Tailor-made additives for the elimination and prevention of microfoam in water-based coatings

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1. Introduction

Microfoam and its elimination are a major problem during paint production and application. Especially for water-based coatings applied by airless spray application, elimination of microfoam is an extreme problem. This problem gives high demands to formulators and applicators as well as to application equipment manufacturers and raw material suppliers.

2. Formation of macro- and microfoam

It is common to distinguish between macro- and microfoam formation. In both cases air is distributed in the water-based coating. The main difference which makes the distinction necessary is the location of the distributed air. In case of macrofoam the air forms foam bubbles at the coating surface stabilised with a surfactant double layer (foam lamella). In case of microfoam entrapped air is located in the coating film held in place in the coating by high coating viscosity hindering the raising of micro-bubbles to the surface and/or additional surfactants. Often different measures have to be taken to cure either of these foam species.

(figure 1)

2.1 Distribution of air

There are several possibilities for air to become distributed in water-based coatings. One main source is the incorporation of air during paint production. The second main source is the incorporation of air during the coating application procedure by for example rolling, dipping, flowing, brushing and by curtain or spray application. Airless spray application without any doubt is the application method most likely to create microfoam problems.

In addition it is possible that air is distributed in the coating due to chemical reactions during the curing process (CO₂ formation). Finally it is possible that during application on porous substrates like wood, air is rising up through the pores into the coating and consequently forming micro- or macrofoam bubbles.
2.2 Negative influence of macrofoam

The occurrence of macrofoam can cause several problems. The first to mention is the significantly increased volume of the coating material. This causes problems when filling the material into containers. Secondly macrobubbles that stay at a coating surface disturb the optical appearance and are an easy point for mechanical attack. By the use of suitable defoamers the formation of macrofoam can be effectively prevented and foam bubbles are destroyed. This mechanism will not be discussed further in this paper.

2.3 Negative influence of microfoam

The presence of microfoam in coatings influences optical and physical properties of the coatings.

- Especially in clear coatings microfoam causes a significant reduction of gloss and clarity. In case of wood coating formulations for example this leads to a less brilliant appearance of the wood substrate.
- Microfoam has a negative influence on the rheology of the coating material, leading to flow and levelling problems of the coating.
- Microfoam creates pinholes during the drying or curing process of the coating film. These defects give a point of contact for environmental influence (such as humidity or oxygen, acidic rain or salt) leading finally to corrosion in the case of metal substrates and bacterial and fungal attack in the case of wood substrates.

2.4 Formation of microfoam during airless application

Procedures giving an excess of microfoam formation are the spray application and especially the very economical airless or airmix application. The incorporation of air during paint production seems to be not the major reason for microfoam formation in airless applied coatings [2].

The main problem is that under the high pressure in the airless spray gun more air is solubilized in the coating. When the coating is leaving the spray gun and the spray nozzle a decrease in pressure takes place leading to an supersaturation of soluble air. This forms microfoam bubbles (10 \(\mu\)m – 70 \(\mu\)m in diameter) in the coating film which are very stable, especially if foam stabilising substances such as emulsifiers are present as mentioned before.

Taking Stoke`s Law into consideration it becomes clear that these little micro-bubbles (due to their low radii) rise very slowly to the surface. In addition a high coating viscosity can reduce the velocity of rising micro-bubbles. Consequently the high viscosity and high film thickness as present in an airless spray application increase the microfoam problem tremendously.
3. Paint additives to eliminate microfoam

Certainly it is possible to reduce the microfoam problems by modifying the application method and by optimising the coating formulation. However, since the resulting application process and the film properties may not be negatively influenced, these possibilities are limited and in many cases do not lead to a complete problem solution.

Beyond all doubt it would be much easier if the simple addition of a paint additive to the coating formulation could reduce or eliminate effectively the formation of micro-bubbles.

To develop our first deaerator for water-based formulations we chose one of the most difficult applications for our tests: airless spray applied, water-based wood coatings.

4. Tests performed

4.1 Test method for the generation and evaluation of microfoam

The evaluation method best describing the realistic results was the visible evaluation of the applied coating. This visible evaluation was supported by microscopy.

4.2 Tested formulations

For testing and evaluation of the different additive classes and modifications water-based clear and pigmented formulations used for application of wooden window frames or furniture were prepared. These formulations, based on pure acrylic or acrylic styrene emulsions are starting point formulations of different raw material suppliers (see attached formulations). The addition of the tested additive classes and modifications varied from 0.3 up to 1.2 % active matter on total. Depending on the formulation the point of addition of the tested products was different. In the case of pigmented formulations products are added during grinding stage. In the case of clear or transparent formulations the addition was done as early as possible during the production process. 24 h after preparation the formulations were tested by a lab airless equipment or a specially designed equipment so called “mini airless equipment”.

