Dyeing of synthetic fibers in supercritical \( \text{CO}_2 \)

For the first time the works Hagen of the engineering firm Uhde GmbH, Dortmund, have been represented with textile machinery at the ITMA in Milan. The company, up to now mainly working in chemical equipment construction, has gained experiences, which are of great importance for the construction of finishing machines for dyeing in supercritical \( \text{CO}_2 \). Development work was carried out in close cooperation with the German Textile Research Centre North-West, Krefeld.

Dyeing of polyester fibers in supercritical \( \text{CO}_2 \) was presented for the first time at ITMA '91 in Hanover. In the meantime development work has been greatly intensified so that the dyeing of polyester fibers (including microfibers), polyamide fibers, elastane and triacetate has become practicable. For PET and polyamide in particular Ciba-Geigy AG, Basel, has introduced a complete range of colors to the market. First industrial experiences with this technology were gained by the leading sewing yarn manufacturer Amann in a project supported by the German Federal Ministry of Research and Technology, Bonn, for the dyeing of PET yarns.

Recently the DTNW has succeeded in dyeing polyolefin fibers like polypropylene and gel-spun, highly molecular polyethylene, without addition of carriers or by fiber modification, in supercritical \( \text{CO}_2 \), with special, but commercially available dyes; wash and light fastness were good. The color intensity achieved in all shades is comparable to that of polyester.

First preliminary trials have shown that fibers, which had been regarded as undyeable up to now like for example para-aramide, can be dyed with this process. The results with this high-draft material were not yet satisfactory; however. Within the next two years, this problem will be further investigated by the DTNW in another research project.

The DTNW also cooperates with the industry to dye hydrophilic fibers like cotton, viscose and linen in supercritical \( \text{CO}_2 \), and to develop corresponding dye systems where a reactive attachment of the dye to the substrates is aimed for.

**Uhde pilot plant**

For more than fifty years Uhde Hagen has worked in high pressure technology. They produce high pressure equipment and machinery to complete high pressure ranges up to 14,000 bar. High pressure technology is to be found in many applications of high pressure extraction (e.g. in the food industry).

Some time ago Uhde included the construction of plants for supercritical fluids dyeing (SFD) in a future-oriented delivery program, in close cooperation with DTNW, Krefeld. Uhde experiences in high pressure plant construction permit the design of complete pilot and large-scale plants for the industry. A high pressure dyeing plant for the textile finishing industry can thus be designed on the basis of test results or according to specifications of the textile finisher. The textile industry is among the industries with the highest water consumption. Because costs for water and waste water are continually rising, and the legislator lays down increasingly stringent limits for the pollution of waste water, textile finishing methods have to be used in future which will use no or very little water. An example for such a method is the use of supercritical \( \text{CO}_2 \) instead of water for the dyeing of textiles made from synthetic fibers (polyester, acetate, nylon).

Dyeing with supercritical \( \text{CO}_2 \) is carried out analogous to aqueous systems. The dissolving capacity of the supercritical \( \text{CO}_2 \) corresponds to that of solvents with small polarity. As in the case of other material properties, it can be determined by the selection of suitable pressures and temperatures. In contrast to aqueous dyeing, where the dye is transported to the fiber through micelles, from which it has to be released in molecular-dissolved form, the dye in supercritical fluids is transported directly from the molecular disperse solution. Because of the low viscosity of the supercritical fluids it is transported directly from the molecular disperse solution. Because of the low viscosity of the supercritical medium, it is more easily transported into the pores and capillary systems of the fibers and/or fiber bundles. The diffusion coefficients for dissolved molecules, like e.g. dyes, are much higher than in the case of liquids. These two properties render dyeing with supercritical \( \text{CO}_2 \) much more economical.

When dyeing with supercritical \( \text{CO}_2 \), with correctly selected dyestuffs the dye yield is the same as with conventional dyes. Dyeing of blended shades and even black is also possible with SFD. Light-, rubbing- and washing fastness of textiles dyed with SFD are identical with those of an aqueous dyeing. The SFD process is very fiber preserving. Even sensitive polyester tips and nonwovens can be dyed with SFD problem-free. Compared to conventional dye processes, SFD has many advantages to offer. Because no water is needed, there is no waste water. Dyeing times are considerably shorter, because pure dyestuffs are used. A reductive washing off of the textiles is unnecessary, because the dyestuff which is not absorbed is removed with the supercritical \( \text{CO}_2 \). After degassing the dyeing container at the end of the dyeing process, the \( \text{CO}_2 \) has adopted a gaseous state. The dyeing process which is necessary for aqueous dyeings can be omitted. Surplus dyestuff is precipitated and both the dyestuff as well as the \( \text{CO}_2 \) can be reused. Furthermore \( \text{CO}_2 \) is non-toxic, easy to handle and suitable for food.

These plants for supercritical dyeing work with the high pressure extraction technology, which has been used successfully for many years in industry. High pressure plants can be operated safely and without problems, either manually or fully automatically. It goes without saying that in the layout and construction of such plants all rules and regulations are adhered to. Layouts according to all respective national standards are possible.