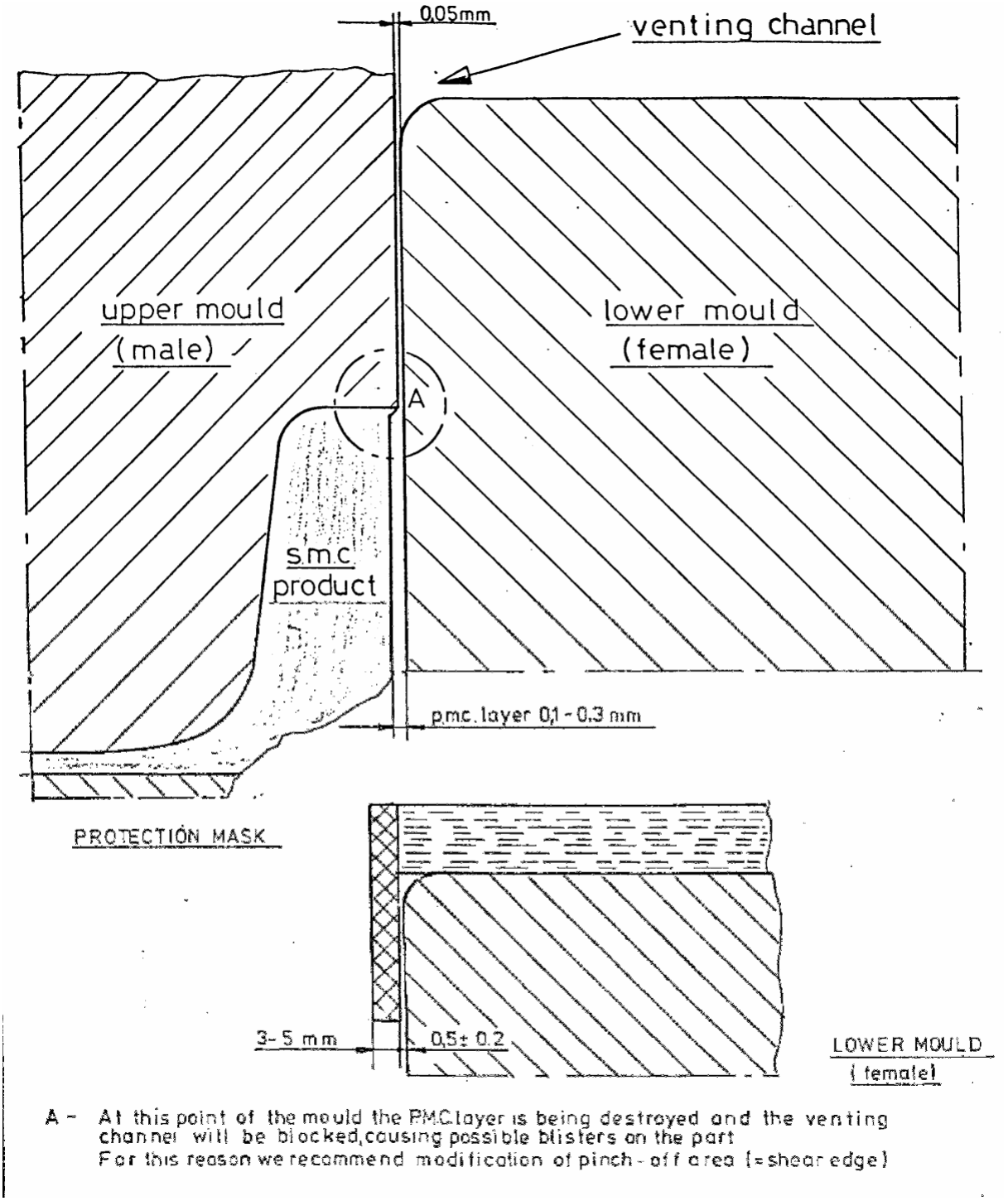


Figure 1: Traditional mould vent design for uncoated SMC products.

Despite a mask is being used during spraying of the PiMC the venting channel will be covered with PiMC. Upon closure of the mould this PiMC layer will be mechanically sheared-off and block the venting channel. This will cause air entrapment and blisters in the part.

