

ADDITIVES

The background of the image is a vibrant red with a series of flowing, wavy lines that create a sense of depth and movement. The lines are layered, with some appearing closer and more saturated, while others recede into the background, giving the overall effect a three-dimensional, liquid-like quality. The lighting highlights the curves, creating bright highlights and deep shadows that emphasize the undulating pattern.

TO CONTROL THE RHEOLOGY OF PAINTS AND COATINGS

By Leo Procopio, Paintology Coatings Research, LLC

Formulating paints and coatings to provide the right balance of properties is a complex undertaking. Getting the rheology profile correct is just one important task on the formulator's to-do list, but it is crucial to the ultimate success of the coating.

The rheology profile influences properties of the coating throughout its lifetime, from manufacture, storage, mixing, and application, to the resulting film properties. To control and optimize the rheology of liquid coatings, the formulator typically relies on additives, often referred to as rheology modifiers, thickeners, and thixotropes.

This article reviews some of the basics of rheology and rheological additives and includes comments from a roundtable discussion with industry experts on existing challenges and new developments.

BASICS OF RHEOLOGY

Rheology is defined as the science examining the flow and deformation of materials. When considering fluids such as liquid paints and coatings, the aspect of rheology discussed most often is viscosity. The viscosity of a fluid is a measure of its resistance to deformation under a given stress and is a material property that we associate with the coating as being either “thick” or “thin.” To understand viscosity and its importance for coatings, a quick review of the principles is helpful.

As Isaac Newton did many years ago, consider a fluid between two plates as in *Figure 1*, where the bottom plate is static, and the top plate is moving at a certain velocity (v) due to an applied force (F). When a force is applied to the liquid, flow of the liquid will occur to relieve the strain from the force.

The shear stress (τ) is defined as the shear force (F) per unit area (A) that results in flow of the liquid and has units of Pascals (1 Pa = 1 N/m²) or dyne/cm². The shear strain (γ) describes the deformation of the fluid and is defined as the ratio of the horizontal displacement (ΔL) to the height (h). The velocity of a fluid layer near the top plate will be higher than the velocity of a fluid layer near the bottom static plate.

Shear rate ($\dot{\gamma}$) describes the velocity gradient, or the change in liquid velocity per unit height between the shear plates, and is defined as v/h , where $v = \Delta L/t$, and t is the time it takes the top plate to move the distance ΔL . Shear rate has units of reciprocal seconds (s⁻¹). Viscosity, which we already noted is a measure of the resistance of the fluid to deformation, is the ratio of shear stress (τ) to shear rate ($\dot{\gamma}$), and is reported in units of Pa·s or dyne·s/cm² (where 1 dyne·s/cm² = 1 Poise (P), and 1 Poise equals 0.1 Pa·s).

When the viscosity of a fluid is constant at varying shear rates, it is said to exhibit ideal or Newtonian viscosity (*Figure 2a*). Newtonian fluids include simple fluids such as water, solvents and oils. However, most liquid materials, including paints and coatings, are non-Newtonian in nature, and have a viscosity that changes with shear rate. The viscosity of paints and coatings generally decreases with increasing shear rate, also known as shear-thinning or pseudoplastic behavior (*Figure 2b*). Shearing the coating will break down structure within the liquid, and lead to a lower viscosity versus when the coating is at rest and unperturbed.

Some fluids, such as high-solids dispersions, can show an increase in viscosity with increasing shear rate, also known as shear-thickening or dilatant

behavior (*Figure 2c*). Generally, dilatant flow is not desired, as it can cause problems during manufacture and in processes such as mixing and pumping.

SHEAR RATE AND PHYSICAL PROCESSES

Paints and coatings are subjected to physical processes that are characterized by a wide variety of shear rates. The settling of pigments due to the force of gravity, for example, is a very low-shear-rate process. The sagging of an architectural paint applied to a wall is another process that occurs under low shear. Mixing a paint by hand or with a low-speed overhead mixer is a medium-shear process, while dispersing pigments and mixing with a high-speed Cowles disperser is a high-shear-rate process.

Application methods span the range of shear rate. Coatings applied by dip or flow coater application experience a low-to-medium-shear rate, while paints applied by brush or airless spray are subjected to high shear. Application of coil coatings by reverse roll coaters is another example of a very high shear-rate process. *Figure 3* describes the approximate ranges of shear rate that are involved in various processes during the manufacture, storage, and application of paints and coatings.

