Two Approaches to Improve Substrate Wetting of Aqueous Coatings

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Abstracts

The "classic" approach to improve substrate wetting of aqueous coatings is to use an additive, which reduces the interfacial tension of the liquid paint on the substrate/coating interface. Fluorinated surfactants and silicone surfactants are the most effective substances in this group of additives. Their typical properties, advantages and disadvantages will be highlighted with several examples.

A new and unique opportunity is for multi-layer systems not to use a substrate wetting additive, but to raise the surface energy of the primer surface, so that no substrate wetting additive is needed for the topcoat. A highly branched, polyethylene glycol modified hydrophilic acrylic polymer has been developed, which – unlike other surface additives – is able to raise the surface energy of the dry coating film substantially. This results in perfect substrate wetting and good intercoat adhesion when recoated.

The improvements can be clearly demonstrated by measuring the contact angle of water droplets on the crosslinked coating surface. The hydrophilic polyacrylate increases especially the polar component of the surface energy very significantly.

Test results with the new additive will be presented in aqueous and non-aqueous coatings. Highest performance has been achieved always in formulations where the additive was slightly insoluble or incompatible. Suggested applications include aqueous and non-aqueous industrial primers, primer-surfacers, basecoats... any coatings which need a better recoatability with topcoats.

1. Introduction

For many years, the increase of the surface energy of crosslinked coating films (resulting in improving wettability by the next coating) was classified as a very difficult task. Most of the additive approaches failed, since always those additive molecules migrated up to the air interface, which were reducing the surface tension / surface energy.

The market demand for surface tension increasing additives finally resulted in a new approach. High surface energy molecules could be brought up to the surface by using a different principle: Controlled incompatibility. This paper describes details of the new technology and the effects achieved.
2. **Basic conditions of substrate wetting**

Using a simplified explanation, the very basic condition of the substrate wetting of a liquid coating can be described as follows: The surface tension of the liquid paint must be lower than the surface energy of the solid substrate. Typical surface tension values of coating ingredients and surface energies of substrates are shown on Fig.1.

![Typical surface tensions / Surface energy](image)

For many years coating formulators used only one tool to improve the substrate wetting over primers, basecoats, middle coats etc.: They reduced the surface tension of the next coating. This is always the first approach to improve the wetting of crosslinked coating films, but the method has many disadvantages.

The first problem is, that a low surface tension of the coating on the top is not ideal to achieve the best possible leveling. Secondly, many of the additives, used for substrate wetting, may cause a serious foam stabilization. The foam stabilization is most significant by using fluorinated surfactants.

Typical additive structures for substrate wetting are modified polysiloxanes for non-aqueous coatings (Fig.2), and silicone surfactants (Fig.3) or fluorinated surfactants for aqueous coatings.

Depending on the substituents of the molecule of polymeric silicones (Fig.2), different levels of surface tension reduction and compatibility can be adjusted.

For aqueous silicone surfactants (Fig.3) the main tool to adjust the additive performance is to vary the length (short to long) and composition of the polyether tail (more polar, less polar), and the number of dimethyl- and trimethylsilicone groups in the hydrophobic head of the molecule between ~ 3 to 5.
Silicone surfactants like on Fig.3 became very popular coating ingredients of the last decades, their main disadvantage is probably the sensitivity to high pH (9.5 and higher) as the silicone structure can slowly decompose. Fluorinated surfactants are more stable in this respect, but they may cause foam stabilization, and there are many negative environmental issues with them, so that their usage in coatings is decreasing over the years. Acetylenic glycol based surfactants are mainly used in ink and overprint varnish formulations.

A very typical example of substrate wetting failure is shown on Fig.4., where an aqueous white coating was not able to wet the epoxy flooring underneath.
3. **New approach to improve substrate wetting**

Incompatibility of coating ingredients may cause a phase separation of the incompatible component. By using this principle, and building slightly incompatible structures with high surface tension / surface energy, it is possible to bring molecules up to the surface, which then INCREASE the surface energy of the crosslinked film. The additive structure, used for this effect, is a highly branched polyether modified polyacrylate (Fig.5.)

![Fig 4: Poor substrate wetting on epoxy flooring](image)

![Fig 5: Orientation of high surface tension molecules to the surface by incompatibility](image)

This additive structure is especially active in aqueous systems, increasing the surface energy of the crosslinked film significantly.
In non-aqueous systems the additive is also working, but a higher level is needed to achieve a good performance (Fig.6.).

Fig. 6.

Fig. 7. shows an experimental series with 9 different solvent-borne saturated baking polyester resins, modified with 5% of the additive. In those cases where the resin is remaining crystal clear, there is little chance to get improvements. In cases of turbidity, however, the additive has been found incompatible enough to get separated to the coatings surface, increasing its surface energy and improving its recoatability.

Fig.7.
Fig. 8. indicates results of the surface energy measurement of coating films in a system, where the additive was incompatible enough to be separated to the air interface. Especially the polar component of the surface energy is increased substantially – which explains why the wetting of such coating films much easier, by using almost any types of coatings above.

Fig. 8.

![Increasing surface energy in coating films](image)

According to Fig. 10., the wetting-up of an aqueous automotive basecoat can be significantly improved by using just a low dosage of the new additive.

Fig. 9.

![Polymer 3560 in automotive OEM coatings](image)
In this comparative test the "unmodified" primer-surfacer could be wetted by the aqueous basecoat in a continuous layer by using ~ 15 µm dry film thickness, but by using only 0.2 % hydrophilic polyacrylate this thickness could be reduced to only ~ 8 µm.

4. Limitations of the new technology

The polyether structure of the incompatible acrylic polymer is sensitive to high temperatures (above ~ 160-170 °C, 10-15 minutes baking time) where the polyether structure can be cracked / decomposed, and the molecule is losing its hydrophilic character including the ability to create a high surface energy.

Another limitation is that the hydrophilic polyacrylate molecule is not cross-linked with the resin network, so that it can be removed by washing or wiping the surface. In continuous industrial coating processes this is usually not a problem.

However, in the case of exterior industrial maintenance coatings or heavy-duty coatings, the method has its limitations due to the long time and exposure to weather during the time, spent between the application of each coating layer.

Fig.11. is showing the contact angles of water droplets on the same coating, baked at 140 and at 200°C.
5. Summary

The “classic” approach to improve substrate wetting over a coating surface is to reduce the surface tension of the next coating material. This method is widely used, but has some limitations. The “new” approach is to use a special, hydrophilic, highly branched polyacrylate additive in the primer coating material. The additive will be separated to the coating/air interface, creating there a higher surface energy, thus improving wettability by the next layer. The new technology can be used in principally all types of liquid coatings, where the additive is incompatible enough to come to the coating/air interface.