4.3 Airless application

For the first screening test we designed a reduced airless construction so called “mini airless equipment” allowing the applicator to fix the distance of spray nozzle and substrate. The working pressure was 160 bar (pump ratio = 1:40) using an 11/20 spray nozzle. For these first evaluation tests the wet film thickness was adjusted to 415 µm using a glass panel as a neutral substrate. The main advantage of this so-called “mini airless equipment” is the reduced amount of coating necessary for testing. Only 50 g of coating is necessary to create an airless application showing a high correlation to the picture one achieves by using a normal lab airless spray equipment.
The extended practical testing were done by a lab airless spray equipment from Böllhoff (pump ratio 1:40, film thickness 350 - 400 µm). For substrates, glass as a neutral substrate and oak and meranti wood as realistic substrates were chosen.

4.4 Microfoam evaluation

Immediately after airless application or after drying the coated panels were observed by microscope and the micro-bubbles calculated for a certain area. In order to document the test results a camera was used. In addition to observe the living cycle of a micro-bubble the microscope was alternatively linked to a video camera. (figure 2)

![Microscopic evaluation of microfoam](image)

figure 2: microscopic evaluation of microfoam

5. Results obtained

5.1. Testing of different substance classes

As a general starting point different chemical substances were tested with regards to their ability to eliminate microfoam, such as:

- silicone polyethers
- acrylates and modifications
- polyesters and modifications
- products of hydrocarbon chemistry such as fatty alcohols

The relating pictures (figure 3) taken via microscopy show the effectiveness to microfoam elimination of representatives of the above mentioned substance classes. Comparing the different results it became obvious that the most promising results are obtained working with products from substance class A. Based on these results the substance class A was selected as basic chemistry and with further steps we tried to optimise and increase the effectiveness of this product.
5.2 Modification of substance class A

For further optimisation of microfoam elimination different modifications of the substance class A were prepared and tested. These products differ in more hydrophilic or more hydrophobic character achieved by variation of the molecular weight. (figure 4) Additionally the influence of a possible organic modification adjusting as well the hydrophilic and hydrophobic character of the product were tested with regard to microfoam elimination.

The obtained test results showed clearly that a product with a strong hydrophobicity does not lead to the best results. For effective microfoam elimination a certain hydrophilicity and with that a certain solubility with the coating system is necessary. This is fulfilled by substance A.1. (figure 5)

\[
\text{variation of chain length (n)} \quad \Rightarrow \quad \text{high/low compatible silicone backbone}
\]
\[
\text{variation of EO/PO units (x, y)} \quad \Rightarrow \quad \text{hydrophilic/hydrophobic polyether modification}
\]

figure 4: structure of substance class A
figure 5: variation of hydrophobic and hydrophilic modification
5.3 Influence of hydrophobic particles

In general the addition of hydrophobic particles (for example fumed silica) increases the effectiveness of defoaming. For the test series described in this paper, a solid-free and a filled version of the up to now most promising substance A.1 were compounded and tested due to their effectiveness in eliminating microfoam. Finally the practical test showed that the addition of hydrophobic particles gives an increase in effectiveness making the addition of these hydrophobic particles vital.

5.4 Summary of the test results

Based on the described test results the ideal additive to reduce and to eliminate microfoam in airless applied water-based wood and furniture coatings is based on silicone with a certain molecular weight and balance of hydrophobicity and hydrophilicity. These characteristics are obtained by a specific length of the silicone backbone and variation of the polyether modification linked to the backbone.

The resulting product shows an optimum balance between solubility and insolubility with the coating system. This balance of solubility ensures that the active product remain in the coating, being available for microfoam elimination and not to migrate to the coating surface.

6. Approach for a better understanding of the processes taking place

The new product is effective as well during airless application as during the drying process of the coating system. In order to distinguish the well known silicone polyether defoamers from the described silicone polyether the newly developed product is classified as a deaerator. This different designation is meant to emphasise the fact that the working mechanism of this new product is different to the defoaming process.

6.1 Airless spray application

There is prevailing opinion that the microfoam formation occurs because of paint droplets leaving the spray nozzle and splashing into the coating film. This impact causes a splash with a high crown formation.