FIGURE 1—Definition of Some Key Rheological Parameters for a Liquid Under Shear

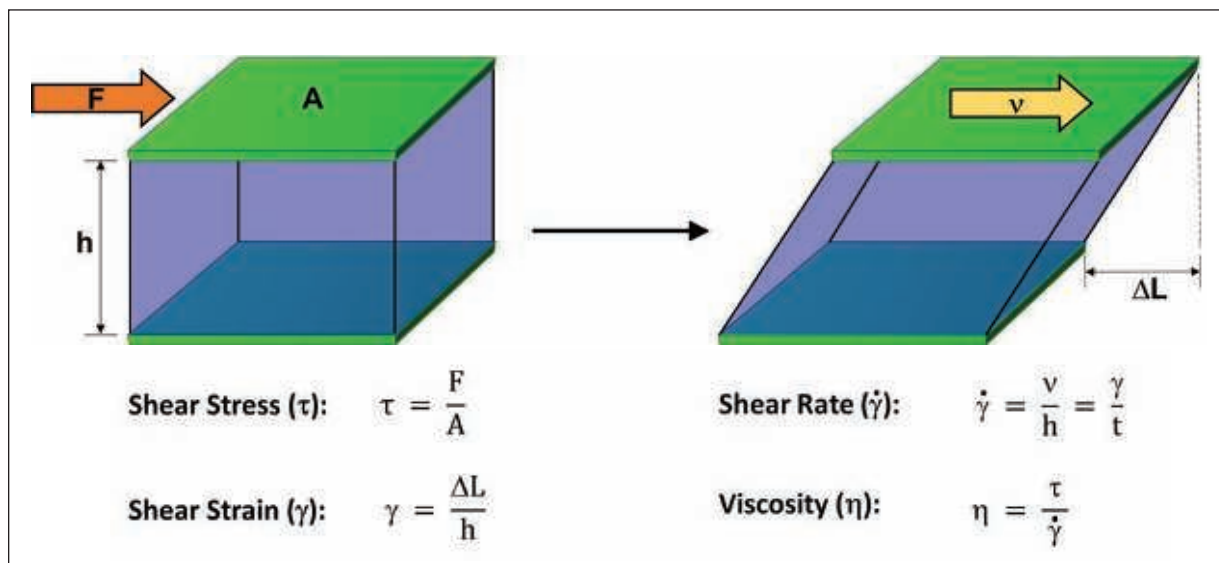
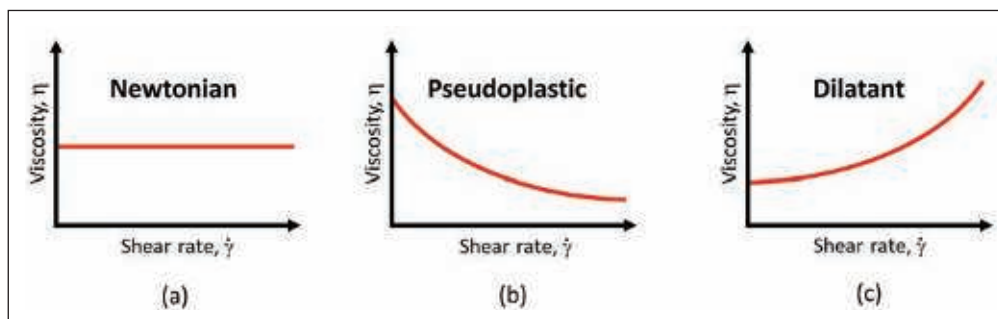


FIGURE 2—Types of Rheology Profile Displayed by Liquids



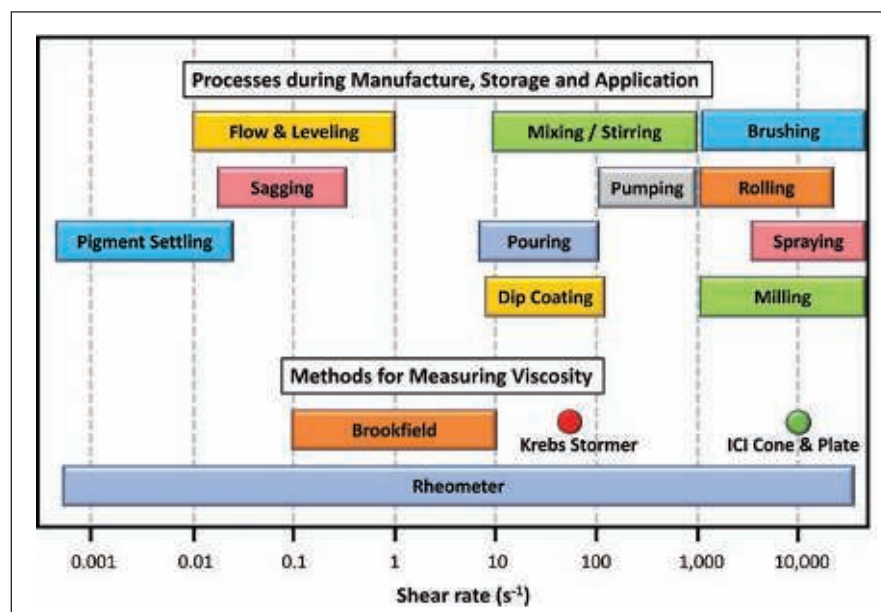
Also shown in *Figure 3* is a description of the shear rate ranges covered by some of the common instruments used to measure the viscosity of paints and coatings. The Krebs Stormer viscometer is a very common piece of equipment in paint laboratories for measuring viscosity (reported in Krebs Units or KU) of coatings such as architectural and industrial maintenance paints.

It uses a paddle-type rotor that is rotated at a constant 200 rpm; higher viscosity paints require a higher force to rotate the paddle at the set speed. Because it operates at a fixed shear rate of about 60 s^{-1} , the Stormer viscometer provides a consistent standard for comparing different paints. However, based on *Figure 3*, while it is a good instrument to use when optimizing for medium-shear processes such as mixing and pouring, it is clearly not the right one to use when trying to optimize low-shear processes such as sag resistance or high-shear processes such as spray application or brushing.

