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High volume, high quality – Thanks to HTS

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What works in other sectors can work in coatings development too. It has been almost a decade since the first paint maker deployed high-throughput screening to boost the efficiency of its coatings testing. A paint maker, a raw materials producer and a machine builder share their experiences with this technology.

Countless test and measurement procedures are available for testing the appearance of a painted surface. Looks aside, the physical and chemical properties of a coating are crucial quality indicators and purchasing criteria. There have been no major changes in the procedure for developing coatings in recent decades. So instead of endlessly re-inventing the wheel, it might be instructive to look outside the box. Given that the key to success lies in learning from one another, there is no

reason why processes that have brought results in other industries cannot serve as a template for ringing one's own changes.

Originally employed in biotechnology and pharmaceutical research, high-throughput screening (HTS) has changed the face of research into coating raw materials development. It is now firmly entrenched in the pharmaceutical industry. At the turn of the millennium, it dawned on raw material producers that the technique could theoretically be applied to the development of paints and coatings. Increasingly complex paint specifications, shorter times to market, the need for efficient development processes and ultimately REACH meant that new ways had to be found of developing and optimising coating formulations and testing new or alternative raw materials. About ten years ago, the first company set out to emulate the example of pharmaceutical research and deploy high-throughput screening in paint and coatings development.

Initial scepticism is waning

High-throughput technology is used by between 25 and 30 plants in the paint and coatings industry, estimates *Thomas Brinz* of Bosch Packaging Technology. Bosch itself has installed 20 such plants, he adds. Half of them are fully automated. Semi-automated plants for spray application tend to be more popular with SMEs. "The market was initially very sceptical about the suitability of high-throughput technology for coatings development," recalls Brinz. Since then, though, HTS has become increasingly accepted and is being deployed on a much wider scale. "The competitive advantages to be gained from it are encouraging more companies to follow suit and embrace the technology," he continues, adding that automated colour evaluation is 16 times more reproducible than its manual counterpart. "Once people see these benefits, then HTS becomes attractive and people want to implement it. This trend is what you see now more and more. People see HTS at their supplier and at their competitor or they hear about it at conferences, so they feel that they must have it too. I think since last year especially this 'must have' attitude is the case," says *Sander van Loon* of VLCI, a Dutch company that provides HTS services for various industries.

Best for liquid paints

The most common use of high-throughput screening in paints and coatings is in liquid coatings development, according to Brinz. The first paint maker to apply it for this purpose was Stuttgart-based Wörlag, which has been operating a fully automated high-throughput plant in its combinatorial laboratory since 2006. The HTS plant there consists of four modules: formulation, application, handling and drying. "Everything is automated," says *Sabine Ansoerge*, head of the laboratory at Wörlag, "from weighing out the raw materials to the finished test sample". The plant is specifically designed for liquid coatings. "We can prepare and coat any heat-drying formulation, whether 1K or 2K," says Ansoerge, who sees the laboratory as an in-house service provider for coatings development at Wörlag. At BASF, too, researchers and paint experts developed a plant with Bosch that has been up

and running in Ludwigshafen in 2007. It started conducting tests on behalf of BASF teams outside the Europe region in 2012. In-house, BASF uses the plant for screening coating formulations and developing and testing raw materials in various coating systems. But the company also allows external partners, such as paints manufacturers, to conduct their own tests.

Ansoerge believes that HTS has two significant advantages. The first is its efficiency. The technology can automatically create a large number of different mixes in a short period of time. Given that the average liquid coating consists of anywhere from ten to 15 components, finding the right formulation of binders, pigments and additives takes time, especially in view of the increasing requirements on adhesion, colour, effect and flow. "We use high-throughput technology to do routine laboratory work, and that frees up developers to concentrate on other projects," says Ansoerge. The second advantage, says the laboratory head, is the documentation work, which has become even more accurate thanks to the plant. "Because each and every parameter is logged, we can analyse in greater precision the extent to which a specific modification has affected a coating."

