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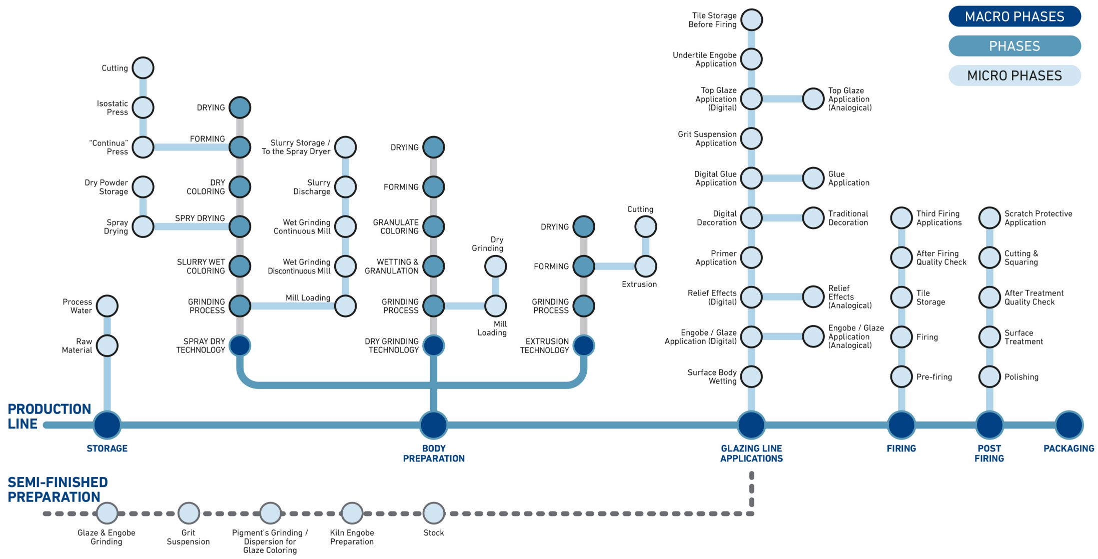
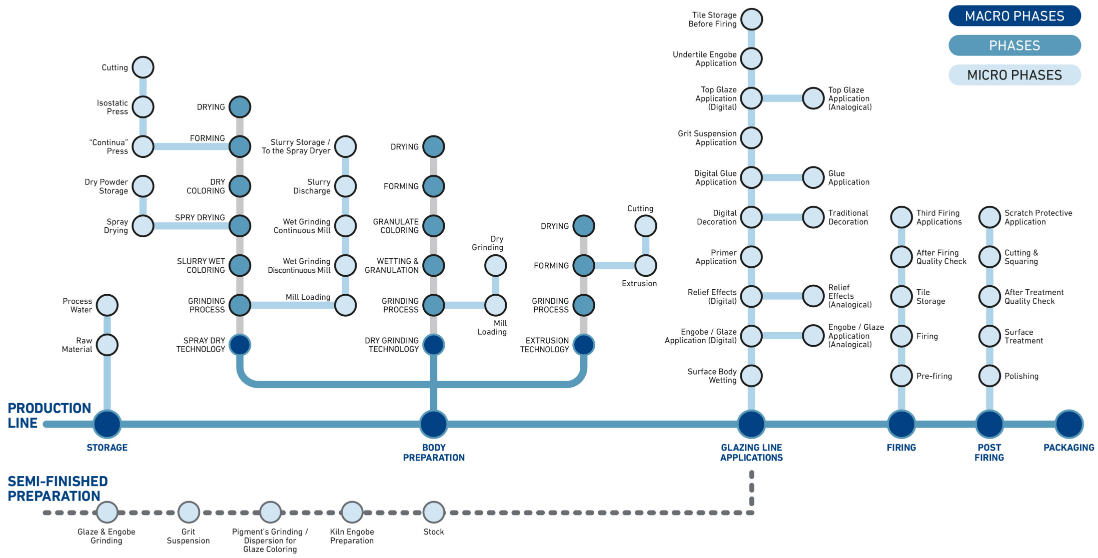
APPARENTLY INVISIBLE YET CONSTANTLY PRESENT

