Characterizing Powder Coatings in Oscillation

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Introduction

Powder coatings are coatings that are applied as a free-flowing, dry powder. The main difference between a conventional liquid paint and a powder coating is that the powder coating does not require a solvent to keep the binder and filler parts in a liquid suspension form. The coating is typically applied electro-statically and afterwards cured under heat to enable flow and form a "skin". The powder may be a thermoplastic or a thermoset polymer. It is usually used to create a hard finish that is tougher than conventional paint. Powder coatings are mainly used for coating of metals, such as household appliances, alloy extrudates, drum hardware, and automobile and bicycle parts. Newer technologies allow for the utilization of other materials, such as MDF (medium-density fiberboard), to be powder coated using different methods.

As an overview here is a list of several advantages of powder coatings over conventional liquid coatings:

- Powder coatings emit zero or near zero volatile organic compounds (VOC).
- Powder coatings can produce much thicker coatings than conventional liquid coatings without running or sagging.
- Powder coating overspray can be recycled and thus it is possible to achieve nearly 100% use of the coating.
- Capital equipment and operating costs for a powder line are generally less than for conventional liquid lines.
- Powder coated items generally have fewer appearance differences between horizontally coated surfaces and vertically coated surfaces than liquid coated items.
- A wide range of specialty effects can be accomplished which would be impossible to achieve with other coating processes.

For optimum material handling and ease of application, most powder coatings have a particle size in the range of 30 to 50 µm and a glass transiton temperature (T_G) around 200 °C. For such powder coatings, film build-ups of greater than 50 µm may be required to obtain an acceptably smooth film. The surface texture which is considered desirable or acceptable depends on the end product. Many manufacturers actually prefer to have a certain degree of orange peel since it helps to hide metal defects

Fig. 1: Thermo Scientific HAAKE RheoStress 6000, a rotational rheometer for individual demands.

that have occurred during manufacture, and the resulting coating is less prone to showing fingerprints. However, as to be shown in this article, differences in surface texture, that may arise from different curing kinetics and/or different visco-elastic properties, can lead to undesired creaking noises when the coated surfaces are strained. The method of choice to monitor curing processes rheologically is the oscillatory test. At a constant frequency (1 Hz) and a constant strain (0.01) the material changes can be monitored via the moduli G' and G" as well as the complex viscosity $|\eta^*|$ and the tan(δ) as a function of temperature and/or time.

Experimental Results and Discussion

The rheological properties of powder coatings need to be determined before, during and after the temperature induced curing step to understand how a certain formulation will work towards a specific processing step as well as the actual application of the finished part. As for these complex, multi-component systems the visco-elastic behaviour cannot be modelled adequately but has to be determined experimentally with a rotational rheometer. As an example, Fig. 1 shows the Thermo Scientific HAAKE RheoStress 6000, a rotational rheometer for R&D as well as demanding QC applications.

In this contribution we want to compare 2 different powder coatings (Powder Coating 1 and Powder Coating 2 or PC 1 and PC 2 respectively) with each other. The supplier of these products stated that the properties of the two materials are the "exact" same, not just during the cure but also afterwards. However, in reality the two systems behave very different in their real life application, many customers where especially complaining about the orange peel in the surface texture of one material leading to an enhanced noise generation under friction. How can we now find a rheologically meaningful solution to this problem? First of all, as described before, the visco-elastic behaviour during and after the curing should be of major importance.

Fig. 2 shows the time dependent visco-elastic properties of these 2 different powder coats at curing temperature of 180 °C.

As one can see from Fig. 2 the two "identical" materials show a very different behaviour during the curing at 180 °C and as a result of that a very different profile of the finished coating. Starting out at comparable viscosities (and visco-elastic moduli) it can be seen that PC 2 not just starts to cure earlier than PC 1, but that it also shows a faster kinetic as the slope of G' during the curing is higher than for PC 1. A faster kinetic means that we could work faster with PC 2, however what does this mean for the fully cured coating? What can also be observed in Fig. 2 is that both materials reach the same level of G", however PC 2 reaches higher values in elastic modulus G'. As a direct result of this, the so-called loss factor or damping function tan (δ) (which is nothing but the ratio of G"/G') reaches lower values for PC 2. In real life this means nothing else than that PC 2 builds up the tighter network with smaller mesh size due to the faster curing kinetic. During build-up of the network a lot of tension is frozen into the system due to the small mesh size. Those tensions will support the emerging of orange peel on the fully cured surface, thus yielding the answer to the question why PC 2 shows a high level of noise generation under friction.

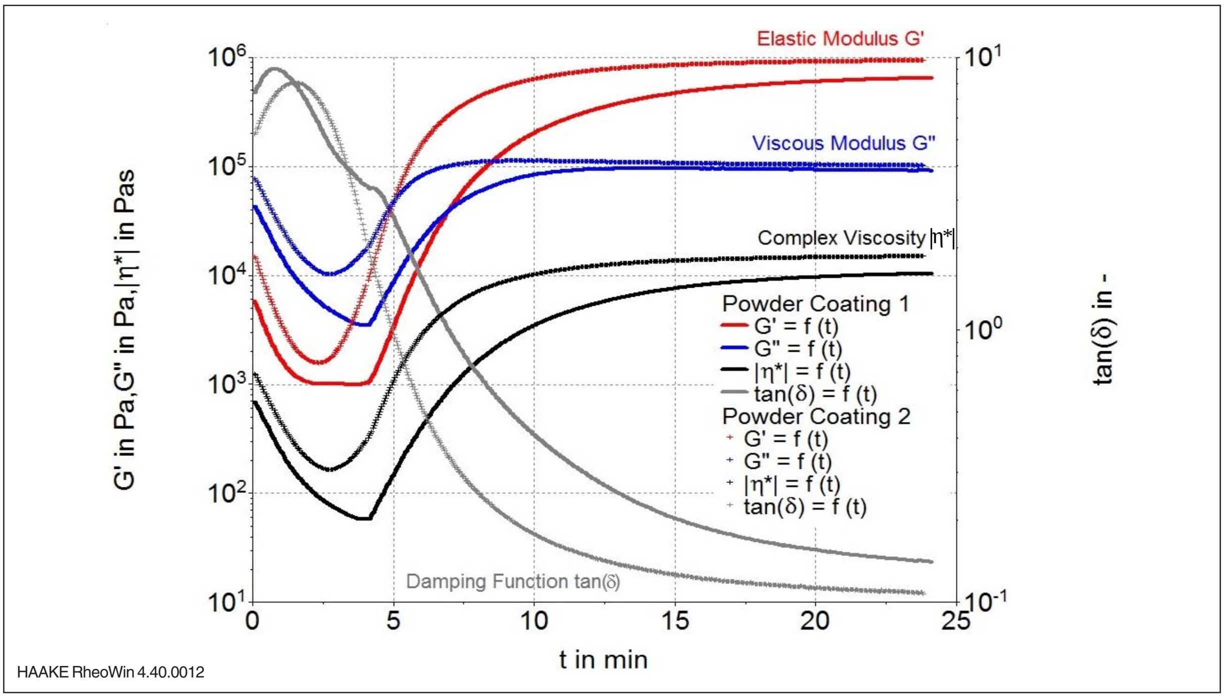

Fig. 2: Visco-ealstic material functions G',G", |η*| and tan(δ), as a function of time for 2 different powder coatings at 180 °C.

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Material Characterization

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