Ceramics Keramik
Céramique

Additives for the optimisation of the pressure casting process

ZSCHIMMER & SCHWARZ
GmbH & Co KG
CHEMISCHE FABRIKEN

Max-Schwarz-Straße 3-5
56112 LAHNSTEIN/GERMANY
Fon +49 (0) 2621/12 485
Fax +49 (0) 2621/12 403
www.zschimmer-schwarz.com

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ZSCHIMMER & SCHWARZ GmbH & Co KG · CHEMISCHE FABRIKEN · Max-Schwarz-Straße 3-5 · 56112 LAHNSTEIN/GERMANY · Fon +49 (0) 2621/12 485 · Fax +49 (0) 2621/12 403 · www.zschimmer-schwarz.com

1. Introduction

In the conventional slip casting process, the slip is cast into a porous plaster mould and de-watering by the capillary suction force of the mould. As the water is extracted through the pores, the particles of the raw material form a cohesive layer on the wall of the mould, i.e. the body. The body's thickness depends on the time the slip remains in the mould, or in the core casting process, on the distance of the mould halves from each other.
For economic reasons, a body formation rate as high as possible should be achieved. For the conventional process this is restricted.
Further disadvantages of the conventional casting are:

- the moulds require drying after each use
- for the production of a high quantity of pieces a correspondingly high number of moulds is required, as a result of the low casting rate combined with the rapid abrasive wear of the plaster moulds
- the large area required for the storage of the moulds as well as for the production of the cast pieces
- the high cost of disposal of the moulds

Owing to these disadvantages, the plaster moulds used in conventional slip casting are, where possible, replaced by pressure casting machines that work more efficiently. In contrast to the conventional slip casting, in pressure casting the water is not extracted by the capillary activity of the mould but by pressurising the slip. During this pressure filtration, the water is being forced into the capillaries of a porous plastic material. After having removed the cast body, the mould is flushed out with water and then re-filled with slip. Advantages of this procedure are:

- higher productivity
- improved product quality
- lower unit costs
- less space requirement
- possible savings of personnel costs

2. Possibilities of optimising the pressure casting process

The working possibilities during the pressure casting process may be optimised by

- the composition of the body
- the density of the slip
- the temperature of the slip
- process technology parameters like pressure and time
- utilisation of chemical auxiliaries

The formation properties of the slip and of the body may be influenced by the composition of the mass. Low amounts of fine particles favour the formation of the body, but at the same time give low green strength. Decreasing the litre weight and reducing the deflocculant content at the same time, may contribute to an acceleration of the body formation. Increasing the slip temperature decreases the slip viscosity and so facilitates the de-watering. Machine parameters like the extent of the pressure required as well as the duration of pressurising must be co-ordinated with the articles to be manufactured, particularly with the required body thickness.
Besides the influence of operational and mass specific parameters, a further optimisation of de-watering as well as of body properties, is possible by using the following additives:

- deflocculants
- filtration agents
- temporary binders

The application of deflocculants enables working with high solids contents. Using temporary binders can improve the mechanical resistance in the green state.
Filtration agents contribute decisively to improve the working properties in the pressure casting. The application of these auxiliaries accelerates and balances the de-watering of the slip, thus leading to a more homogeneous body composition as well as to shorter casting times, and therefore to the rationalisation of the total production process.

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3. Mode of action of the additives in the pressure casting process

Generally, for pressure casting bodies, the particle size distribution of the mass is optimised to the production process. Conventional bodies contain a higher proportion of fines and therefore show good green strengths. On the other hand, the high proportion of fines slows down de-watering, as the fine particles form a compact film on the surface of the mould due to their high migration velocity. This film inhibits the further transport of the water into the mould which leads to a decrease of the body forming rate. Therefore, a high proportion of fine particles necessitates the addition of an auxiliary which agglomerates these particles and thus enables a better water permeability.
To avoid undesired effects such as a big increase in slip viscosity, or insufficient stability of the body after the removal from the mould, a filtration agent adapted to the working conditions is to be used. If necessary, this can be combined with a suitable deflocculant and/or temporary binder.