At every stage of the ceramic production process

A journey through problems & solutions



#24 CERAMIC SUSPENSIONS & RHEOLOGICAL BEHAVIOR



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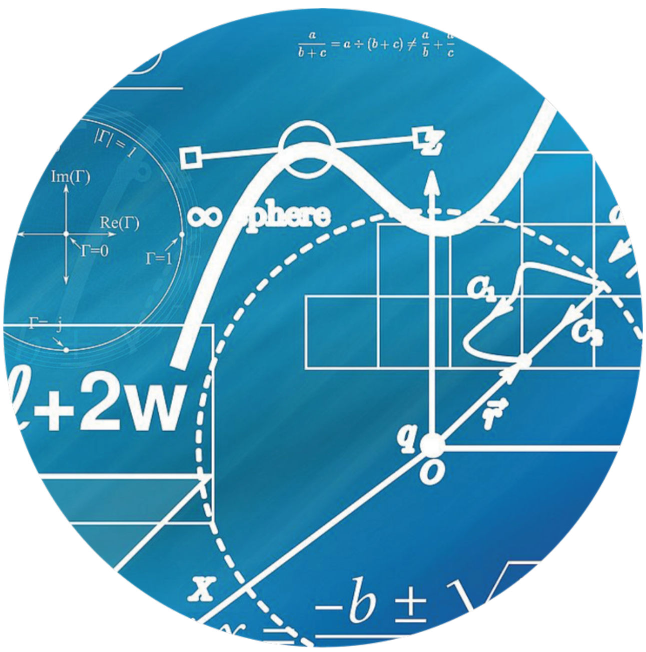
1. Definition

Rheology is the science that deals with the flow and the strain rate of matter.
It's a branch of physics that studies the origin, nature and deformation's characteristics of a matter under the influence of external forces, with particular regard to non-Newtonian liquids***.

Its main goal is to define the correlations between causes (forces) and effects (deformations and flows) identifying all mechanisms that are the basis of the different rheological behaviors on a microscopic and molecular scale.

***MOST SIGNIFICANT DIFFERENCE BETWEEN NEWTONIAN AND NON-NEWTONIAN LIQUIDS
Newtonian fluid: fluid with a constant and unchanged viscosity, regardless of the strain rate
Non-Newtonian Fluid: fluids whose viscosity changes with the strain rate (the relative flow velocity)



2. Rheology in ceramics

In ceramic industry, when it comes to rheology, we usually refer to the physical features of aqueous suspensions involved in the production process

Following here the most significant:

- CERAMIC BODIES
- GLAZES
- ENGOBES
- DIGITAL INKS
- GRIT SUSPENSIONS

To develop a good application, analysis and adjustments of the rheological features are required. The rheological study of ceramic bodies, for example, helps to provide the systems with the proper stability, making the slurry easily manageable both during its transport within the plant and in application.

3. How to study the rheology of ceramic suspensions

Ceramic suspensions are usually evaluated by means of specific tools called **rheometers** able to collect all information about the flow of the fluid under examination.

These properties are carefully checked to ensure the proper conditions of the suspension involved in the production process: in most cases modifications are needed to adjust the values according to the application conditions of each ceramic producer.

Following here the most important rheological parameters:

- VISCOSITY: the viscosity of a fluid measures its resistance to deformation at a given rate
- FLOW LIMIT: it is the value of the minimum force required (shear stress) to run a fluid
- RHEOLOGICAL BEHAVIOUR: Plastic, Pseudo-plastic, Newtonian

The data collected by rheometers are displayed using a two-dimensional Cartesian diagram: while the vertical axis shows the SHEAR STRESS, the horizontal axis expresses the VELOCITY GRADIENT*.

