

# 枝化结构的新功能添加剂

## New Functional Additives with Branched Structures

通过应用现代合成方法，毕克化学 (BYK) 正在生产带有定制结构和新属性的枝化聚合物添加剂。

例如，具表面活性的聚丙烯酸酯被证明了能提供优异的流平性、提高表面能和改善固化涂层的润湿。此外，介绍了基于定制的枝化、球状共聚物的新型润湿分散剂。

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这些可流动、无溶剂的添加剂对所有类型的颜料展现出广泛的适用性。另外，这种枝化的核/壳润湿分散剂可以应用在反应型体系中，而不对成膜物的使用期、交联密度和贮存稳定性造成负面影响。

枝化聚合物结构以受控的方式制备，需要复杂的聚合方法和特殊的原材料。然而，具有定制枝化聚合物结构的添加剂提供了新的特点，如低粘度、高流动性和高效率。

如图1所示，标准的聚醚-改性的线性聚丙烯酸酯在一个液体涂料体系中，相比枝化聚醚-改性聚丙烯酸酯添加剂具有更高相容性。换句话说，新型的定制枝化聚合物结构具有更高的向空气/涂层界面迁移的倾向。这些类型的聚丙烯酸酯在作为流平剂使用时更为有效。另一方面，枝

By applying modern synthesis methods, BYK is producing branched polymer additives with tailor-made structures and new properties. For instance, a surface active polyacrylate is presented that gives excellent levelling, increases the surface energy and improves the wetting of cured coatings. Additionally, new wetting and dispersing agents based on tailor-made branched, spherical copolymers are introduced. These flowable, solvent-free additives exhibit a wide compatibility with all types of pigments. In addition, such branched core/shell wetting and dispersing agents can be applied in reactive formulations without negative impacts on pot life, cross-linking density and storage stability.

The preparation of branched polymer structures in a controlled manner requires the application of sophisticated polymerisation methods and special raw materials. However, coating additives with tailor-made branched polymeric structures offer new features, such as low viscosity, higher mobility and greater efficiency in the curing of coating film.

As depicted in **Figure 1**, a standard polyether-modified linear polyacrylate exhibits a much greater compatibility within a liquid coating formulation than a branched polyether-modified polyacrylate additive. In other words, the new tailor-made branched polymer structure possesses a higher tendency to move to the air/coating interphase. These types of polyacrylates are more efficient when applied as a levelling agent. On the other hand, the branched, highly surface-active structure allows for the design of a levelling additive that exhibits hydrophilic polyether sidechains.

Hydrophilic polyether sidechains attached to the polymer backbone of the branched polyacrylate levelling additive are responsible for a hydrophilic surface effect, as shown in **Figure 2**. When a cured coating - that contains the modified branched polyacrylate - is subjected to an over-coating procedure, excellent wetting and spreading of the second coating layer is observed.

The hydrophilic effect induced by the branched, modified polyacrylate has been measured on a cured 1-pack water-borne OEM primer. Next to excellent levelling and

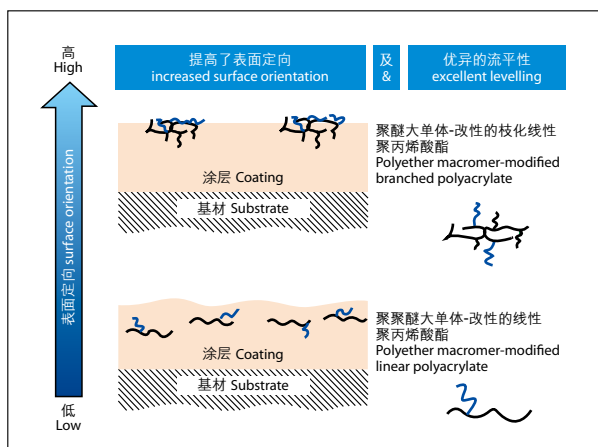


图1：具表面活性的传统型改性聚丙烯酸酯和更有效的、枝化改性聚丙烯酸酯结构的比较  
Figure 1: Comparison between conventional surface-active modified polyacrylates and more effective, branched modified polyacrylate structures

化、高表面活性的结构允许设计出亲水性聚醚侧链的流平添加剂。

链结在枝化聚丙烯酸酯流平剂的聚合物主链上的亲水性聚醚侧链，形成了一种亲水性表面效果（图2）。当含有改性枝化聚丙烯酸酯流平剂的固化涂层进行下一道涂覆时，将观察到第二道涂层具有优良的润湿和铺展性。

枝化改性聚丙烯酸酯的亲水性效果已经在水性固化OEM底漆中得到验证。除了涂层优异的流平性和高光泽，根据Owens-Wendt-Rabel和Kaelbe的方法，由水、甘油、乙二醇、正辛醇和正十二烷这五个标准液的接触角测定的表面能被观察到显著的提高。如表1所示，标准的聚丙烯酸酯添加剂不影响固化涂层的表面能。通过应用0.3%wt的枝化聚醚-改性聚丙烯酸酯添加剂，固化膜的总表面能已增加到52.4mN/m。与不含添加剂的对照物相比，涂层表面能的色散部分已经减少到50%以上，至10.0mN/m。与此相反，固化涂层表面能的极性部分已经显著增加到42.4mN/m。水接触角非常低（30°），表明了该液态涂料具有更好的润湿性。

在另一个水性聚酯-三聚氰胺树脂的OEM底漆里，添加有枝化丙烯酸酯助剂，水平和垂直地静电喷涂于CED底板上，都能获得优异的流平性。而添加标准聚丙烯酸酯流平剂，通过对照，观察到固化涂层的表面能轻微下降2.2~41.3mN/m。与此相反，通过使用0.2%wt的亲水性添加剂，得到固化涂层的表面能增加18.1~61.0mN/m。通过水性底漆，高表面能有助于下一道底色漆更好的润湿。这