3.1 Criteria specific for the process

The required property profile of a filtration agent is determined by four influencing factors which are closely connected:

- composition of the body
- properties of the slip
- process technology
- properties of the cast piece

Thus a processing field is defined in which the filtration agent must be effective.
This is shown in figure 1 (left-hand side).

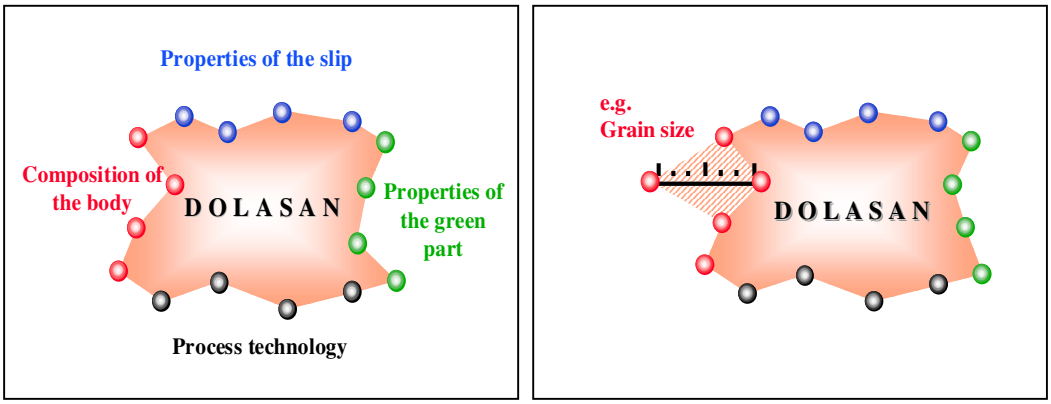

Figure 1: Required property profile of a filtration agent and adaptation when the profile changes

The parameters specific for the body include the composition of the raw material, the specific surface as well as the grain size distribution.
The properties of the slip are influenced by the solids content, the composition of the body, the degree of water hardness and the slip's temperature.

Detailed information on this item can be found in ***"Mechanisms of action of deflocculants and dispersants in ceramic bodies"***.

Important properties of the cast pieces are thickness and stability of the body. The structure should be homogeneous and the shrinkage must range in acceptable limits.
The process technology determines pressure and duration of the pressure casting process.

Every body, every slip, every cast piece to be produced, and every process technology installed requires an adapted specific solution. Through a corresponding variation of the filtration agent, this adaptation is possible as shown in figure 1 (right-hand side).

ZSCHIMMER & SCHWARZ offers different filtration agents under the DOLASAN name, which guarantee customised solutions for different initial conditions which are specific to the bodies and the processes.