VISCOSITY's value is displayed on the diagram by the slope of the curve and it is the result of the relation between shear stress and velocity gradient.
The greater is the curve, the higher is the viscosity.

*VELOCITY GRADIENT is a physical quantity related to the fluid's movement speed.

4. Rheological behaviors of ceramic suspensions

Following here the most representative behaviors of ceramic suspensions:

a) NEWTONIAN BEHAVIOR

Linear-rate rheological behavior.
The viscosity value remains constant even in case of variation in shear stress or velocity gradient.
Oil and water are the most significant examples of this behavior: these fluids never change their viscosity value whether they are quickly or slowly stirred.

In ceramics, the Newtonian behavior is well represented by digital inks that must be Newtonian to be correctly applied by digital printheads.
If inks' rheological behavior were plastic or pseudo-plastic, the piezoelectric impulse system (that develops the ink drop) would not be effective, leading to a lower printing definition or, at worst, preventing the formation of the ink-drop. Printheads basically would not be able to spray and discharge the ink on the raw ceramic support.

b) PLASTIC BEHAVIOR

Behavior marked by a specific flow limit, i.e. by a shear stress below which the fluid acts as a solid.
In other words: when the fluid is resting, it is very compact but when it undergoes to a movement, the fluid softens becoming more liquid. Pastry cream is a typical example for this category.

In ceramics, the most representative pseudo-plastic fluids are slurries for ceramic body and grit suspensions.
These fluids must be able to keep the grit in suspension while they are resting, behaving (we might say) as a solid. On the other side, during application, the suspension must show a de-structuring process, behaving as a pseudo-plastic fluid: the viscosity decreases while the he velocity gradient gradually increases.

During the application by means of spray systems, the fluid undergoes to a very high speed, thus strongly decreasing the viscosity value and, therefore, allowing a proper nebulization.
To reach this rheological behavior, it is important the use of specific chemicals able to provide the suspension with:

- Suspending action that ensures the flow limit
- Binding action that provides the system with cohesion and homogeneity
- Pseudo plasticity

Without these chemicals, the mixture would easily show sedimentation phenomena, just like sand in water, compromising the application.
What about slurries for ceramic bodies?
In this case, it is important to highlight that all clays, by their very nature, are marked by a strong plastic behavior.
This is the reason why these suspensions require chemicals able to drastically decrease (or remove) both the flow limit and the very high viscosity, turning the jelly system into a fluid system.

c) PSEUDO-PLASTIC BEHAVIOR

Behavior marked by a decrease in viscosity with an increase of the shear stress or the velocity gradient. Unlike plastic behavior, however, there is no flow limit and so there is a lack initial force. Due to this absence, the fluid behaves as a liquid when resting and it needs a very little effort (almost zero) to move.
Self-levelling resins for floor applications are a typical example of this category.

All glazes for airless applications can be part in this group.
They are nothing but water suspensions of extremely fine vitreous or natural particles. The chemical and physical features of the particles as well as their size mean that these systems almost do not require a flow limit, since the sedimentation of the solid particles during the resting phase is very slow.
The lack of flow limit finally ensures a good and proper levelling during application. The rheological curves of pseudo-plastic and plastic fluids are actually very similar, differing each other only in the presence/lack of flow limit.

d) DILATING BEHAVIOR

Rheological behavior marked by an increase in viscosity with the increase of the velocity gradient.
In ceramics, dilating behaviors are unusual and they are basically avoided, since they are not suitable for ceramic production processes.
They may lead to problems during application, negatively affecting a good technical or aesthetic result. Since the viscosity value increases as the speed gets faster, a spray application could be very difficult or even impossible.

To better understand this behavior, we can have a look at the world of motorcycling or extreme sports. Today, in fact, are available on the market protective suits made with materials marked by dilating technical features: they are basically soft, allowing the person who wears them to easily move but, in case of an impact (that develops an increase of the movement speed) they immediately harden, protecting from possible contusions.