Time and material savings

Growing complexity is not just restricted to the formulations, painting techniques are also becoming more complicated. The days when the base coat was just applied, dried and then sprayed with a clear coat are long gone. Premium colours are now applied wet in wet onto the metal: two coats, one drying process. In addition to that process, the Wörlag plant can simulate what is known as the integrated paint process (IPP), in which the primer is still wet when the colour-defining base coat is applied. The fully automated plant runs overnight. Over the course of a 17-hour shift, the plant applies a two-coat finish to seventy samples, i.e. it creates 140 formulations, which are specified by bar code. The system collates the mixing data so that the developers can assess the quality of the results. Although the plant always appears to be repeating the same task over and over again, the reality is quite different. Each and every formulation sprayed onto a substrate is different, as the hunt continues for the perfect mix. The savings on time and materials are enormous. To prepare one mixture by hand requires between half and one kilogram of liquid paint. The HTS plant requires just 80 ml. This means that up to ten formulations can be created in a day. Clearly, a human has no chance against the combinatorial laboratory in the development phase. Will HTS cost a lot of jobs? "Maybe there is some fear around that jobs will be cut because of HTS. But we keep explaining that this is not the case and that HTS is thus an extension of your lab. And by showing lots of examples of what you can do with HTS, this fear mostly disappears," says van Loon. "You can focus on the data instead of making samples. So one can go from a trial and error way of working towards a more fundamental approach. And that is what HTS provides, besides speeding up your R&D of course," he continues. The HTS plant at BASF in Ludwigshafen is just as efficient. It speeds up the testing of pigments, resins, dispersions and additives in coating formulations under practical

conditions, and can handle all kinds of coating systems, from waterborne or solventborne to 100-percent solids. First, the HTS plant automatically blends the liquid and powdered starting materials in the right proportions to yield the paint formulation. The pH and viscosity are then adjusted before the formulation is applied by knife coating or pneumatic spraying to the substrates, which may be sheet metal, glass or wood. Curing takes place in a special UV module and two ovens. Finally, the HTS plant characterizes the coating by determining such basic properties as colour, gloss and layer thickness, chemical and scratch resistance, as well as surface defects and levelling properties. This all happens in record time: screening, including preparation and testing of up to 100 formulations, usually take no longer than a couple of days. This provides great scope for varying all kinds of parameters in formulation and application to test their influence on the coating properties. For BASF, the plant's advantages include rapid production and application testing of a large number of comparable coating samples under realistic conditions with simultaneous optimization of several coating properties.

HTS gives a competitive edge

High-throughput technology ups the pace considerably because it enables developers to adopt a totally a new approach to their work by facilitating the application of experimental design to coatings formulation. "This means we are not limited to testing just two or three factors," says *Nicole Hörner* from the coating maker's development department. In fact, the interactions of up to seven factors can be examined. If, for example, she wants to check the influence of film thickness, drying times, coating conditions, and flash-off times on the surface finish, she simply arranges for 50 panels to be coated.

This cannot be done manually, as the coating processes simply take up too much time and the variations are too complex. "We now do tests that we would never have tried before because we simply didn't have the capacity. That's definitely given us a competitive edge," says Hörner. "Most importantly, because you can examine several factors simultaneously, you gain a different perspective of what is going on – for example, the interactions during application or the relationship between raw materials and concentration create a very different picture," she adds. "As well as that, concentration gradients for comparing additives are now much easier to compile for whenever I need to find out how much I need of a particular additive to meet a coating specification."

High capital costs a deterrent for paint makers

For all its benefits, high-throughput technology does have its limitations. "In the end, the machine is still only a dumb machine," says Ansorge. This means that it must receive the right input. Her colleagues who operate the plant, as well as other colleagues wanting to use it, must keep training to acquire the necessary further skills. She also believes that developers need to change their mindset. According to BASF, "the limitations of an HTS plant are partly physico-chemical effects, e.g. pot lives too short, dispersion times too long, long ripening periods before measurements, and partly organizational shortcomings, e.g. ever-changing paint grades, unstable ingredients, inefficient raw materials procurement and over-extended maintenance intervals. A wealth of experience with the plant has been gained over recent years by the researchers and paint specialists at BASF. By identifying and eliminating these effects and shortcomings ahead of tests, the BASF team keeps improving its HTS performance.