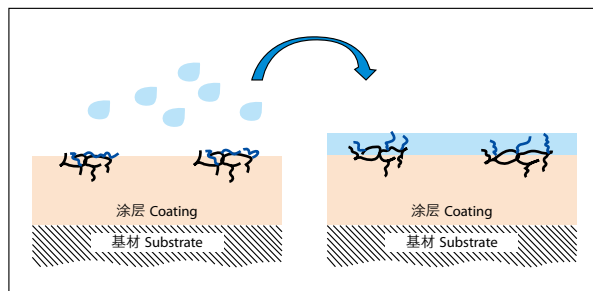


图2：枝化聚丙烯酸酯添加剂的聚醚侧链强烈促进该涂层表面的润湿

Figure 2: Polyether sidechains of the branched polyacrylate additive strongly promote the wetting of the coating surface

high gloss of the coating, a significant increase in surface energy determined from the contact angles of five standard liquids, which are water, glycerine, ethylene glycol, n-octanol and n-dodecane according to the method by Owens-Wendt-Rabel&Kaelbe was observed. As depicted in Table 1, a standard polyacrylate additive does not influence the surface energy of the cured coating. By applying 0.3% wt of the branched polyether-modified polyacrylate additive, the total surface energy of the cured film has been increased to 52.4 mN/m. The disperse part of the coatings surface energy has been reduced by more than 50% to 10.0 mN/m compared to control without additive. In contrast, the polar part of the cured coating's surface energy has been significantly increased to 42.4 mN/m. The contact angle towards water is very low (30°) and indicates much better wetting of liquid formulations.

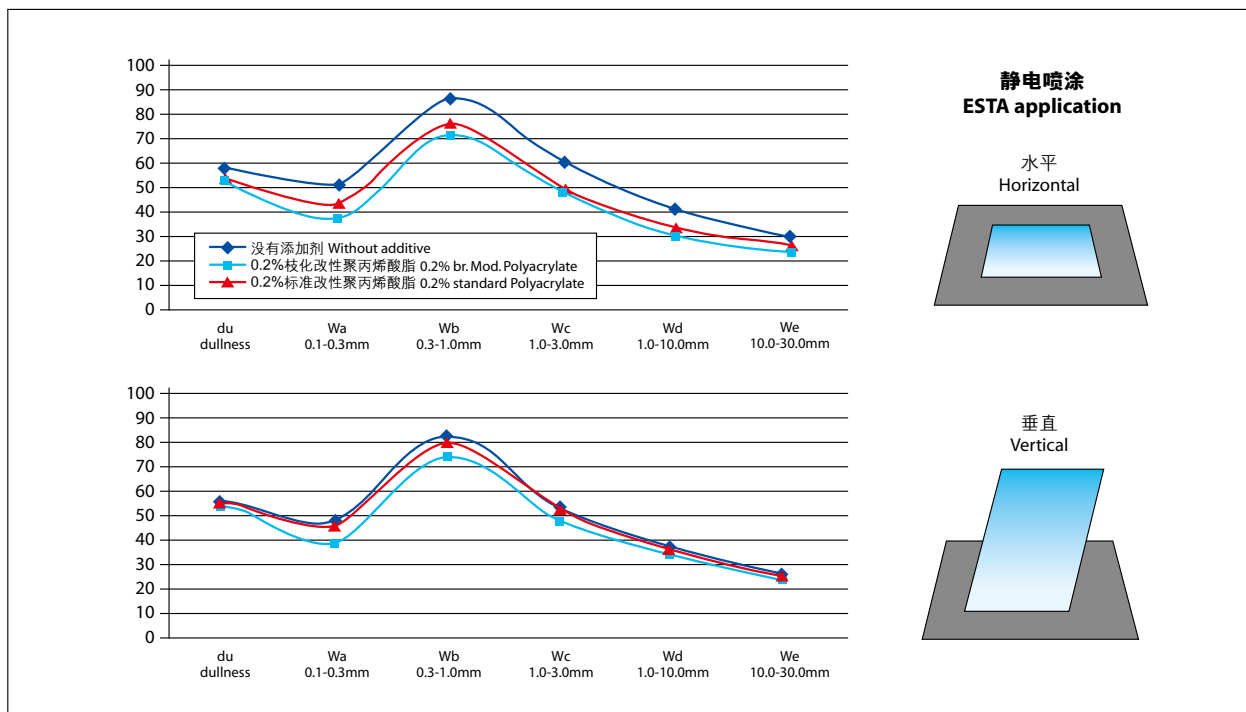


图3：经毕克化学双扫描波检测，在CED面板上，水平和垂直方向的静电喷涂水性聚酯-三聚氰胺底漆，含有亲水性添加剂的流平性能

Figure 3: Levelling performance of the hydrophilic additive applied in a horizontally and vertically ESTA-coated water-borne polyester-melamine primer surfacer on a CED panel determined with a BYK Wave-scan dual

表1: 通过使用少量定制的枝化聚丙烯酸酯助剂, 提高了水性OEM底漆的表面极性和亲水性

Table 1: The surface of a water-borne cured OEM primer becomes very polar and hydrophilic by modification with small amounts of tailor-made branched polyacrylates