To correlate paint viscosity with low-shear-rate processes, the Brookfield viscometer is a common instrument used in paint labs. It is a rotational viscometer that can use several different cylindrical and disc-shaped spindles and different rotational speeds to measure viscosities (typically reported in units of centipoise or cP) over a range of low-to-medium-shear rates.

For viscosities at high-shear rate, the ICI Cone and Plate viscometer is a common piece of equipment. With a shear rate of about $10,000 \text{ s}^{-1}$, it is useful to formulators trying to optimize viscosity for brush, roller and spray applications that fall in that high-shear range. ICI viscosities are typically reported in

FIGURE 3—Examples of Shear Rates for Various Processes Used in the Paint and Coatings Industry, and for Some Common Methods of Measuring Viscosity



units of Poise (P). A standard water-borne architectural paint designed for brush application will have an ICI viscosity of approximately 1.0 – 1.5 P. Much lower viscosities will lead to poor film build, and much higher values will lead to excessive brush drag.

A well-equipped paint laboratory can evaluate viscosity at low-, medium-, and high-shear conditions for a moderate price with the three viscometers already mentioned—Brookfield, Krebs Stormer and ICI Cone and Plate viscometers. It is recognized that these instruments will only provide viscosity data at a few values or small ranges of shear rate.

However, for a more complete picture of the rheology profile of a coating, paint chemists can turn to a more expensive and more advanced rheometer which can make measurements across a wide shear range. Of course, evaluating a coating in the real-world application is the final test of whether the coating rheology has been optimized. There have also been reports in the literature of test method development using an instrument that records position and forces applied during the roller application of architectural paints in an attempt to correlate standardized testing of rheology with real-world application and end-user preferences.¹

TARGETING A VISCOSITY PROFILE WHEN FORMULATING

So, what viscosity should a formulator target when designing a coating? This question is complicated by the fact that for pseudoplastic fluids such as coatings, viscosity changes with shear rate. Understanding the viscosity response of a coating across the range of shear rates is important for paint formulators because of the many physical processes which coatings experience, as illustrated in *Figure 3*, and will help in answering the question.

When designing a new coating, formulators will rely on rheological additives to target the optimal rheology profile to perform best across all these processes. For example, to prevent sedimentation and pigment settling during storage, targeting a higher viscosity at low shear is better. Dense pigments and extenders are more prone to settling in paints with low Brookfield viscosities. Resistance to sagging is also aided by a higher viscosity at low-shear rate. This must be balanced with the need for good flow and leveling, also a low-shear-rate process, but which would be aided by a lower viscosity.

As another example, in spray applications, a stream of paint is broken up into small droplets as the paint leaves the spray gun, and this atomization process is generally enhanced by a lower viscosity at the high-shear conditions that occur in spraying. On the other hand, if formulating for a brushing application, a higher viscosity at high shear will be desired to allow for greater film build. If viscosity is too low and a thin film results, properties such as hiding or substrate protection (e.g., corrosion) might be sacrificed.

ADDITIVES FOR RHEOLOGY CONTROL

In solventborne coatings, the dissolved resin can have a strong influence on viscosity. At a given solids level, higher resin molecular weight and polymer backbone stiffness leads to higher solution viscosities. Polymer design and volume solids are variables used to control viscosity in solventborne coatings, and additives are often used to improve sag resistance and pigment settling.

Common thixotropic agents used in solventborne systems include organically modified clays (organoclays), polyamides, and castor oil derivatives.

Waterborne coatings, especially ones based on latex polymers, will typically rely on additives to control rheology. Because latex polymers are colloidal particles and insoluble in water, the polymer molecular weight and backbone stiffness have no effect on viscosity. However, particle size, particle-size distribution, and volume fraction (concentration) have a strong effect on viscosity of the latex. As the latex concentration approaches the theoretical maximum volume fraction, small changes can lead to large increases in viscosity. For this reason, latex coatings are usually formulated at latex concentrations low enough to avoid the issue and typically use water-soluble thickeners to control rheology.

There are a variety of water-soluble, organic rheology modifiers and thickeners used in waterborne systems, including cellulose, alkali-soluble (or swellable) emulsions (ASE), hydrophobically modified alkali-soluble emulsions (HASE), and various types of associative rheology modifiers such as hydrophobically modified ethoxylated urethanes (HEUR) and hydrophobically modified polyethers (HMPE). Inorganic rheology modifiers are also used in waterborne systems, typically for anti-settling and anti-sag properties, and include