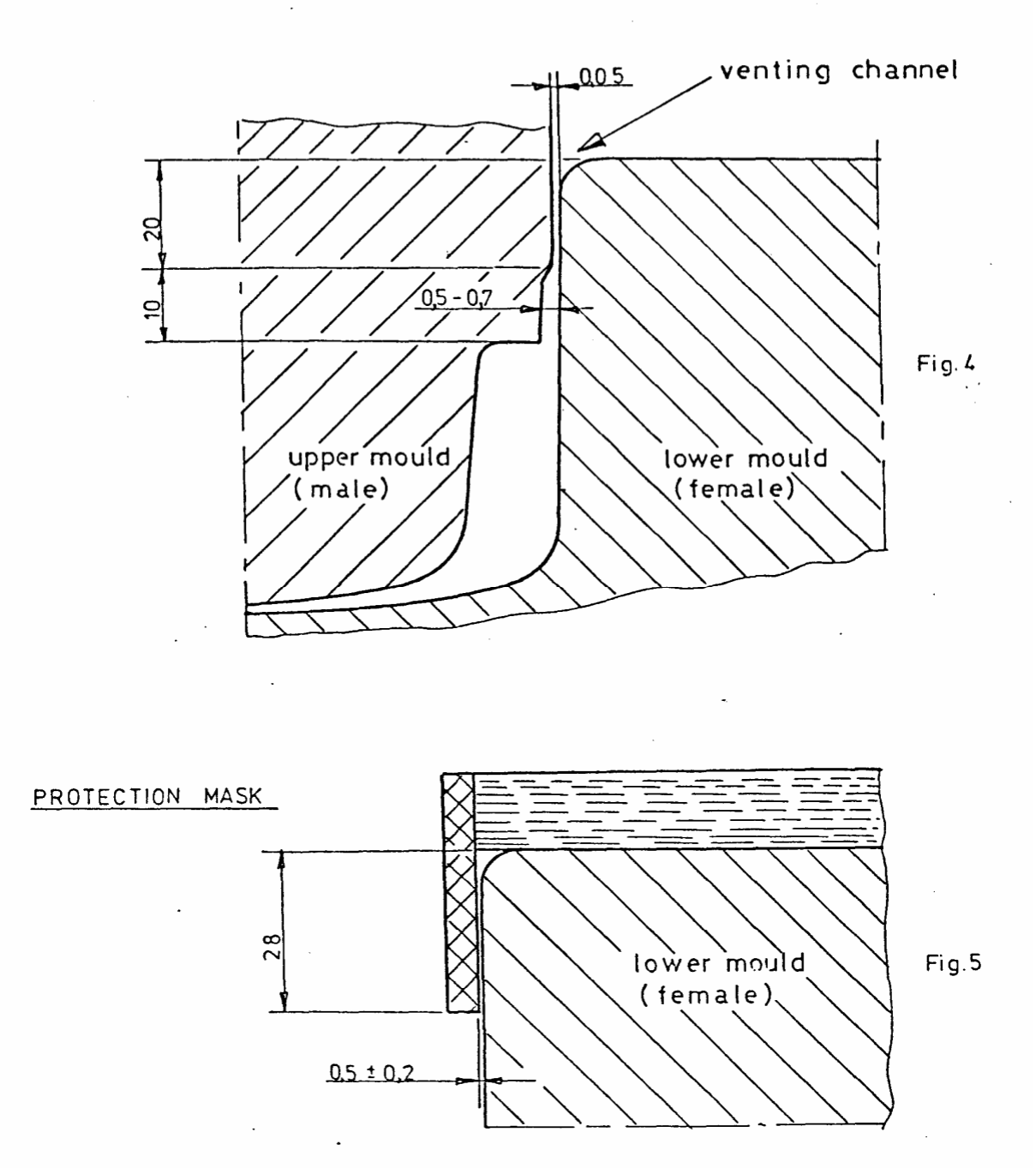


Figure 2: Adapted mould vent design for existing moulds.

An easy and relative cheap way to adapt the venting channel is to increase the size of the venting channel in the region where the PiMC is being sprayed.