	表面能 Surface energy (mN/m)	色散部分 Disperse parts (mN/m)	极性部分 Polar parts (mN/m)	水接触角 Contact angle of water	光泽 Gloss 20°/60°
空白 control	27.4	21.8	5.6	89°	55/89
0.6%标准聚丙烯酸酯 0.6% standard polyacrylate	25.0	21.4	3.6	89°	52/87
0.3%枝化改性聚丙烯酸酯 0.3% branched modified polyacrylate	52.4	10.0	42.4	30°	55/87

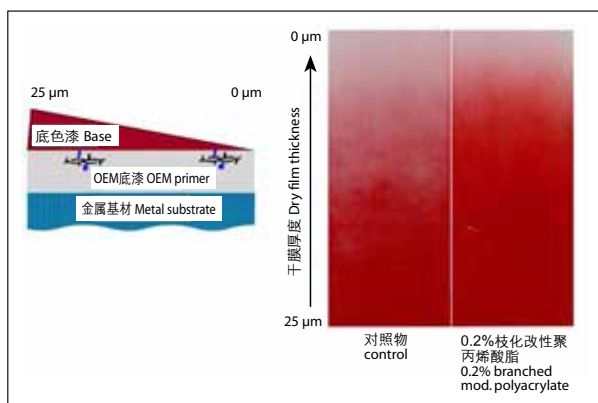


图4: 相对于对照面板, 经过枝化聚醚-改性聚丙烯酸酯添加剂改性的红色OEM底色漆, 在右边的底漆涂层上显示出更好的润湿

Figure 4: The red OEM basecoat shows a much better wetting onto the primer surfacer coating on the right-hand side, modified with the branched polyether-modified polyacrylate additive, compared to the control panel



图5: 以二氧化硅为载体的枝化改性聚丙烯酸酯, 100%固体添加剂的「抗雾」效果

Figure 5: "Anti-fogging" effect obtained with the branched modified polyacrylate applied as 100% solid additive on a silica carrier

里, 着色的底色漆 (红色) 被应用到涂覆有标准底漆和涂覆有改性底漆的两个CE面板 (图4右边: 左面板: 标准和右面板: 改性底漆)。通过静电喷涂 (ESTA), 红色OEM底色漆的厚度已从面板顶端的0 μm 增加到面板底端的25 μm。

在低膜厚区域, 与没有添加剂的对照面板相比, 涂覆有改性底漆的面板上, 红色水性OEM底色漆, 显示出更好的润湿和铺展性。

In another water-borne OEM primer based on a polyester-melamine resin, excellent levelling results with the branched polyacrylate additive were obtained with both, horizontal and vertical electrostatic spray applications (ESTA) on a cathodic electro-deposition coated panel (CED panel). The outstanding performance of the branched polyacrylate additive in comparison to a standard polyacrylate levelling agent is shown in Figure 3.

With the standard polyacrylate for water-borne formulations, a slight decrease of the surface energy of the cured coating by 2.2 mN/m to 41.3 mN/m with respect to control has been observed within that formulation. In contrast, an increase of the surface energy of the cured coating by 18.1 mN/m to 61.0 mN/m was obtained by the use of 0.2% wt of the hydrophilic additive. A high surface energy contributes to a better wetting of the primer layer by a water-borne basecoat. Here, a pigmented basecoat (red) has been applied onto both CED panels coated with a standard primer and with the modified primer respectively (Figure 4 righthand side: left panel: standard and right panel: mod. primer). The thickness of the red OEM base coat has been increased from 0 μm on the top end to 25 μm on the bottom end of the panel by electrostatic spray application (ESTA).

The panel coated with the modified primer exhibits a much better wetting and spreading with the red water-borne OEM basecoat as compared to the control panel without additive already at low film thicknesses.

Because of the branched polymer structure, it is possible to obtain 100% solid, flowable surface additives with this technology. In addition, for powder coating applications a branched modified polyacrylate on a silica carrier is available, which was used in a hydroxylated alkyl amide-cured (HAA) polyester powder coating (Figure 5). Again, a very good levelling performance was observed with the branched modified polyacrylate. Moreover, due to the induced high surface energy, the modified powder coating exhibits an "anti-fogging" effect in humid conditions. Compared to the standard coating, small water drops do not just condensate on the panel's surface, but spread immediately. Therefore, the modified powder coating panel (Figure 5: left hand side) shows a clear, non-foggy appearance.

The hydrophilic effect has been proven on the HAA/ polyester powder coating panels by the application of a water-borne blue paint, as well. Again, in contrast to the standard, excellent levelling and wetting of the modified panel is observed (Figure 6).

The concept of branched, tailor-made polymer structures is applicable to wetting and dispersing agents, as well. Again, a sophisticated polymerisation technology and unique