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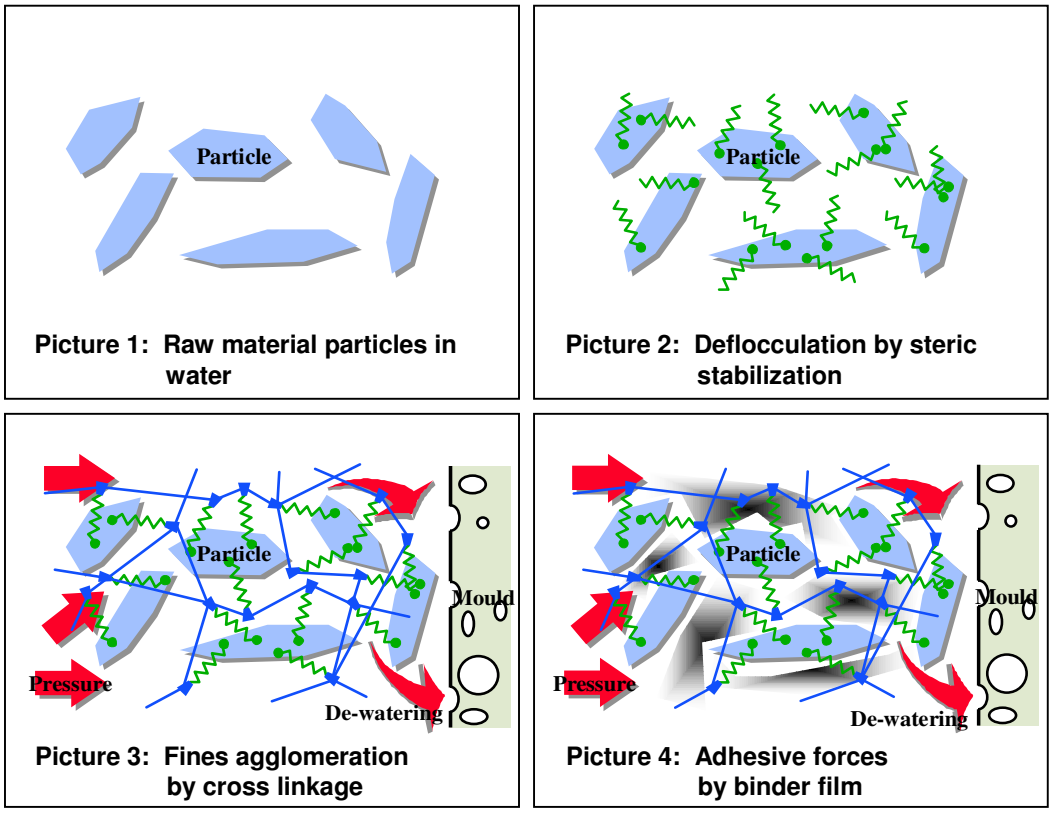
3.2 Mode of action of the filtration agents from Zschimmer & Schwarz

In the pressure casting technology the filtration agent may fulfill the following three functions:

- deflocculation of the slip
- **defined, pressure stable cross-linkage**
- temporary binding of the cast piece

The deflocculation effect in combination with a suitable deflocculant allows the preparation of a slip with high solids contents with acceptable viscosity values.
The cross-linkage agglomerates the fine particle proportion in such a way that effluent channels for water are maintained and the de-watering is accelerated. The body structure becomes more homogeneous and it can be removed more quickly from the mould.
The binding effect improves the stability of the pieces directly after their removal from the mould.
The defined composition of the filtration agents allows the three functions to be adapted to the customer's working conditions.

Figure 2 illustrates the different functions of the filtration agents in connection with the mode of action of the deflocculants and temporary binders used in addition.



Picture 1: Raw material particles in water

Picture 2: Deflocculation by steric stabilization

Picture 3: Fines agglomeration by cross linkage

Picture 4: Adhesive forces by binder film

Figure 2: Mode of action of the additives in the pressure casting process

Picture 1 of figure 2 shows raw material particles distributed in water.

The deflocculation effect, caused by filtration auxiliaries as well as by deflocculants, is shown in picture 2.
This effect is brought about by steric stabilisation. The stabilisation is achieved by positively charged function groups of the additive being attracted by the negatively charged particle surfaces, whereas the negatively charged function groups of the polymere chains of the additive (shown in green colour) repel each other. These controlled attracting and repelling forces lead to an even distribution of the particles in the slip, and thus to an optimised dispersion.

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Picture 3 illustrates the agglomeration effect of the filtration agent (in blue colour). During the pressure casting process, pressure is applied on the slip from outside in order to transport the water as rapidly as possible in direction of the mould wall. An optimum de-watering is achieved, if the following conditions are fulfilled:

- the agglomeration of the finest particles prevents their penetration into the capillaries of the mould as well as the development of a fine particle barrier which would disable the further de-watering
- the agglomeration takes place by setting up a pressure stable network, which guarantees that the effluent channels for the water are maintained

This leads to the acceleration of the de-watering and thus to the increase of the body formation rate.
The binding effect of the filtration agent is created by the described cross-linkage.

A temporary binder, used additionally to the filtration agent, forms a film which covers the raw material particles, so that adhesive forces act between them (picture 4). The increased dry strength achieved can be advantageous especially for large pieces or those which are particularly susceptible to cracking.