When this crown seals it is possible that air voids are entrapped [4]. Taking this into consideration it is possible that smaller paint droplets will show a reduced entrapping of air voids splashing into the coating. The necessity of smaller paint droplets to avoid microfoam formation was observed and mentioned several times [2], [5].
6.2 Drying process and dissolution of air bubbles

With the video technology linked to the microscope it was possible to observe the living cycle of a micro-bubble during the drying process. During drying the micro-bubbles get smaller and smaller until they disappeared completely, giving the speculation that the air of the micro-bubbles diffuses into the coating. This is called dissolution. The newly developed deaerator is able to strengthen the dissolution process of the air bubbles. This increased dissolution process by silicone polyether can be related to the surface activity of this product. Owing to this surface activity the silicone polyether is able to orientate at the interface liquid/air micro bubble. Surfactants stabilising micro-bubbles will be pushed away finally leading to a difference in surface tension at the micro-bubble surface. These differences can lead to destabilisation of the micro-bubbles forcing the dissolution process.

The fact that hydrophobic particles increase the effectiveness of the silicone polyether can be explained by the high surface area of these particles. High surface area increases the chance of contact of the silicone polyether to the interface liquid/air micro-bubble. Finally this leads to enforced destabilisation of the micro-bubbles and increased dissolution process.

7. From active matter design to commercial products

7.1 Deaerator concentrate

The above described product was made commercial as a deaerator concentrate by Tego as the first deaerator for water-based coatings and enjoys a lot of success in the coatings industry.

It finds application not only in airless-spray applied wood coatings, but also in industrial and anti-corrosion coatings, and even in printing inks. In pigmented coatings it is preferably used at the grinding stage. When adding it at the let-down stage or to clears it has to be incorporated with sufficient shear or prediluted e. g. in glycol ether.

It provides outstanding effectiveness with regards to microfoam elimination. Since it is also able to prevent and destroy macrofoam, generally no additional defoamer has to be used.

7.2 Deaerator emulsion

Still there are other applications in the coatings industry that require effective deaeration. There are low viscosity industrial coatings for spray-application, wood and furniture coatings for curtain coater application, etc. into which the above described deaerator may be difficult to incorporate.

To provide a suitable deaerator also for these applications a new product was designed, based on a relatively similar chemistry, also filled with fumed silica, but supplied as emulsion with specific particle size distribution.
This deaerator emulsion has proven to be highly suitable for a variety of different applications and is highly compatible even with sensitive binder systems, such as water-reducible polyesters, 2p PU systems, etc.

8. Conclusion and outlook

With the described development of two tailor-made deaerators for water-based coating systems it has become possible to eliminate microfoam effectively in most water-based coating formulations.

The ideal deaerator is based on polyether siloxane copolymer, either compounded as a 100 % concentrate, or formulated as a special emulsion. Nearly every day these products find new applications that we had not even thought of when developing them. They deaerate automotive fillers, they cure the microfoam problem in water-based flexographic inks printed with chamber-blade technology, or even work in water-based PVC coatings applied by curtain coater, ...

It is up to the additive supplier to stay in close contact with the paint formulators to proceed with this success story and possibly develop a third product in the future, when the need for a different property profile arises.

References


Appendix:

Formulations

**Transparent high-build coating for wooden window frames**

<table>
<thead>
<tr>
<th>Ingredients</th>
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<tbody>
<tr>
<td>1. Styrene–acrylic emulsion</td>
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<td>2. Water</td>
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<td>3. Preservative additive</td>
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<td>4. Co-Solvent 1</td>
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<td>5. pH adjustment to 8.2</td>
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<tr>
<td>6. Co-solvent 2</td>
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<tr>
<td>7. Silicone polyether deaerator</td>
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<td>8. Light stabiliser</td>
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<td>13. Slip and anti- blocking additive</td>
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**White pigmented high-build coating for wooden window frames**

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<td>3. PU Thickener 2</td>
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<td>6. Preservative additive</td>
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<td>7. pH adjustment to 8.2</td>
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<td>8. Co-Solvent 1</td>
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<tr>
<td>11. Substrate wetting additive</td>
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<td>12. Titanium dioxide</td>
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<td>13. Modified Acrylic emulsion</td>
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<td><strong>Total</strong></td>
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**Clear, mat furniture coating**

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<tr>
<td>4. Co-Solvent</td>
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<tr>
<td>5. Co-Solvent</td>
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<td>6. Silicone polyether deaerator</td>
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<td>7. Water</td>
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<tr>
<td>8. pH adjustment to pH 8.2</td>
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<td>9. Wax emulsion</td>
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<td>10. Matting agent</td>
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<td><strong>Total</strong></td>
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