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RHEOLOGY OF SCREEN PRINTING INKS

The term **Rheology** derives from the Greek terms "rhei" (flow) and "logos" (science). Rheology describes the flow properties of a fluid or a flowable substance. The general measure is viscosity of a fluid, indicated in mPas. The higher the viscosity is, the thicker a fluid will be. However, in most cases this viscosity is not constant, but depends on the shear rate. Generally screen printing inks show plastic properties. The ink is paste-like and only starts to flow after being subjected to a certain degree of strain (flow limit). Viscosity will be reduced with an increasing shear rate and will increase again when shear rate is reduced. If structure (viscosity) only builds up again after some time, we are talking about thixotropy. A well known example for thixotropy is the flow property of ketchup. By shaking the bottle you will temporarily destroy the structure so that the ketchup can flow from the bottle. Thixotropic fluids will require some time to "regenerate".

Evaluation of an ink using a rotary viscometer (in this case cone-plate geometry)

Many other printing processes usually do not require plastic fluids, fluids with Non-Newtonian viscosity or thixotropy. These properties however are essential for a good printability of screen printing inks. In the screen process you will have a great range of various shear rates within a short period of time. There is no mechanical strain during standstill, so that the ink is influenced only by gravity. In that stage the ink should not flow at all so that it will not drip through the screen. When flooding the screen shear rates are higher. In order to evenly cover the screen with ink it would be disadvantageous if the ink would be too thick or too thin. Shear rates will be highest when the ink is printed through the screen. Then the ink has the lowest possible viscosity. Standstill times, flooding and squeegee operation will require a totally different screen ink viscosity. These requirements are met by the shear thinning properties of the ink.

Viscosity depends on shear strain. This can be visualized by flow curve or viscosity curve (examples on page 5). Newtonian fluids will have a constant viscosity beyond a range of shear rates. Some popular examples are low viscous oils. However, honey also being a thick mass will show a Newtonian flow property. Both aforementioned substances would not be suitable for the screen process.

Rheopectic fluids show an opposite behavior than Non-Newtonian fluids (pseudoplastic fluids). The viscosity increases with growing shear rates. Highly solid systems such as plastisols for example may show such properties, however, such systems can only be processed very slowly in the screen process. If rates are too high the film will tear. The requirements for best possible flow properties resulting in good printability mostly depend on processing parameters. In addition to pseudoplastic properties a certain degree of thixotropy is of advantage for solid prints so that the ink film can slightly flow after application and can form an even and smooth surface. On the other hand mainly Non-Newtonian properties are required for process printing or printing of fine lines. As soon as the ink has been printed through the screen and is no longer influenced by shear forces the tough or solid structure should immediately reform, so that dots and lines will remain unchanged and will not run prior to drying or curing.

Adjustment of Rheology by Ink Manufactures

Naturally any ink manufacturer will try to adjust flow properties of ink products to result in best possible printability. As there are no general standard processing conditions for screen printing, inks are adjusted to cover a broad range of different processing parameters. The raw materials are essential for the flow properties of an ink. Technical requirements (such as adhesion on difficult substrates, resistances, forming properties etc.), however often necessitate a choice of raw materials, which may not be the best for printability. In addition the different colour pigments within one ink range also have an influence on rheology. In that respect formulations are often adjusted with additives and auxiliary agents to achieve the closest possible approximation to the required properties.

Modification of Rheology by Printers

It is a generally known fact that viscosity also depends on temperature. The warmer the environment is, the more "liquid" the ink becomes. Generally thinners are added to adjust viscosity. The general characteristics of the viscosity curve will remain as they are (to a certain extent and provided the recommended addition is not exceeded), however the curve will shift downwards. In addition, the viscosity is reduced with low shear rates such as with high ones. This can be of advantage with high squeegee rates, high printing speeds and lower temperatures. On the other hand, addition of our "thickening powder" will generally cause the viscosity curve to steepen, that means the viscosity will be increased mainly with low shear rates.

Although it is essential for printability the flow curve by itself is not a criterion for the evaluation of printability. Elasticity of the ink and surface tension in combination with the substrate are also important factors. Rheology by itself is a science, so that we only refer to the parts essential for the printing process and printers. Otherwise we would go far beyond the scope. Colloquial terms used are "too thin" for low viscosity, "too thick" for high viscosity and "paste-form" for thixotropic or Non-Newtonian viscosities. Often Newtonian flow properties are described with "too much float".