3.3 Advantages of the application of filtration agents

Using the filtration agents offered by ZSCHIMMER & SCHWARZ the following advantages may be achieved:

- ability to adapt conventionally cast bodies for pressure casting
- utilisation of pressure casting bodies with a higher proportion of fine particles
- increase of the body formation rate because of faster de-watering
- improved homogeinity of the body
- increased stability of the de-moulded cast pieces
- shorter formation times

In order to offer the optimum solution for the working conditions of each customer, different DOLASAN-types are available as filtration agents.
DOLASAN 24 has minimal influence on viscosity. DOLASAN 34 slightly increases the viscosity of the slip. The filtration properties themselves of the different filtration agents vary only slightly.
The described effects are also influenced by any deflocculants and temporary binders which are used additionally. Therefore, trials should be made in order to find out which filtration agent shows the optimum effect on the respective body.

3.4 Application examples

The following example of a porcelain body and of a sanitary body demonstrate the influence DOLASAN has on the properties and the filtration of the slip.

For these tests 1 kg dry mass was prepared with the corresponding quantity of mixing water, an effective deflocculant and DOLASAN. The slip was homogenized for 30 minutes with a Vollrath stirrer at 750 UpM. The slip viscosity was determined with:

- Gallenkamp viscosimeter (directly and after 1 minute)
- Brookfield viscosimeter

The pressure casting tests also included the conventional casting of cups, as the filtration agents have also positive effects on the conventional method. The residence time of the slip in the plaster mould was 15 minutes. For the main tests, disks with a diameter of 11.5 cm were prepared by pressure casting in three steps. In the first step the slip was impacted with low pressure in order to protect the form. In the second step the body was formed with high pressure. In the third and last step, this body was hardened after removing the surplus slip.
After drying the articles at 110 +/- 5 °C to constant weight, the body thicknesses were determined.

3.4.1 Porcelain body

The filtration properties of a porcelain body which is already prepared in the pressure casting, should be improved by adding a filtration agent. The parameters of the body as well as the pressure-time-profile of the pressure casting tests are shown in table 1.

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Solids content	Litre weight	Step	Pressure- time- profile Pressure [bar]	Time [s]
68 %	1.725 g/l	1	5	30
		2	20	120
		3	4	90

Table 1: Parameters of the porcelain body

In test 1 the customer´s standard deflocculation method was used.

In test 2 the deflocculant was replaced, achieving a lower viscosity as well as an increased body thickness at a constant litre weight, in both the conventional casting and in the pressure casting.

In test 3 the deflocculant content remained constant and the filtration agent DOLASAN 24 was applied in addition at 0.15 % calculated on the solids content of the slip. The result was a further decreasing in viscosity with respect to the standard slip, as well as with respect to the modified slip without filtration additive. During pressure casting, the body formation could be accelerated and therefore the thickness of the body could be increased. Furthermore, the thixotropy-values which were higher in test 2 than at the standard, could be decreased again.

Test 4 showed slightly higher viscosity and thixotropy values at a constant content of filtration additive and a lower deflocculant addition, but a further acceleration of the body formation.
The detailed results of the described tests are shown in table 2.

Test	**1** 0,45 % Waterglass	**2** 0,25 % DOLAPIX SPC 7	**3** 0,25 % DOLAPIX SPC 7 0,15 % DOLASAN 24	**4** 0,20 % DOLAPIX SPC 7 0,15 % DOLASAN 24
Gallenkamp 1 (°)	314	325	339	312
Gallenkamp 2 (°)	311	317	337	291
Brookfield (mPas)	390	270	150	260
Body thickness conventional (mm)	3.0	4.3	4.3	5.7
Increase in body thickness (%)		+ 43.3	+ 43.3	+ 90.0
Body thickness Pressure casting (mm)	5.8	8.5	9.8	11.9
Increase in body thickness (%)		+ 46.6	+ 69.0	+ 105.2

Table 2: Test results of the porcelain body

3.4.2 Sanitary body

The parameters of the sanitary body already used in the pressure casting as well as the pressure-time-profile of the pressure casting tests can be seen in table 3.