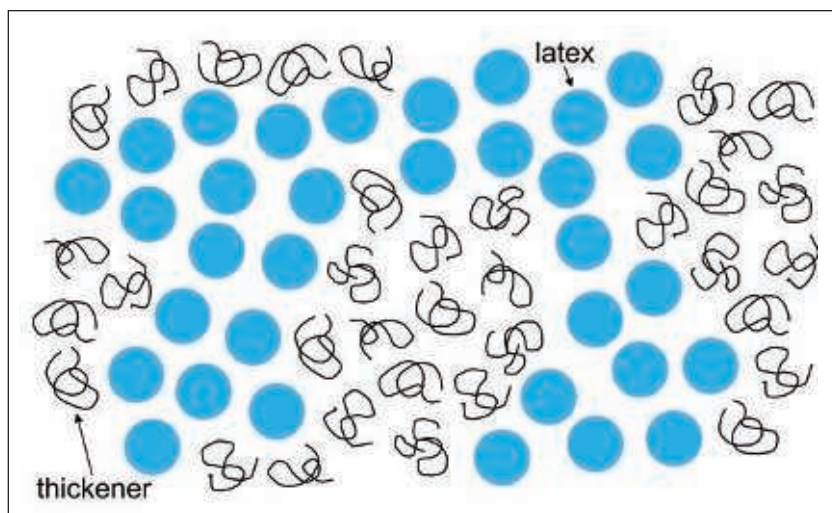
clays (e.g., attapulgite and bentonite clays) and fumed silicas. Some of these rheology modifier chemistries will be discussed in more detail below.

Organic rheology modifiers for waterborne coatings can be classified according to how they thicken the paint. There are two basic mechanisms of thickening utilized by these rheology modifiers—associative and non-associative.

Non-associative thickening works via a volume-exclusion mechanism, where typically high-molecular-weight, water-soluble polymers swell with water and take up hydrodynamic volume in the coating (*Figure 4*). Examples include hydroxyethyl cellulose (HEC) and ASE thickeners, which create viscosity through chain entanglements and particle flocculation (i.e., depletion flocculation).

Associative thickeners are water-soluble polymers containing hydrophobic groups that interact (or associate) with one another and with other components of the coating formulation, particularly the latex particles, to create a network structure (*Figure 5*). An increase in viscosity results from the network restricting the motion of the latex particles. Examples of associative thickeners include HEUR and HMPE rheology modifiers. There are also rheology modifiers which rely on a combination of associative and non-associative mechanisms for thickening, including HASE and hydrophobically modified HEC, or HMHEC thickeners.

FIGURE 4—Thickening Mechanism for Latex Coatings with Non-Associative Rheology Modifiers



Non-associative rheology modifiers are water-soluble polymers that thicken the water phase of a coating. Higher-molecular-weight polymers tend to have a higher viscosity in a solution, and that holds for water-soluble rheology modifiers such as cellulosic ethers and ASE thickeners. Cellulosic thickeners are derived from a natural product, cellulose.

The most common cellulosic derivative used in paints and coatings is hydroxyethyl cellulose (HEC), which is available in various molecular weights. HEC thickeners are non-ionic and yield good viscosity stability across a wide pH range. As a derivative of a natural product, HEC is susceptible to microbial attack. Cellulase enzyme produced by microbes can break down cellulose thickeners and lead to viscosity loss in an already-formulated paint. Manufacturers have developed grades that are modified to be more resistant to such attack.

HEC thickeners are particularly good at creating viscosity at a low-shear rate, and thus offer good resistance to pigment settling, sag, and syneresis. They are also not affected greatly by the presence of surfactants; therefore, viscosity drop on addition of colorants is less of a concern than with associative thickeners such as HEURs. HEC thickeners can, however, have a negative impact on film gloss.

Higher-molecular-weight grades of HEC have greater thickening efficiency

compared to lower-molecular-weight grades, but are also more shear thinning as chain entanglements are broken down on shearing. To achieve high viscosity at high-shear rate—for example, to improve brush drag or film build—a formulator must add an adequate amount of HEC. With high levels of a high-molecular-weight HEC, the paint formulator risks having an excessive low-shear viscosity, which will lead to poor flow and leveling.

With a low-molecular-weight HEC, the risk is needing to use too much water-soluble polymer and having poor water resistance in the final film. The compromise is often to use a medium-molecular-weight grade. Hydrophobically modified HEC or HMHEC thickeners incorporate hydrophobe groups into the polymer that also build viscosity through an associative mechanism and are also more effective at building high-shear viscosity. HMHEC grades also give improved spatter resistance in roller application versus unmodified HEC, which has been an historical problem for coatings thickened with HEC.

Alkali-soluble emulsion (ASE) thickeners were developed to mimic the rheology of cellulosics but with greater ease of use. While HEC thickeners are supplied as a dry powder, ASE thickeners are supplied in liquid form. ASE thickeners are typically copolymers of ethyl acrylate (EA) and methacrylic acid

(MAA) and made by an emulsion polymerization process. They are supplied as unneutralized, low pH, high-solids dispersions of insoluble polymer in an easy-to-use, low-viscosity liquid form.