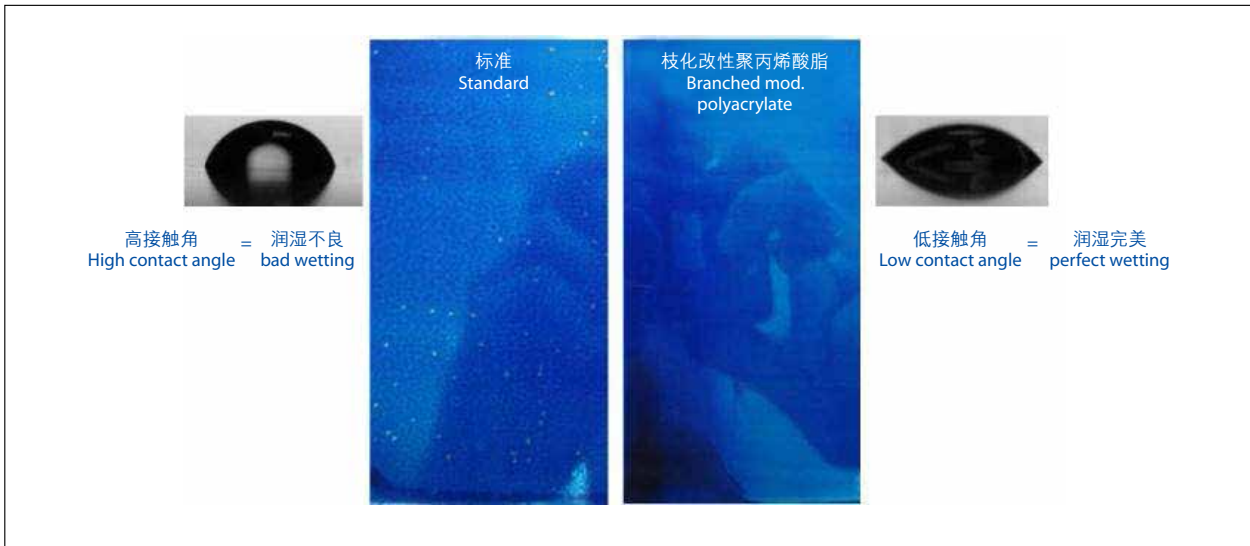


图6：水性蓝色涂料，改性HAA/聚酯粉末涂层面板出色的流平和润湿性  
Figure 6: Excellent leveling and wetting of the modified HAA/polyester powder coating panel a water-borne blue paint

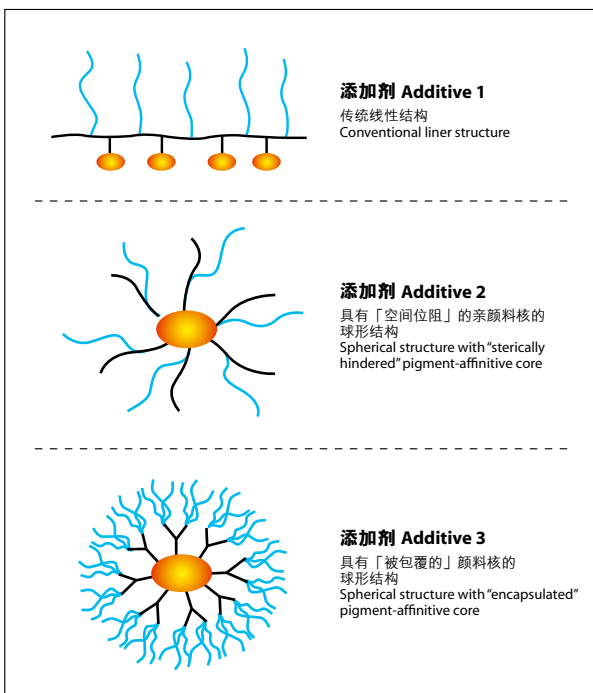


图7：作为润湿和分散剂，两代枝化、球状共聚物和传统线性梳型共聚物进行比较  
Figure 7: As wetting and dispersing agents, two generations of branched, spherical copolymers are compared to a conventional linear comb copolymer

由于枝化聚合物结构，可通过这项技术获得100%固体份的、可流动的表面添加剂。另外，对于粉末涂料的应用，以二氧化硅为载体的枝化改性聚丙烯酸酯是可获得的，其被用在羟基烷基酰胺固化（HAA）聚酯粉末涂料中（图5）。再一次观察到枝化改性聚丙烯酸酯有非常好的流平性能。此外，由于涂层的高表面能，改性粉末涂层显示出在潮湿条件下的「抗雾」效果。相较于标准的涂料，小水滴没有在面板的表

building blocks are required for the manufacture of such structured polymers. On the following pages, a comparison of a conventional linear wetting and dispersing additive 1 with two generations of branched, spherical copolymers, additive 2 and additive 3, is exercised. The additive structures 2 and 3 will be referred to in the text as core/shell copolymers, as well (Figure 7).

There is a variety of wetting and dispersing additives available on the market, all of them are designed for special applications and requirements. In general, a wetting and dispersing agent is constructed as a polymer that exhibits one or more pigment-affinitive groups (red ellipses - usually containing amino groups - in Figure 8) and one or more resin-compatible polymer chains (blue lines in Figure 8) attached to the polymer backbone (black line in Figure 8).

According to the theory of electrostatic repulsion and steric stabilisation of pigment primary particles, we assume that the resin-compatible polymer chains are responsible for the solubility of the copolymer in the formulation and help in wetting the pigment particle. The pigment-affinitive groups of the copolymer are expected to strongly adsorb onto the pigments surface by electrostatic forces, hydrogen bonding or nonpolar van-der-Waals interactions. The molecular composition of the copolymer has to be carefully designed to obtain wetting and dispersing agents allowing fast wetting of the pigment agglomerates, strong viscosity reduction during grinding and an outstanding stabilisation of the primary particles in the pigment concentrate, slurry or paste.

Since the molecular structure of the copolymer has large influences on the performance as a wetting and dispersing agent, there are strong effects of the copolymer shape on the physical properties to be observed, as well. As depicted in Figure 8, a copolymer with a spherical shape, composed of a hyperbranched pigment-affinitive core and polymer sidechains, is available in solvent-free, flowable delivery form compared to a conventional linear comb copolymer of comparable molecular size.