Solids content	Litre weight	Step	Pressure- time- profile Pressure [bar]	Time [s]
72,5 %	1.819 g/l	1	5	30
		2	15	600
		3	4	180

Table 3: Parameters of the sanitary body

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Test 5 was run as reference trial.
At an addition of 0.10 % DOLASAN 34 in test 6, the viscosity remained nearly constant with an almost unchanged thixotropy, despite of decreased addition of deflocculant. Compared with the reference trial, body formation could be accelerated in the conventional casting, as well as in the pressure casting and therefore the body thickness could be increased.
The detailed results can be found in table 4.
On account of the excellent de-watering ability of DOLASAN, the body formation time as well as the re-pressurising time could be decreased during the wash-basin production. During removal from the mould, the cast piece was firm over the full cross-section.

Test	**5** 0,20 % GIESSFIX ZS	**6** 0,15 % GIESSFIX ZS 0,10 % DOLASAN 34
Gallenkamp 1(°)	317	316
Gallenkamp 2 (°)	312	309
Brookfield (mPas)	360	380
Thickness of the body conventional (mm)	3.5	4.4
Increase in body thickness (%)		+ 25.7
Thickness of the body Pressure casting (mm)	9.9	12.0
Increase in body thickness (%)		+ 21.2

Table 4: Test results of the sanitary body

The following table 5 shows an example which demonstrates the economy of the application of DOLASAN.

	Sanitary body without filtration agent	Sanitary body + 0,10 % DOLASAN 34
Total cycle (min)	20	18
Pieces per cycle	8 wash-basins	8 wash-basins
Body formation time (min)	10	8
Pieces in 8 hours	192 wash-basins	213 wash-basins
Inrease in output		**+ 11 %**

Table 5: Increase in output by application of DOLASAN

As table 5 shows, it is possible to increase the number of pieces produced in one shift by 11 % through the addition of 0.10 % of DOLASAN 34. Taken into consideration that if the working conditions allow it the deflocculant quantity may be additionnally reduced, this shows a significant improvement in economy.

3.5 Information on the application of the filtration agents

In order to guarantee an optimum distribution of DOLASAN in the body, the filtration agent should previously added to the mixing water. The deflocculant and the body materials are then added.
Addition to the prepared slip is also possible. In this case, DOLASAN should be pre-diluted in water in the proportion 1:3 and then slowly added by using a rapid stirrer. When adding the solution to the slip, the cross-linkage of the fine particles may increase the viscosity. However, the viscosity decreases again during homo-genisation. A re-adjustment can eventually be carried out by adding water or deflocculant.

