The State of Wire Enamel Research

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Introduction

Wire enamels are used for coating copper and aluminium wires. The enamelled wires are then used in electrical insulating systems, e.g. in electric motors, generators and transformers.

The enamelled wires require certain material, processing and system characteristics for their respective applications. They are reflecting the enamel applied, the procedure of the coating, the blank wire and the copper quality.

The Altana Electrical Insulation group is a manufacturer of wire enamels. Its goal is to produce appropriate products for the needs of the market. That applies in terms of both quality and quantity.

Structure and processing of wire enamels

Wire enamels are solutions of polymers, e.g. polyesters, polyester imides, polyamide imides, polyurethanes, in solvents or in solvent blends. They also contain catalysts and other additives.

The mechanism of film formation on a copper wire will be described with the example of a polyester imide enamel. Apart from the chemical basis of the polymer, this process is decisive for the quality of the subsequent copper wire, and in many cases it is also the route for product improvements.

A polyester imide wire enamel comprises a solution of a polyester imide resin in a solvent blend. The enamel also contains a curing catalyst and, if necessary, colouring agents, additives, etc. Each enamel is characterised by its polymer content and its viscosity. High viscosity is obtained if there is a high polymer concentration in the enamel, or the polymer has a high molecular weight. The solvent blend does not have a boiling point, but rather a boiling curve, i.e. the solvent boils in a uniform manner over quite a wide temperature range. This later results in a smooth enamel film.

Following application, the wire is fed with the wet film that has been applied into the curing oven. There the temperature of the enamel rises and its viscosity falls, and at the same time the solvent blend evaporates. The concentration of the polymer in the enamel increases, resulting in higher viscosity. In parallel to this, the polymer begins to cross-link, i.e. the polymer molecules react with one another in the presence of the catalyst, the size of the molecules increases, and the molecular weight and the viscosity also continue to increase. These three effects are attuned within an enamel

in such a way that the wet enamel cures in uniform quantity on the wire, and there are no disturbances of surface quality.

The goal of curing is to evaporate all of the solvent blend, and to cross-link all of the polymer molecules. That gives a strong, uniform, insoluble and unmeltable film. In practice, wires are usually given multiple applications of enamel in order to achieve the desired layer thickness. The first layer adheres to the copper wire, and the subsequent layers to a cured enamel film. Adhesion between the individual layers is optimal, because all layers have the same composition. The goal of the enamel formulation is to ensure the most uniform possible curing process, by means of well attuned solvent composition and an appropriate starting polymer. In principle, curing of all the other wire enamels operates in the same way, e.g. polyester, polyurethane and polyamide imide enamels.

Research into wire enamels

The research activities of Altana Electrical Insulation in wire enamels are based on the chemistry of the products, their processing, and the requirements for the properties of enamelled wires, as well as economic aspects.

One area which is given particular attention by research is the raw materials. There have been changes in various raw material sources in the course of recent years. A number of old established suppliers have given up manufacture of various chemicals in Europe. Suppliers from Asia offered substitutes. Extensive testing programmes were conducted to determine the quality of these raw materials, and their effect on the finished products.

Meta-cresol and para-cresol are available only to a limited extent as the principal solvent for wire enamels, and are correspondingly expensive. Alternative cresolic solvents and cresol-free solvents were examined with respect to their characteristics as a solvent, their availability, and their price. The work involved was very extensive, with particular attention given to the Isosolve area.

The production processes of resins and wire enamels are being improved continuously in order to meet the high quality standard required and to fulfil the economic requirements from customers.

The polymer in the wire enamel determines the characteristics of the subsequent enamelled wire. Despite the standardisation of characteristics by the IEC, there are often additional requirements from customers. Variation in the composition and structure of the polymer permits variation in the desired characteristics. A number of customer-related development projects are running for this purpose.

Apart from these typical R&D activities, there is naturally also explorative research. For example, this includes the use of alternative enamelling processes by customers, alternative curing mechanisms for the resins, and examinations of nano-particles with respect to the properties of copper enamelled wires. The main objectives are improvement in the characteristics of the products and the application processes. Other major research areas are focused on environmental protection and the availability of raw materials.

Organisation of research in the ALTANA Group

ALTANA Electrical Insulation has production and research facilities located around the globe. The acquisitions of recent years have meant that, apart from various sites and a wide range of products, the ALTANA Group has also acquired new research laboratories. This made it urgently necessary to harmonise the products, technologies and research projects.

A natural approach is to organise research activities in such a way as to avoid reduplication of work, and ensure that each project is handled by the partner with the best conditions for that research project. There are local projects aimed at meeting the requirements of the local market in each case, and there are global projects, which are important for the whole of the ALTANA Group. Head of Research is Dr. Ulrich Häring. The research activities are coordinated by the Research Centre at Beck Electrical Insulation in Hamburg.

The role of Deatech s.r.l. in Italy is to make continuous product improvements in the standard product range, e.g. polyesters, polyester imides and bondcoats. This unit has conducted a solvent project in recent years, with enormous accumulation of knowledge about new cresolic solvents. It also works on subjects such as low-VOC lubricants for enamelled wires and new nano-particles, handled by Dr. Giovanna Biondi and Dr. Patrizia Spurio.

Wiedeking GmbH, which has a reputation as a specialist in solder-capable enamelled wires, naturally puts the main emphasis on polyurethanes. The main subjects handled there by Dr. Mühlenbrock and his staff are improvements in thermal stability and reduction of soldering times.

P.D. George in the USA has its main focus, alongside the usual customer-specific activities, on the Isosolve issues and low-cost nano-particles. Dr. Murray also has a research focus on enamelled wires with internal lubricants.

Tongling Siva in China supplies all types of enamelled wires to the rapidly growing market in that region. Our research colleague there, Mr. Ye Lixing, works particularly on subjects that are relevant to the Asian market, e.g. examination of the influence of ageing in tropical climate on the dielectric strength of enamel films.

At Beck India, research is headed by Dr. Jain. It is concentrating on the transition from polyester to polyesterimide, validating the use of local raw materials.

The Research Centre in Hamburg works on enamels for new alternative enamelling processes and alternative curing mechanisms for resins. It is also responsible for issuing and distributing reports and patent administration. The UL activities are based at Beck and at P.D. George. All areas are likewise active in the national and international standardisation bodies. And naturally there is high priority for cooperation with customers, suppliers and enamelling machine manufacturers. This intensive form of cooperation is vital for the continued success of ALTANA Electrical Insulation.

It’s a well-known fact that there are interactions in the electrical machines between the wire enamel film and the impregnating material. As we are developing both product groups on our own, we are turning our attention to this subject in good time, leading to an optimization of the impregnating system.

Prospects

The Group’s strong geographical presence, its product portfolio and its global activities in application engineering, research and development, make the market leader ALTANA Electrical Insulation a high-powered partner for our customers, for raw materials suppliers, and manufacturers of wire enamelling machines. We know we are only successful, if our customers are successful, too. And that’s what also we scientists are working on worldwide.