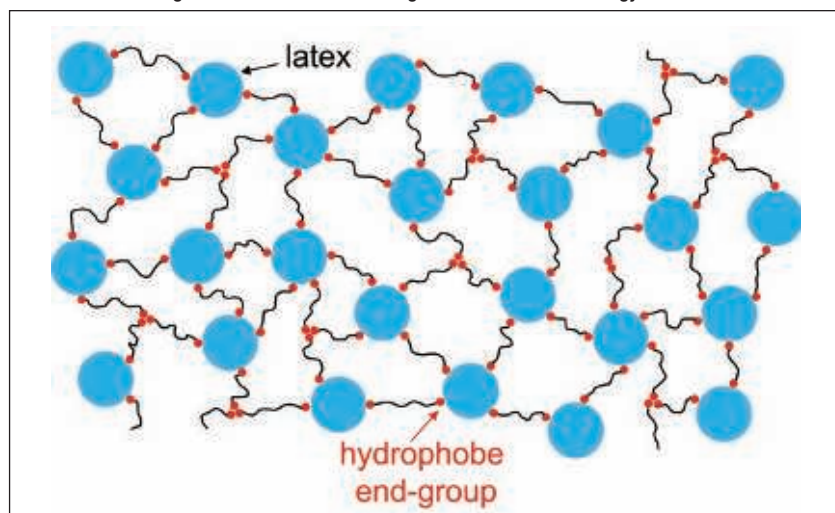
The weight percent of MAA in the polymer is fairly high, and upon neutralization to a higher pH, the polymer swells, becomes more water-soluble, and starts to uncoil. Once uncoiled, the ASE polymer chains thicken the coating through the volume exclusion mechanism. The degree of thickening depends on the molecular weight of the polymer. Because neutralization is the trigger that activates the thickening ability of ASE thickeners, formulators can rely on ammonia or other neutralizing bases in the coating formulation to activate the thickening action. Adjustments in the amount of neutralizer will be needed to maintain a suitable pH.

ASE thickeners are proficient at building high viscosity at low shear for coatings with good anti-settling and sag-resistance properties and give rheology profiles that are steeply shear thinning. Due to the high level of carboxylic acid functionality, ASE thickeners can impart some water sensitivity to films and negatively influence properties such as scrub resistance for architectural paints or corrosion resistance for industrial coatings. Other limitations can include flow and leveling that is not ideal.

As mentioned, HASE rheology modifiers create viscosity by a dual mechanism involving both volume exclusion and hydrophobe association. HASE thickeners are acrylic polymers that make use of the ASE technology; i.e., they contain enough acid functionality to impart solubility on neutralization and thicken through volume exclusion as shown in Figure 4.

However, they are typically lower molecular weight than ASE thickeners and also incorporate hydrophobic groups into the backbone, which are available for association with both each other and latex particles as shown in Figure 5, once the HASE is solubilized. HASE rheology modifiers allow for formulation of a wide range of rheology profiles relative to ASE and HEC; some products are more effective at increasing viscosity at low shear and others are more effective at building viscosity at

FIGURE 5—Thickening Mechanism for Latex Coatings with Associative Rheology Modifiers



mid- and high-shear rates. They generally provide better flow and leveling than cellulosic thickeners, have better gloss capability, and are suitable for flat through gloss formulations.

Relative to HASE, hydrophobically modified ethoxylated urethane (HEUR) rheology modifiers are non-ionic, lower molecular weight, and have a higher density of hydrophobe groups. HEURs are water-soluble polymers based on a polyurethane backbone formed by reacting polyethylene glycols with isocyanate crosslinkers and capped with hydrophobic end-groups. HEURs and related associative thickeners such as HMPEs create viscosity through the development of a three-dimensional associative network, as shown in *Figure 5*. The hydrophobic end-groups are driven to associate with one another and latex surfaces due to their poor solubility and exclusion from the aqueous phase. The degree of associative thickening with HEURs is higher than in HASE and HMHEC. HEURs are known for their excellent flow and leveling, excellent spatter resistance, and good water resistance and gloss potential. Variables in their production such as molecular weight, hydrophobe size, and hydrophobe density have allowed HEUR products to be tailored for effectiveness across the range of shear rates.

One weakness of associative thickening is its susceptibility to be interrupted by other hydrophobe-containing species in the paint formulation, in particular by surfactants and water-miscible coalescents and solvents. Water-miscible solvents such as ethylene glycol butyl ether (Butyl CELLOSOLVE) or diethylene glycol butyl ether (Butyl CARBITOL) can increase the solubility of the hydrophobes in the aqueous phase, and thus interrupt the driving force for their association with each other and the latex surface. Industrial coating formulations that contain high levels of solvents such as Butyl CELLOSOLVE are notoriously difficult to thicken with associative rheology modifiers.

Surfactants compete with thickeners for the latex surface and interrupt associations between hydrophobes on thickener molecules. Disrupting the

three-dimensional network results in a lower viscosity. This effect is particularly problematic in medium to ultra-deep tint bases, where high levels of colorants containing surfactants are added to pre-thickened tint bases.² Viscosity drops on colorant addition can be significant, with a simultaneous negative effect on coating properties such as sag resistance and brush loading.

Paint manufacturers can try to compensate for the viscosity drop by over-thickening the tint base, but that leads to higher cost, handling issues for the higher viscosity bases, and differing viscosities in tinted coatings based on the type and amount of colorant added. Another approach is to use non-associative thickeners such as HEC, in the place of associative thickeners, but this results in worse flow.