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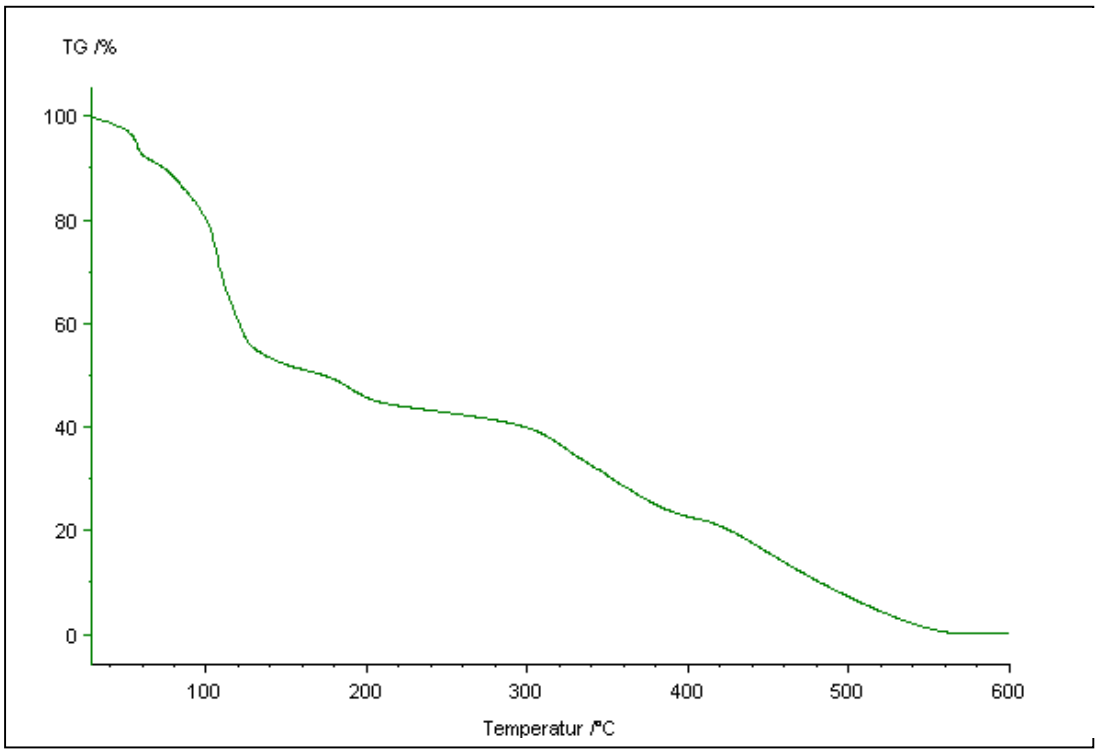
3.6 Information on the burn-out behaviour of the filtration agents

The raw material basis of the filtration agents are organic polymeres which burn off consistently over a wide temperature range. The residue on ignition of DOLASAN is 0.1 % maximum. Picture 3 shows the TGA curve for DOLASAN 24 in order to demonstrate this.



Picture 3: TGA curve for DOLASAN 24

4. Cleaning of pressure casting moulds

In pressure casting, over a period of time, fine particles deposit in the porous system of the pressure casting moulds and block the channels. For cleaning the moulds ZSCHIMMER & SCHWARZ offers a low hazard cleaning agent which is pH-neutral. Its effect is based on two principles:

- encrustations are dissolved through excellent wetting properties
- multivalent cations like calcium, magnesium or aluminium are complexed and extracted with the cleaning water.

The complexing of multivalent cations is explained in the information ***"Mechanisms of action of deflocculants and dispersants in ceramic bodies"***.

5. Summary

The processing and production properties of articles that are prepared by conventional casting or by pressure casting, can be positively influenced by the application of chemical auxiliaries. Compared with deflocculants and temporary binders the most influential of these are filtration agents.

The purpose of the application of filtration agents is to reduce the production time and therefore to increase the productivity. This is achieved by accelerating body formation as well as by decreasing the after hardening time. The article removed from the mould shows a more homogeneous structure and better stability.

The working principle of the filtration auxiliaries by ZSCHIMMER & SCHWARZ can be adapted to the customer's requirements by varying the components included them. According to the requirements, the principle can be optimised with regard to deflocculation, cross-linkage or binding.

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The application of filtration agents is not restricted to silicate ceramic bodies. It is also possible to use them in other ceramic bodies and but this needs to be evaluated by the respective user.

6. List of products

Finally, figure 4 shows some standard products of ZSCHIMMER & SCHWARZ which are recommended for the pressure casting process.

Deflocculants / dispersants	Filtration agents	Temporary binders	Cleaning agents for resin moulds
GIESSFIX ZS GIESSFIX 162 DOLAPIX PC 67 DOLAPIX SPC 7	DOLASAN 24 DOLASAN 34	OPTAPIX AC 95 PRODUKT KB 2112	GLYDOL 1131

Figure 4: Some standard products from ZSCHIMMER & SCHWARZ for the pressure casting process

One particular advantage is that all auxiliaries listed can be applied separately as well as in combination with each other. Therefore, the ceramic producer cannot only dispose of one additive, but of a system of additives which are modulated with each other and which can be adapted to the respective working conditions.

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