To get the results you need, says Ansorge, it is best to opt for a customized plant. She describes the time spent designing the plant as being very protracted. "Some of the plant specifications ran to over 50 pages. Trying to quickly get to grips with everything that the machine maker wanted proved a bit of a challenge," says adds. Not only that, but making changes or retrofits to the plant was long-winded, too. So, she recommends making provision at the design stage for future changes in test specifications. And she wishes the plant were a bit more versatile. All these different factors are reflected in the purchase price. Which is why paint makers are still a little bit hesitant, she suspects. SMEs, especially, find that negotiating this terrain is fraught with difficulty. "The financial aspect, the need to have a certain willingness to take risks, and reservations about handing over knowledge to a machine are making paint makers cautious," says Brinz. That the machine could steal jobs is not a theory he subscribes to. "Yes, working with the machine is more demanding, but



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it also opens up new vistas in coatings development." Besides, many coating methods and application tests are beyond the HTS plant and are still performed by hand in the traditional way.

BASF, too, expects HTS technology to increasingly spread throughout industry: "The advantages are so obvious that it will eventually be adopted by SMEs. Of course, the initial outlay on plant acquisition and team training is not insignificant." But, given the complexity of the HTS coating plant, the costs are reasonable. More essential, believes BASF, is to have an experienced operator team that maintains close contacts with customers and in-house experts. "HTS needs a good number of projects to keep it running and to be beneficial for the company. So, bigger companies have more or larger projects and can afford to buy such equipment", explains van Loon. Roughly 20 % of VCI's customers are from the coatings industry, both raw material suppliers and formulators. Although, in practice, mostly big and medium sized companies are using HTS, according to van Loon. "At first, we started HTS services for the coating formulator, but we found that there was much more potential and willingness in collaboration in the personal care field. But since this year, the interest from the coating industry grows again", he continues. For van Loon it is difficult to say to what extent the use of HTS will spread in the coatings industry. "I think that most big companies will have at least one HTS workflow. The trend these days is sharing facilities and knowledge, so maybe the bigger part from small to multinational companies will use HTS services on project basis like we offer. For own and specific R&D, medium sized companies might also buy their own HTS plants".

Intensive maintenance and cleaning

Any plant that is regularly allowed to run overnight requires a lot of care. "Coatings are sticky. We clean the machine after every run in order to prevent errors in dispensing or application," says Ansorge. This means that lab staff spend up to one hour a day on cleaning, with a major cleanup scheduled once a week. HTS cannot be used to test coatings during maintenance, which is carried out quarterly and takes three to four days. Add in a service and the plant is out of action for about 2.5 weeks every six months.

Theoretically endless application areas

The plant in Stuttgart can only simulate pneumatic application. It is not designed to replicate the electrostatic application techniques commonly employed by customers in the automotive industry. "It's not possible to do a one-off pass on a sample whose different paint layers have different drying temperatures. Nor can the plant adjust or measure rheology. Yet, over time, work-arounds for these limitations are eventually found. Overall, the plant has proved very enriching for our development work," says Hörner in conclusion. Ansorge shares the view that the benefits predominate: "High-throughput screening is making inroads in the paint industry and it's on an upward trajectory. The progress of HTS is being followed with interest. All it takes is for two or three other companies to follow suit and others will climb aboard, because no-one wants to be left behind in the competition stakes." But there may be another reason for the



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competitive advantage. Not every industrial company using the technology wants to advertise that fact. It is almost as if they want to keep competitors in the dark about advantages that might make them wiser.

Market expansion expected, other industries to follow

Brinz believes that the reason why HTS technology has established itself in liquid paints only is that: "New technologies always succeed first in large areas and segments. It takes a while for niche areas to catch up." Theoretically, the scope for use is not limited to any one specific medium. A plant for the powder coatings segment would be possible, but would be more expensive than its liquid coatings counterpart, explains Brinz. The next major area to embrace high-throughput technology will be the close relative of the coatings industry: adhesives. "The first adhesives projects are already up and running. There have also been inquiries from Europe and the USA about coatings and adhesives. High-throughput technology will spread throughout the market. Brinz is certain of that. ◀