During the past several years, there have been some HEUR products introduced which address the issue of viscosity drop on colorant addition. One technology uses a hydrophobe group that associates more strongly and is less likely to be disrupted by surfactant.³ This approach relies on a novel solution using a pH trigger that prevents the thickener hydrophobes from strongly associating with themselves in the as-supplied neat thickener, which could otherwise lead to unusable high viscosities. A hydrophobic amine group is incorporated into the HEUR backbone. At low pH, the amine is protonated and the resulting charge repulsion prevents the hydrophobe association, which would otherwise create high viscosity. Once added to a formulated paint at higher pH, the amine is deprotonated, and the hydrophobe groups are then available for association.

Other factors that affect the efficiency of HEUR thickeners include the latex particle size and hydrophobicity of the latex polymer surface. HEURs are more efficient with smaller-particle-size latexes due to the higher surface area available for association with the hydrophobes. When two similar latex polymers are formulated at equal volume solids and PVC, the latex with smaller particle size will require less HEUR thickener to reach a target viscosity.

However, latex polymer composition can also have a large effect on HEUR efficiency, as more hydrophobic backbone compositions require less HEUR to reach viscosity targets. For example, HEURs are generally more efficient at building viscosity with styrene-acrylic latexes compared to all-acrylics, which in turn are more efficient than vinyl acetate-acrylic copolymers.

CONCLUSION

This article is a brief introduction to some of the important aspects of rheology and rheology modifiers, and formulators would be well served by continuing to learn more about this critical aspect of paint formulation. Rheology influences many properties during the life of a coating, including during its manufacture, storage, and application.

The rheology profile can also affect both the ultimate film performance, as well as the end-user attitudes towards a particular paint and brand. A large body of literature exists to further that continued learning, and in the meantime, manufacturers of rheology modifiers continue their research and development of new additive products to make the formulator's task less complex.

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LEO PROCOPIO, Ph.D., President & Owner, Paintology Coatings Research LLC, Lansdale, PA; lprocopio123@yahoo.com.

ROUNDTABLE Q&A

CoatingsTech asked several industry experts about various aspects of rheology modifiers, including market needs and trends, remaining challenges, and new products.



How does your company participate in the rheology modifier market for paints and coatings?

Williams, Dow Coating Materials:

Dow is a leading supplier of HEUR and HASE rheology modifiers for the water-borne coating industry. We have a long history of inventing in this space. Today our ACRY SOL™ product line is extensive and well adapted to serve multiple end-use markets and applications.

Sullivan, Münzing: Münzing produces HEUR and HASE type of rheology additives for water-based coatings, paints, tints, adhesives and inks. The product portfolio of polyurethane thickeners covers the entire rheological profile from highly pseudoplastic, through pseudoplastic to Newtonian.

Moore, BASF: BASF offers a broad portfolio of rheology modifier chemistries for water-based, solvent-based, and solvent-free systems in the paint and coatings markets. RHEOVIS additives are synthetic rheology modifiers designed for aqueous systems, including non-ionic associative (HEUR / HMPE), anionic associative (HASE) and non-associative anionic (ASE) technologies. EFKA additives are specifically designed for solvent-based and solvent-free systems consisting of polyamide wax and hydro-genated castor oil chemistries. ATTAGEL attapulgithe rheology modifiers perform as thickening and suspension aids for improved sag resistance and long-term stability. Each product class has its own properties and applications to enable formulators to achieve their desired rheology profile with all types of resins. Our rheology modifiers also provide additional functionalities like wetting properties and health or environmental benefits such as suitability for formulations free of VOCs, odors, APEOs and heavy metals.

Sieto, Elementis: Elementis is a significant supplier in this market. We have a broad portfolio in the market, which includes associative, acrylic, organic thixotropes, and clay-based thickeners.



What are some of the key industry needs and trends driving innovations for rheological additives?

Sorrell, BASF: Customers have requested thickeners that provide thickening in only one part of the rheology curve for targeted viscosity control. Another request we have received is for synthetic versions of the cellulosic chemistries. Also, there is a focus on more sustainable and environmentally free additives (tin-free, low/no VOC, etc.). Additionally, rheology modifiers that provide performance uniformity across different application methods is driving our innovation efforts. Rheology modification has become an increasingly targeted technology. Unique formulations require technologies that can offer varying profile development. Ease of use in formulation preparation and in the final product are key innovation perspectives.

Sieto, Elementis: Developing thickeners which maintain performance or increase efficiency while having no impact on the resin performance. We are always looking to improve sag, scratch resistance, and anti-staining properties in architectural and industrial paints.

Williams, Dow Coating Materials:

Consumers are demanding higher performance paints in terms of appearance and resistance properties. We see properties such as hiding and surface smoothness and “toughness” as key features beyond traditional premium products. Attaining these attributes relies heavily on finding the right additives to help take paint performance to the next level.

PARTICIPANTS IN THE RHEOLOGY MODIFIERS ROUNDTABLE DISCUSSION

Brandon Achord, Ph.D., senior scientist & senior team leader, formulation additives and colorant formulations, BASF

Ramesh Iyer, Ph.D., global sustainability director, Dow Coating Materials

Erin Moore, marketing manager, formulation & performance additives North America, BASF

Chris Sieto, marketing manager, coatings, Elementis

Bree Sorrell, technical specialist, formulation additives, BASF

Leah Sullivan, Ph.D., coatings application manager, Münzing North America

Wenqin (Sunny) Wang, Ph.D., senior R&D scientist, Dow Coatings Materials

Stewart Williams, Ph.D., global segment leader, additives, Dow Coating Materials

Sullivan, Münzing: Due to regulations on harmful substances and growing end-user concerns about environmental and health hazards in coatings, the entire industry is working on more pollutant-free formulations to include no APEOs, parabens, VOCs, and solvents. Additionally, Europe and parts of Asia have noticed a major trend in preservative-free paints and coatings with high pH value. In response, we have been working towards the development of new, pH-stable rheological additives.