One characteristic of screen inks is viscosity η - usually mPas (Millipascal seconds). The former cP (Centipoise) corresponds to mPas.

Viscosity always needs to be evaluated in connection to shear rate and measurement geometry used to determine viscosity. Otherwise a comparison is not possible. The shear rate $\dot{\gamma}$ is 1/s.

Methods to evaluate rheology are a valuable aid in finding solutions for new requirements and challenges in the printing industry. The properties an ink exhibits in the printing equipment can easily be explained with flow curve diagrams. Naturally you will also need a lot of experience. We successfully combine and coordinate science and practical experience.

SUMMARY

Newtonian Flow Property

A fluid which will always have the same viscosity values with different shear rates.

When printing a Newtonian ink or varnish you will always have a product with identical viscosity even though different squeegee speeds are used.

Thixotropy (Non-Newtonian Fluids)

Some of our daily foods, such as yoghurt or mustard are more or less thixotropic fluids. When stirring yoghurt you will see that this product, which originally had a nearly solid form, turns into a fluid mass. If you then let the product rest for a while thixotropy will reform and the product will turn into a creamlike and solid form again.

Non-Newtonian or thixotropic screen inks are used for fine lines and process prints.

Rheopectic Flow Properties (dilatant fluids/shear thickening fluids)

Rheopectic flow properties are characteristics not very beneficial for screen printing. The product becomes constantly thicker with increasing shear or squeegee rates. Therefore only very slow printing speeds can be used when processing inks with rheopectic properties.

One example for a rheopectic property is the so-called transmission of viscous force (coupling). This is a transfer of force during which the rheopectic fluid acts as force transmitter. An increasing rate will cause the rheopectic mass to solidify and transmit the forces.

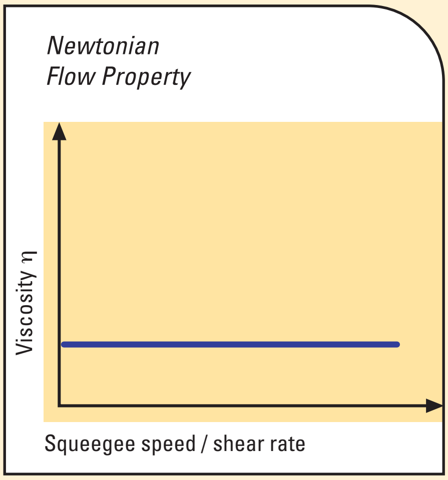
Viscosity

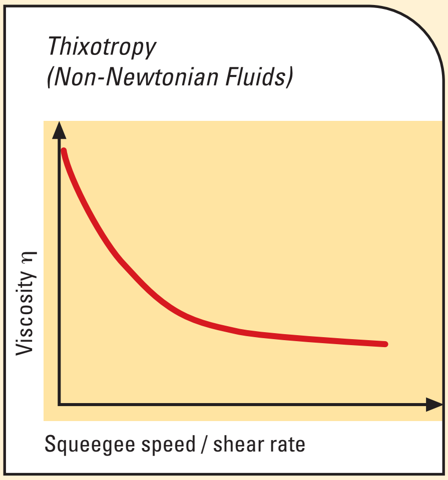
Viscosity is the measure of inner friction of a fluid when subjected to mechanical influences. The most common indication of viscosity values mPas (formerly Poise) always refers to an exactly defined shear force at a certain temperature.

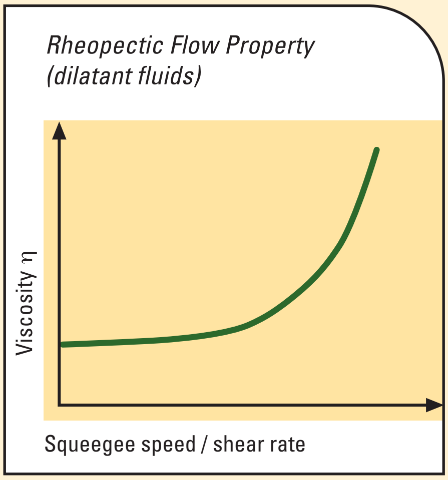
In screen printing squeegee speed will determine the shear force. Generally you could also say thin or semi-fluid instead of viscous.

Flow Property

Fluids may show different flow properties.







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