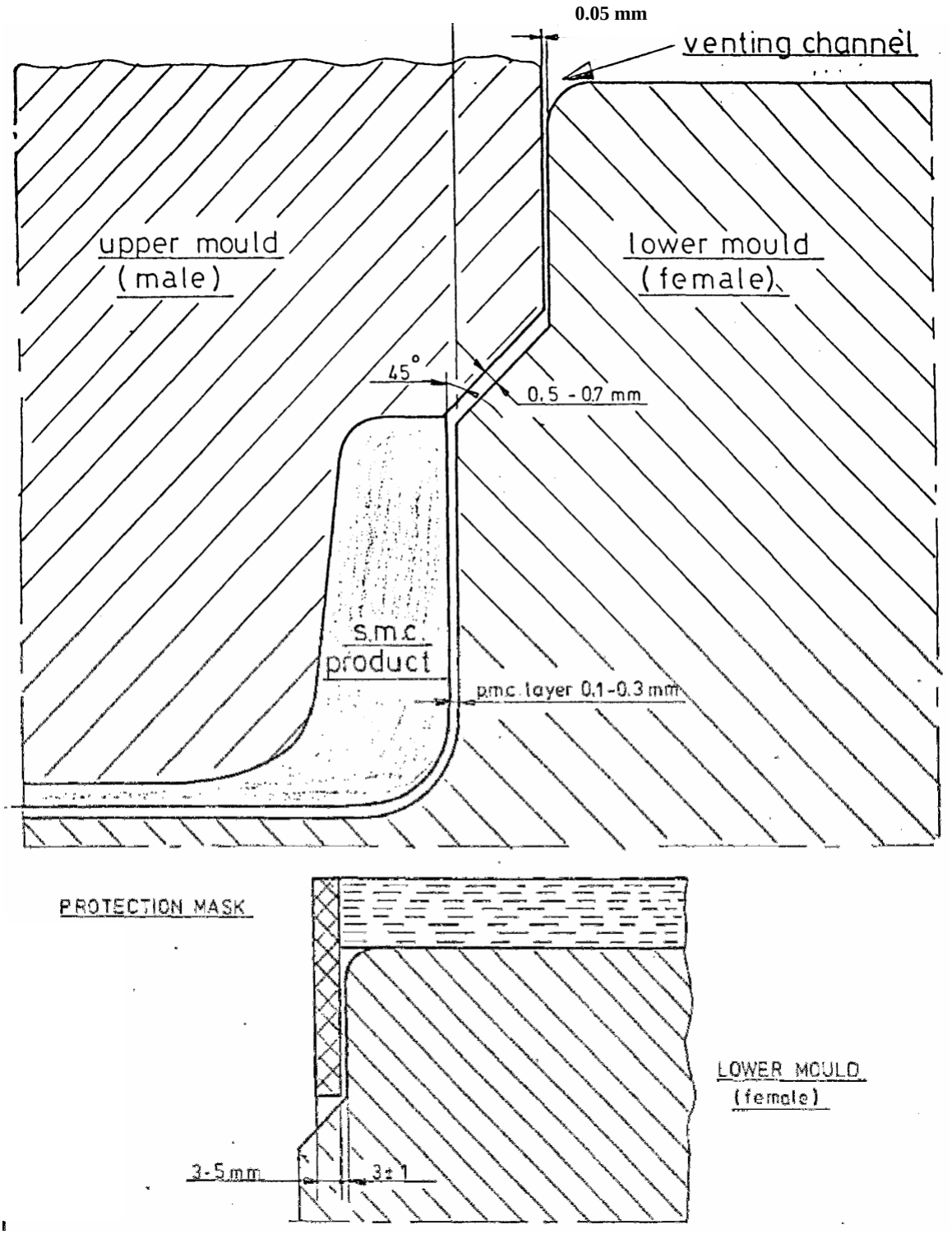


Figure 3: Preferred mould venting design.

For new moulds we advice this design with the venting channel oriented under 45°. During closure of the mould and flowing of the SMC the venting channel is always open providing optimum venting of the mould.

4. Process parameters.

The degrees of freedom during running of the line.

4.1 Robot settings.

For each new part to be produced an optimum spray pattern must be programmed into the robot. During this programming stage one should take care that the film thickness is homogeneous all over the part.

The distance between the tip of the spray gun and the mould surface should be kept constant over all sides of the part to provide an even coating layer.

It is advisable to start the spray program on the surface where the SMC charge is placed or the BMC is injected. This will reduce the risk of shifting of the PiMC layer during the flow of the compound.

4.2 Spray gun settings and coating thickness.

With the air settings of the spray equipment the amount of powder and the “cloud” from the gun is being controlled. These settings, in combination with the speed of the robot arm, should provide a homogeneous coating layer with the right thickness.

The air settings of the fluid bed of the spray gun should be adjusted to provide a constant powder flow through the tubes to the gun.

The high voltage setting of the spray gun is generally between 60 and 100 kVolt. As far as the electrostatic charge is concerned one should be aware that chargeability of the powder is colour dependent and from case to case one should vary the charge.

Depending on the size and shape of the part one should select the proper Teflon tip on the spray gun.

The best quality coating is obtained at a layer thickness between 150 to 200 microns, but in actual use you will find that PiMC is a relatively “forgiving” material that has a broad window of spraying.
One should however preferably “build” the coating in 2 thinner layers.
At first glance one would think that this leads to longer cycle time, but varying the air pressure (resulting in higher powder debit) and by varying the speed of the robot crossing the mould surface one can still obtain reasonable cycle times. Mind you: a slightly longer cycle time may pay itself by reduced rejects.