Moreover, branched, spherical copolymers exhibit a remarkable solubility and compatibility in highly polar formulations, as well as in medium and non-polar formulations, as shown in Figure 9. The applicability of

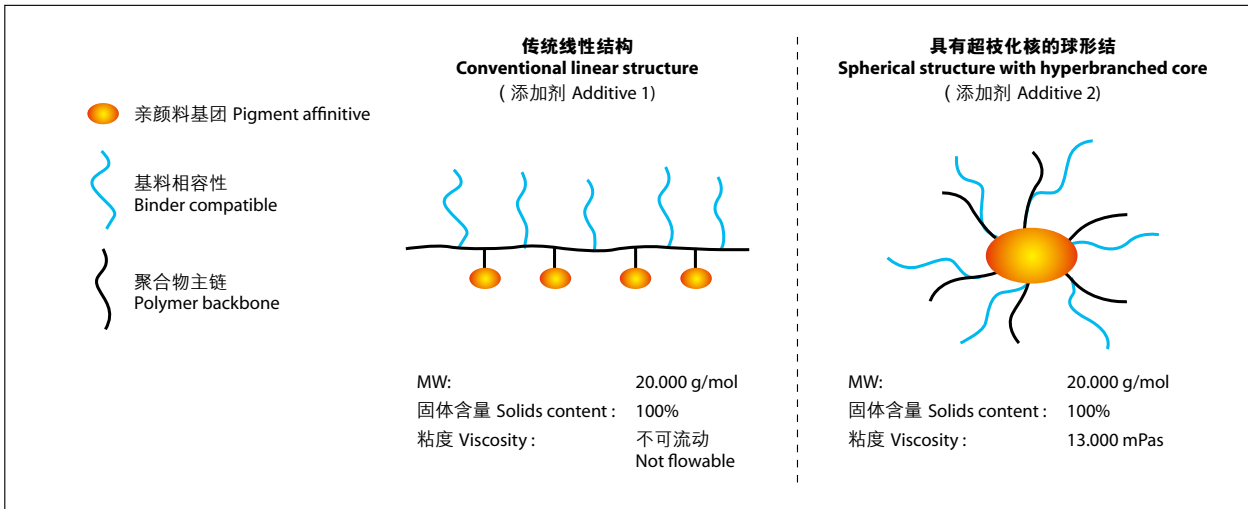


图8：传统的润湿和分散剂与枝化共聚物的物理性质的比较  
Figure 8: Physical properties of conventional wetting and dispersing agent in comparison to a branched copolymer

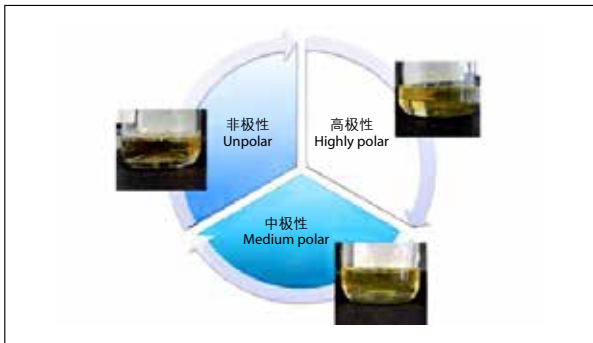


图9：枝化、球状共聚物具有在广泛而显著的相容性  
Figure 9: Branched, spherical copolymers possess a remarkable compatibility in a broad range of formulations

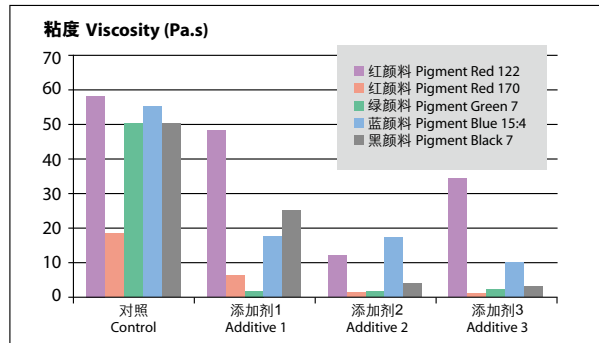


图10：润湿和分散剂聚合物结构在降低粘度方面的比较  
Figure 10: Comparison of wetting and dispersing agent polymer structures in terms of viscosity reduction

面凝结，而是立即铺展扩散了。因此，改性粉末涂料面板（图5左图）显示出清晰、无雾的外观。

同样地，通过水性蓝色颜料的应用，再一次证明在HAA/聚酯粉末涂层上亲水性作用。与标准的对比，观察到改性的样板上出色的流平与润湿性（图6）。

枝化、定制化的聚合物结构的概念同样适用于润湿和分散剂。同时，结构性的聚合物的制造需要复杂的聚合技术和独特的构建模块。接下来的页面，我们将进行比较：传统线性润湿分散添加剂1，以及两代枝化、球状共聚物添加剂2和添加剂3的比较。同样地，在文本中添加剂结构2和3将被称为核/壳共聚物（图7）。

市场上存在多种润湿和分散剂，它们都是为了特殊的应用和要求而设计的。在一般情况下，润湿和分散剂被设计成一个表现出一种或多种亲颜料基团（红色椭圆-通常含有氨基-图8）的聚合物，以及一种或多种连接到聚合物主链（图8中的黑线）的树脂相容的聚合物链（图8中的蓝线）。

根据静电排斥和颜料原始粒子的空间稳定理论，我们假设与树脂相容的聚合物链符合基料中的共聚物的溶解性并帮助润湿颜料颗粒。通过电力、氢键或非极性的范德华

branched, spherically structured wetting and dispersing agents has been investigated for a wide range of pigments from inorganic particles to organic pigments and carbon black, as well. The performance in terms of viscosity reduction of grinds of several organic pigments and a carbon black in a universal grinding resin is depicted in Figure 10. The viscosity was measured at a shear rate of 1/s using cone/plate geometry equipment (25mm, 1° at 23°C) 24h after grinding. The wetting and dispersing additives 2 and 3 with branched, spherical polymer structure generate a significantly greater viscosity reduction with the chosen organic pigments compared to the linear additive structure 1.