ROUNDTABLE Q&A

Q Is the use of biobased materials finding its way into the manufacture of rheology modifiers, and are you seeing interest in biosourced materials from coatings manufacturers or their customers?

Sieto, Elementis: Yes, more customers are asking us for biobased and naturally derived product. We have both. Our clay-based thickeners are based on natural hectorite, which is mined. Our organic thixotropes are based on castor beans which are biobased.

Iyer, Dow Coating Materials:

Consumers are also looking for more sustainable paints which is helping to drive the industry to replace petrochemical-based ingredients with progressively increasing amounts of biobased materials. A life-cycle assessment of a paint containing only petrochemical sourced materials typically shows a higher carbon footprint (CO₂ emissions) versus a paint with equivalent performance that is made in part from biobased sources. It is important that the sourcing of biobased raw materials is done in a thoughtful way from regions where advanced farming practices are pursued and where there are no known water-scarcity challenges. As rheology modifiers are used in small quantities, their contribution to greenhouse gas (GHG) emissions is low in the manufacturing process, but they also offer functional benefits in the storage and use phase of a paint. The progress of EU Green Deal legislation is expected to accelerate more sustainable paints with better environmental profile beyond low odor and VOC.

Sullivan, Münzing: Recently, we have noticed an increased demand from our customers for additives based on renewable raw materials. We have therefore just launched a new series of HEUR rheology modifiers, TAFIGEL PUR R (R = renewable), to meet this demand.

Achord, BASF: For many years, sustainability has been a core pillar at BASF where we focus on developing products that make the best use of our available resources and enhance the quality of life for the world's future. Our ATTAGEL line and some of our EFKA rheology modifiers are derived from natural resources. BASF is also evaluating

the conversion of many raw materials that make up our synthetic rheology modifiers to sustainable and biobased alternatives.

Q Are there any regulatory issues or environment/health/safety (EHS) concerns, such as materials of concern, that is driving new research and product development efforts in rheological additives?

Sullivan, Münzing: The biggest regulatory concern we are grappling with is to make more rheology modifiers acceptable to be used in products that have contact with food. We are looking into new product development for more food contact applications. Again, our industry is working on more pollutant-free formulations (no APEOs, parabens, VOCs and solvents) because of both regulations and end-user concerns about environmental and health hazards in paints and coatings.

Achord, BASF: Nearly all newly developed rheology modifiers in the industry are developed as low or zero VOC. On top of this trend, which has been in the works for some time, APEO-based products are being replaced within the markets we serve. This enhances the overall environmental compatibility, and reduces potential health hazards in the final products offered to the market. Increasingly, food contact is becoming more of a focus in development. Our rheology modifier portfolio offers versatile offerings that also support USDA food compliance for functional and flexible packaging applications. This ensures our customers can formulate for all desired applications.

Sieto, Elementis: One area of huge concern is the use of biocides. We are currently limited on what we can use, and we continue to test and develop products that are biocide free.

Wang, Dow Coating Materials: We are always working to develop new solutions that perform better and are more sustainable throughout the life cycle of paints. We want the products we develop to have minimal environmental impact, which is why we continually try to develop the next generation of sustainable paints.

Q From a rheology perspective, what do you consider as the top challenges for paint and coatings formulators, and do solutions exist today or is innovation required?

Wang, Dow Coating Materials:

Formulators have many choices to optimize overall compatibility of paint ingredients while delivering on paint stability and paint performance. Choice is influenced in part, by what is on the shelf—that is, by formulator experience. But delivering on new paint attributes dictates utilizing new additives and sometimes new rheology modifiers. It is this process of optimizing choice for a given final performance balance that continues to be both an opportunity and source of complexity for our industry.

Sullivan, Münzing: It is possible to solve many problems with available rheological additives; however, this requires profound formulation expertise on the part of coating developers. For example, viscosity drop on tinting is best addressed by formulating pigment concentrates with polymeric dispersants instead of surfactants.

Sorrell, BASF: The biggest challenge is finding the right rheology balance with newer latexes that are on the market. Latexes are being pushed to smaller and smaller particle sizes, which can be a challenge to stabilize with rheology modifiers. A smaller particle size means more surface area, and thus the response to thickeners is much more profound. While the requirement of less thickener may be viewed as a benefit, a certain amount of rheology modifier is needed for good application performance and storage stability. Furthermore, next-generation latexes are doing more by providing improved features in certain performance properties, such as stain resistance or opacity, but can also negatively impact rheology. The efficiency of rheology modifiers while maintaining the desired profile is also a key focus. Many times, the highest efficiency products come with drawbacks such as incorporation difficulty, equilibration time, and final product stability. Final film properties can be impacted strongly using rheology modifiers, and key innovations are required to either eliminate drawbacks or introduce additional functionality to the coating.