4.3. Press settings.

The final closing speed of the press should be chosen as low as possible. This will provide a good flow of the SMC/BMC and low shear forces of the flowing compound on the coating layer. High shear forces may result in rupture and shifting of the PiMC layer, which is still rather soft during this flow step.

In some cases it is necessary to wait some seconds between end of the spray program and moulding to the part. In this waiting the PiMC has some time to cure and build-up strength to withstand these shear forces.

4.4 Mould temperature and reactivity.

The reactivity of the powder is set as such that you obtain a quick melt and hence a fast building of the coating film, but leaving you a long enough operating time to introduce the SMC/BMC into the press and to finish your moulding operation.
The standard temperature for the mould surface is 140 – 150 °C. With the mould surface temperature one can control the reactivity of the PiMC. For large surface areas and thus longer spraying times one can chose for a lower moulding temperature.

Too high temperature should be avoided in order to prevent that the PiMC coat is already fully cured before introducing the SMC/BMC in the mould, because then the chemical bond between the SMC/BMC and the PiMC cannot occur and the coating will break away.
Also too low mould temperatures should be avoided, because this will result in too low cure of the PiMC layer which will result in too low mechanical strength of the coating, which in turn will lead to “washing away” of the film by the shear forces of the SMC/BMC.

4.5 Demoulding.

At the moment of, or shortly before, opening the press the air valves should be opened to let some air flow between the mould and the PiMC covered part. This in combination with a slow opening of the mould will provide optimum demoulding and prevent damage to the coating layer.

4.6. Maintenance.

In the regular maintenance of the mould and press the spray gun must be included. Regular checks on wear of the tubes and inside of the gun should be put into practice.

The PiMC is building a film coating directly on the mould surface. This coating does not only improve the surface of your moulded product, but since the flow of the SMC is underneath this coating the PiMC also acts as a protection for your mould surface. The shear forces during melt and flow of the highly filled SMC/BMC do no longer harm the mould surface, increasing the lifetime of your valuable moulds.

5. Trouble shooting guide.

Suggestions to correct unsatisfactory quality parts.

Despite all precautions taken following our advice from previous sections, failures still can occur. The operator has an important task in noticing these defects in time and take appropriate actions.

Small surface defects can occur because of several reasons.
These small defects however can easily be repaired by locally cleaning the surface with acetone and repair the defect by painting the spot with a two-component polyurethane lacquer of the same colour.
After 24 hours drying period the gloss difference between the PiMC section and the lacquer section can be made identical by treating the polyurethane surface with a very fine sand paper in combination with Commandant cleaner 4. Practice has proven that the adhesion of the polyurethane lacquer to the PiMC surface is excellent.

A well reputed supplier of 2-component polyurethane lacquers is:
De Beer Lakfabrieken BV
Zuiveringweg 89
8342 PE Lelystad
Phone +31 (0)320 292200
Good experience has been obtained with their lacquer:
- Berocryl Series 400.

What can go wrong?

Problem	**Possible cause or remedy**
The PiMC has cracked and has been sheared off at the edge of the part matching the shear-edge area of the mould.	- The pinch-off area might be too narrow or PiMC powder has been sprayed on the shear-edge. - The mask is not completely covering the shear edge. - The pinch off area (shear-edge) is too wide. - The composite is too reactive.
Localized torn coating and cracks at places other than at the edge of the part matching the shear-edge area of the mould.	- Mould temperature too high. - An external mould release agent has been used. - The flow forces of the SMC/BMC during the mould fill out are higher than normal. - The PiMC layer is too thick.

The part shows blisters resp. adhesion problems of the PiMC on the composite material.	- Air entrapment in the SMC caused by a too narrow venting channel. - Venting channel has been blocked by powder. - Dried-out composite. - The catalyst combination in the moulding compound is not suitable to activate the cure of the PiMC. Catalyst system of compound should contain at least 50% Tert.-butyl-perbenzoate.
Poor flow properties of the PiMC and / or porosity.	- The mould temperature is too high for the type of PiMC used. - PiMC has been applied too thick at certain spots.
Shear marks in the PiMC or shifting of the coating.	- The PiMC layer is too thin. - The PiMC layer has not cured sufficiently caused by a too low mould temperature. - The PiMC powder has been applied with a too low electrostatic charge or no charge at all.
The coated part causes sticking or release problems.	Only after all other remedies fail would we advise: - Stir approximately 0.5% of zinc-stearate in the PiMC. - Try to bring about release with an external release agent. Beware that too much release agent can cause shifting of the PiMC layer during flow of the compound.
Small blisters.	- The moulding pressure is too low (should be approximately 80 kg/cm^2).
PiMC covers small holes in which a gelatinous material can be found.	- LP additive has not been incorporated homogeneously in the compound.