Usually, the application of an aminofunctional polymer in a reactive resin system suffers from a number of technical problems such as lower storage stability in epoxy resins, shorter pot life in polyurethane formulations, longer curing times in UP resins or decreased cross linking in acid-catalysed stoving systems. However, branched, spherical polymer structures - such as additive 2 and additive 3 - can be applied successfully in reactive formulations (Figure 11).

An additive of structure type 3, as it is shown in Figure 12, with its branched amino-functional core and a highly branched sphere of resin-compatible polymer chains, is tailor-made for the use in reactive formulations. A comparison of the additive structures 1, 2 and 3 in a reactive

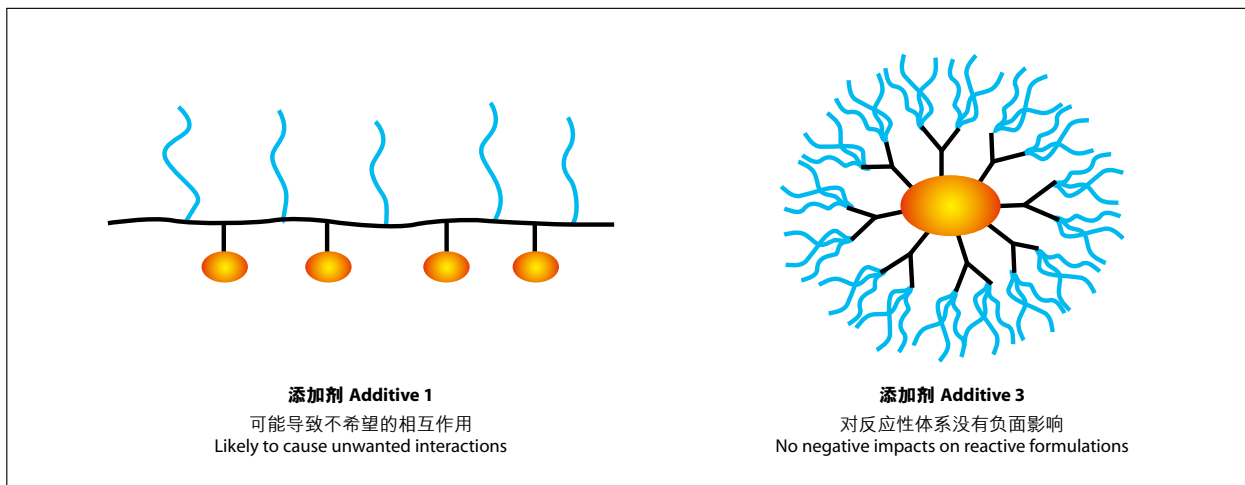


图11: 枝化、球状添加剂3被设计为在反应性体系中应用, 并不对成膜物的适用期、贮存稳定性、固化时间和交联产生不利影响  
 Figure 11: The branched, spherical additive 3 is designed for the application in reactive formulations without negative impacts on pot life, storage stability, curing time and cross-linking

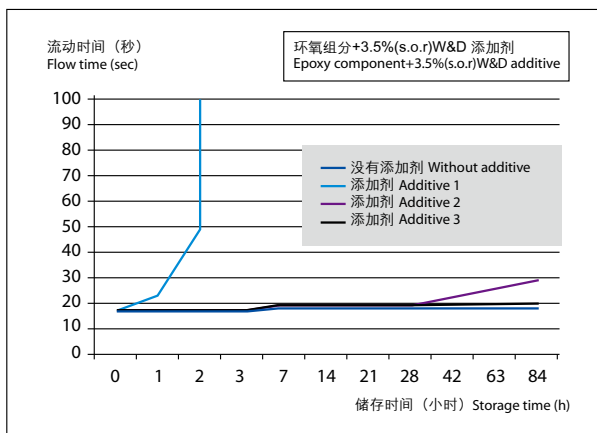


图12: 混合氨基功能性添加剂的环氧组分的贮存稳定性  
 Figure 12: Storage stability of epoxy component mixed with amino functional additives

力的相互作用, 共聚物的亲颜料基团会强烈地吸附在颜料表面上。必须仔细设计该共聚物的分子组成, 以获得对颜料附聚体的快速润湿, 强烈降低研磨粘度, 以及对各种颜料浓缩浆中原始粒子的具有突出稳定性的润湿分散剂。

既然共聚物的分子结构对作为润湿和分散剂的性能具有巨大的影响, 所以也会观察到共聚物的形状对物理性质存在强烈的影响效果。如图8中所描绘的, 相对于同样分子大小的一个传统的线性梳状共聚物, 含亲颜料核的超枝化侧链的、具有球状的共聚物可得到无溶剂的、可流动的供货形式。

此外, 该枝化、球状的共聚物在高极性体系中, 以及在中极性和非极性体系中, 都表现出显著的溶解性和相容性, 如图9所示。从无机颜料到有机颜料以及碳黑, 该枝化、球状结构的润湿和分散剂有广泛适用性。在通用的研磨树脂中, 几种有机颜料和一种碳黑颜料的研磨在降低粘度方面的表现如图10所示。在研磨后储存24小时, 以1/s 的剪切速率, 使用锥/板粘度计 (25mm, 1° 在23° C) 对粘度进行测量。相

system is shown in Figure 12. In that experiment, the storage stability of an epoxy base component modified with 3.5%wt solid on resin of amino-functional wetting and dispersing additives is investigated. The addition of an additive with structure type 1 into the epoxy base component results in a strong increase in flow time within hours and gelling of the system occurs, eventually. The exposed amino groups in additives of structure type 1 and their catalytic activity towards epoxy hardening can explain the low storage stability of the mixture with the epoxy base component in Figure 12. In contrast, addition of an additive of structure type 2 gave good storage stability of the epoxy-base compound. However, the viscosity did start to increase after a storage period of six weeks. A stable viscosity over the entire storage period of twelve weeks was only achieved with the usage of a structure type 3 additive.