Sieto, Elementis: There are a few examples that we solved during the past few years. One example is the use of certain solvents in industrial coatings that cause a reduction in the efficiency of the rheology modifier and reduce sag. We created a product called THIXATROL PM 8058, which has much higher efficiency in these systems. One other example is viscosity drop on adding colorants to deep tint bases. Again, we developed associative thickeners that hold up very well.



Have you introduced any recent products for controlling the rheology of paints and coatings?

Moore, BASF: BASF is working on several new rheology modifiers and adjusting our production to maximize our supply to customers. Our newest innovations, Rheovis PU 1192/1193, are higher-efficiency pseudoplastic thickeners and scheduled to launch in 2022. Additionally, we are exploring new concepts for a HASE product that could be used to partially, or completely, replace HEC use in formulations. We are also continually researching new techniques and test methods for evaluating the performance of our additive portfolio. Our focus for rheology modifiers includes visual methods for identifying flow and leveling potential as well as real-time-force measurements for application ease. Also, BASF is in the process of relocating our associative rheology portfolio to Castelsbisbal, Spain. This site previously supplied many of the same products to regions outside North America. The move to Castelsbisbal will ensure that our quality of supply will be uniform throughout the globe and strengthen our global knowledge on market trends and R&D efforts to better support our global customers.

Sieto, Elementis: Elementis recently introduced THIXATROL PM 8058, a new amide-based organic thixotrope for use in solvent-based coatings such as high-performance industrial coatings for marine and industrial maintenance applications. It provides high viscosity, thixotropy, and thick-layer sag control in high-build systems that contain aromatic solvents (e.g., xylene) and polar solvents (e.g., n-butanol, benzyl alcohol, etc). THIXATROL PM 8058 is activated at low temperatures, enhancing manufacturing efficiencies, storage stability and improved

process control. It also has a high percentage of biobased raw materials to help customers meet high sustainability demands.

Williams, Dow Coating Materials: We recently developed new products such as ACRY SOL™ RM-725, ACRY SOL™ RM-3030, and ACRY SOL™ RM-1600. These products allow for formulating across a very broad spectrum of formulations from economy flats to specialty coatings. We optimized formulations that allow for benefits in both professional and do-it-yourself paints. We are prepared to highlight full formulating guidelines for optimizing features with these products, such as hiding, sheen uniformity, leveling, and cleanability at all sheen levels.

Sullivan, Münzing: Münzing is working to introduce a series of HEUR thickeners using biobased building blocks in NAFTA (TAFIGEL PUR R), which are currently available in Europe. We are also working to introduce a new series of HASE thickeners for high pH value formulations.



What advice would you give formulators who are designing a waterborne coating formulation and trying to optimize rheology with additives?

Sullivan, Münzing: For a truly in-depth understanding of the properties of rheology for finished products during manufacturing, storage and processing, developers should be aware of the basic properties of various rheology additives (e.g. cellulose ether, HASE, HEUR, ASE, etc.). Also, rheology issues may be improved by selecting more appropriate pigments, fillers and dispersing additives as well as appropriate processing conditions (e.g. shear rate, rate and order of addition). Furthermore, the use of a high-end rheometer and the performance of rotational, oscillatory, and combined measurements is essential to identify the causes of problems.

Sorrell, BASF: Optimizing rheology can be tricky with heterogeneous mixtures such as paints. There are many components that can add to or detract from your rheology performance. Therefore, if you are working with a formulation that has evolved over the years, I recommend returning the formulation to the basics. To solve problems, formulating by

addition can unnecessarily complicate rheology optimization. More than any other paint ingredient, rheology modifiers are expected to perform different functions under varying circumstances from in-can particle suspension, in-can feel, brush/roller-applied feel, and drag, spatter resistance, flow, and sag balance.

Achord, BASF: One needs to consider the entire rheology curve when selecting rheology modifiers. Most often a single thickener is not sufficient to provide good in-can storage stability and sag resistance as these two attributes are on opposite ends of the rheology curve. It is best to select a low-mid-shear thickener in combination with a high-shear thickener to provide the best rheology profile for the application. How it will be applied and the environment where the paint will be applied is yet another important factor in rheology modifier selection. For instance, if the coating will be spray applied, select a thickener that is strongly pseudoplastic for improved atomization. If the coating will be subjected to exterior exposure, water resistance will be a key factor, and therefore, the water sensitivity of the thickener choice should be considered.

Sieto, Elementis: Make sure you are open to working with a supplier who can recommend the right product based on your paint system. This will speed up your development time and give you the performance you need.

Wang, Dow Coating Materials: Think rheology early! Your choice could greatly influence film and application properties, as well as overall end user experience. Take advantage of the best measurement science. Design of experiments coupled with high throughput capabilities can speed your journey to the best solution. Test and refine your model with real-world application methods.

Williams, Dow Coating Materials: Be open to change and recognize that a new solution sometimes demands new products (i.e., products not on your shelf). Formulators and suppliers alike have a role to play here in demystifying rheology. We are not alone, but we pride ourselves in providing experts who can translate paint rheology from basics to optimizing solutions for most formulation spaces. ❄