The performance of branched, spherical additives in reactive formulations was evaluated in other examples, as well. Figure 12 shows the influences of the three additive structures on the pot life in the case of a 2-pack polyurethane system (left hand side) and their performance with pigment green 7 in the same formulation (right hand side). Compared to a formulation with no additives (dark blue graph) and in presence of a reactive aliphatic-aromatic curing agent, the pot life was considerably shortened with an additive of structure type 1 (light blue graph) and at least slightly shortened with structure type 2 (violet graph). Structure type 3 (black graph) did not significantly shorten the pot life compared to the formulation without additive.

This remarkable behaviour can be attributed to the exposed amino functionalities in the additive of structure type 1 that are assumed to catalyse the formation of polyurethanes and thus shorten the pot life. In contrast, sterically hindered amino groups, as they are realised in additive type 2, are much less subjected to catalyse the urethane formation. Consequently, the amino core shielded by branched resin-compatible polymer chains in additive 3 is almost not negatively influencing the pot life of the formulation.

In Figure 13, the transparency of the 2-pack polyurethane system coloured with the pigment concentrate based on pigment green 7 is depicted. The additives of structure types 2 and 3 produce an outstanding transparency

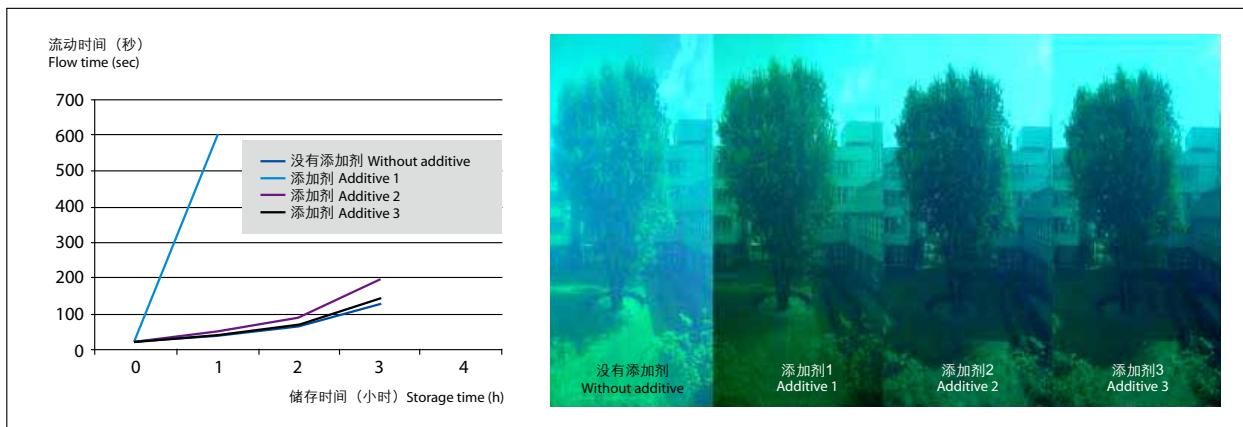


图13：不同的添加剂结构对用颜料绿7着色的聚氨酯涂层的透明度的影响

Figure 13: Influence of the different additive structure types on the transparency of a polyurethane coating pigmented with pigment green 7

较于线性添加剂结构1，用选择的有机颜料，枝化、球状聚合物结构的润湿和分散剂2和3产生更显著的降粘效果。

通常，含氨基官能团的聚合物在反应性树脂体系中的应用会遇到许多技术问题，如在环氧树脂中贮存稳定性较差，在聚氨酯体系中适用期较短，在UP树脂中固化时间较长，或在酸-催化的烘干系统中交联密度减少。然而，枝化、球状的聚合物结构（诸如添加剂2和添加剂3）可以成功在反应性体系中应用（图11）。

结构3的添加剂，如图12中所示，它含有枝化氨基官能团核心和与树脂相容的高度枝化球形聚合物，是专为反应性体系而定制的。添加剂1、2和3在反应体系中的应用比较列在图12中。

在该实验中，环氧树脂中加3.5%（对固体树脂计）含氨基官能团的润湿分散剂的，我们对它的贮存稳定性进行了研究。在环氧树脂中添加结构1的添加物，导致在数小时内流动时间的强劲增长，以及最终体系的胶化。因为结构1暴露出的氨基官能团，催化了环氧树脂固化，如图13中所示，在环氧体系中表现出低贮存稳定性。与此相反，结构2的添加给予环氧体系良好的贮存稳定性。然而，粘度的确在六周后开始增长。在整个12周的贮存中，只有使用结构3的添加剂才能获得稳定的粘度。

枝化、球状添加剂在反应性体系中的性能表现同样在其它例子中被评估。图14显示，在双组分聚氨酯体系（左侧），三个添加剂结构对成膜物适用期的影响，以及在相同的体系中使用绿颜料7时它们的性能（右侧）。相较于没有添加剂（深蓝色曲线）、并有脂肪族或芳族固化剂的体系中，成膜物的适用期在使用结构1的添加剂后（浅蓝色曲线图）明显缩短，在使用结构2（紫色图表）后也至少有轻微的缩短。与不含添加剂的体系相比，结构3（黑色曲线）没有明显地缩短适用期。

这一显著的现象可以归因于在结构1的添加剂中暴露的氨基官能团，它催化了聚氨酯的交联反应，从而缩短适用期。与此相反，由于位阻氨基在类型2添加剂中被实现，它们非常少地催化氨基甲酸酯形成。而在添加剂3中，枝化的相容链屏蔽了氨基核，对体系的适用期几乎没有负面的影响。

in conjunction with a bluish/greenish colour shade, which is yet another indicator of very effective pigment stabilisation. In this case, structure type 1 with a more yellowish/greenish colour shade gives a little bit weaker results compared to the other two dispersing additives. The results shown for the example of the 2-pack polyurethane system were also confirmed in the tests with a 2-pack epoxy and an acid-catalysed stoving system and can be considered essentially representative for the performance of branched, spherical copolymers.

As an example for the application of a branched, spherical wetting and dispersing agent with an inorganic pigment, additive 3 was applied in a reactive epoxy resin filled with aluminium trihydroxide (ATH) as flame retardant. Compared to the initial amount of 37.5%wt of ATH, the use of additive 3 allowed increasing the flame retardant concentration by 40% to 52.5%wt at constant resin viscosity (Figure 14). That result highlights the very broad field of application for branched, spherical wetting and dispersing agents. These core/shell copolymers are effective with a large array of organic pigments and inorganic fillers, as well. Moreover, these flowable, solvent-free additives show outstanding performance even in reactive systems without generating undesired side-effects such as shorter pot life, gelling, longer curing reactions or decreased cross-linking density.

## Conclusion

The newly developed branched polymer structures require sophisticated manufacturing methods and special raw materials. However, branched polymer structures offer great advantages compared to conventional linear copolymers. For instance, a polyether-modified polyacrylate levelling agent has been introduced that exhibits very good compatibility and outstanding efficiency. Moreover, the hydrophilic additive increases the surface energy of a cured coating and therefore improves the wettability and recoatability of a coating or paint. The concept of branched copolymer structures has been transported to wetting and dispersing applications, as well. Innovative dispersing additives based on branched, spherical core/shell structures provide very effective stabilisation of different pigment types without causing any undesired interactions with reactive formulations. These structures allow for solvent-free, flowable wetting and dispersing agents with remarkable performance and very wide compatibility in polar, medium polar and non-polar systems.

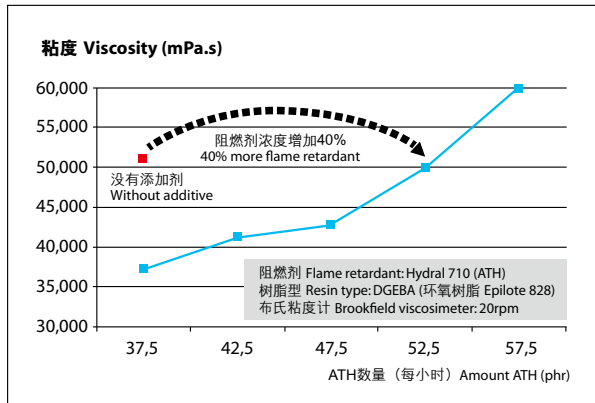


图14：添加剂3的使用允许在恒定的树脂粘度，增加40%的阻燃剂浓度  
 Figure 14: The use of additive 3 allowed increasing the flame retardant concentration by 40% at constant resin viscosity

图13显示不同的添加剂结构对用颜料绿7着色的聚氨酯涂层的透明度的影响。图13的右侧，为绿颜料7的浓缩颜料浆着色的聚氨酯体系的透明性。展现蓝色/绿色的色调，结构2和3的添加剂产生出色的透明度，这是非常有效的颜料稳定性的另一个指标。在这种情况下，相比其它两种分散剂，具有更多黄色/绿色色调的结构1给出的结果较差。双组分聚氨酯体系的结果也在双组分环氧和酸催化烘干体系中被证实，而且可以认为是枝化、球状的共聚物的特性。

作为枝化、球状的润湿分散剂与无机颜料的应用例子，添加剂3应用在填充有作为阻燃剂的氢氧化铝（ATH）的反应性的环氧树脂上。相比起ATH 37.5%wt的初始量，添加剂3的使用允许在恒定的树脂粘度下，把阻燃剂浓度增加40~52.5%wt（图14）。该结果突出了枝化、球状的润湿分散剂非常广泛的应用范围。这些核/壳共聚物对于大部分有机颜料和无机填料同样有效。而且，这些可流动的、无溶剂的添加剂显示出优异的性能，甚至在反应体系中不会产生副作用，如更短的适用期、胶化、延长固化反应或降低交联密度等。

## 结论

新开发的枝化聚合物结构需要精良的制造方法和特殊的原材料。然而，相比传统的线性共聚物，枝化聚合物的结构提供了更大的优势。例如，已经介绍的聚醚-改性的聚丙烯酸酯流平剂，表现出非常好的相容性和出色的效率。此外，亲水性添加剂增加了固化涂层的表面能并因此提高了涂层的可润湿性和可再涂性。枝化共聚物结构的概念已经被转化到润湿和分散的应用中。基于枝化、球状的核/壳结构的创新分散剂提供了不同颜料类型的非常有效的稳定性，而不会引起与反应性基料的任何不希望的相互作用。在极性、中极性和非极性体系中，这些结构赋予了无溶剂、可流动的润湿分散剂卓越的性能以及非常广泛的相容性。



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