

Stretching the Limits

Selective Modification of Film Properties through Uniaxial Stretching

MDO (machine direction orientation) can be used for the production of polymer films that have unique properties. By using an optimized machine and control technology, existing MDO applications can be produced much more efficiently and new areas opened up.

The expectations placed on packaging continue to rise. It must provide enhanced product protection, greater convenience and catch the eyes of consumers while offering optimum efficiency and sustainability. Companies producing flexible packaging are responding to these challenges by developing complex, multi-layer composite films and using special raw materials. Whenever this approach reaches its limits, machine direction orientation (MDO) provides new scope for achieving unique film properties.

In the MDO process, blown or cast films are continuously stretched in machine direction. The tube or flat film is directed over several heated rollers to be raised to a stretching temperature which ranges from 60 to 150 °C depending on the type of film material. The heated film is then stretched in the machine direction by means of the difference in the rotational speed of one or two pairs of temperature-controlled rollers. This stretching process reduces the film thickness and selectively changes the morphology of the film material. Stretch ratios vary with the type of material and intended application but are typically in the range of 1:3 to 1:10. To adjust the shrink properties or to ensure dimensional stability, the stretched film is relaxed on downstream annealing rollers by applying tension and heat. Finally, it is cooled to near ambient temperature on chill rollers.

MDO installations can be used in-line with blown or cast film equipment or off-line as autonomous units. The off-line system, consisting of unwinding, stretching and rewinding, offers maximum independence of the upstream extrusion process. By contrast, the in-line solution has a



lower capital requirement and lower operating costs, and is highly efficient.

Figure 1 shows a schematic layout of a blown film installation with an in-line MDO unit. The flattened tube is directed into the MDO via an optional web center guide. Unwanted air is best prevented from being drawn into the tube by making slits in one or two sides of its folded edges before it enters the MDO unit. The

film exits the MDO and enters an edge-trimming station before being fed to the winding unit.

Specific Modification of Film Properties

The high stretch ratios significantly alter the film's morphology, with both the amorphous and crystalline structures being stretched in machine direction. Fur-

ther, alignment of the molecular structure raises the density and, in the case of semi-crystalline polymers, the crystallinity. These morphological changes in turn exert a significant impact on the film's macroscopic properties. As the degree of stretching increases, the mechanical properties (such as rigidity, tensile, puncture and tear strengths) increase significantly, especially in the stretching direction. Stretching also benefits the film's optical and barrier properties.

This is illustrated by comparing a high-barrier film which has been stretched by a factor of 1:3.2 to an end thickness of 40 µm with a corresponding non-stretched, directly extruded 40 µm film. To ensure comparability, the two films have the same structure and are made from identical materials. The stiffness of both films in machine and transverse directions (MD and TD) is evaluated in **Figure 2**. The stretched film exhibits much higher characteristic values, both in the MD and the TD. Furthermore, the optical characteristics have also benefited from the stretching (**Fig. 3**). Finally, the MDO film presents a 30 % improved oxygen barrier (**Fig. 4**).

Neck-In Effect

Stretching the film in the machine direction does not only lower film thickness; its width is also reduced as a result of neck-in. The outcome is a thickness profile with very thick areas on both sides of the web. To ensure trouble-free downstream processing of the stretched film, the neck-in area must be trimmed on both sides be-

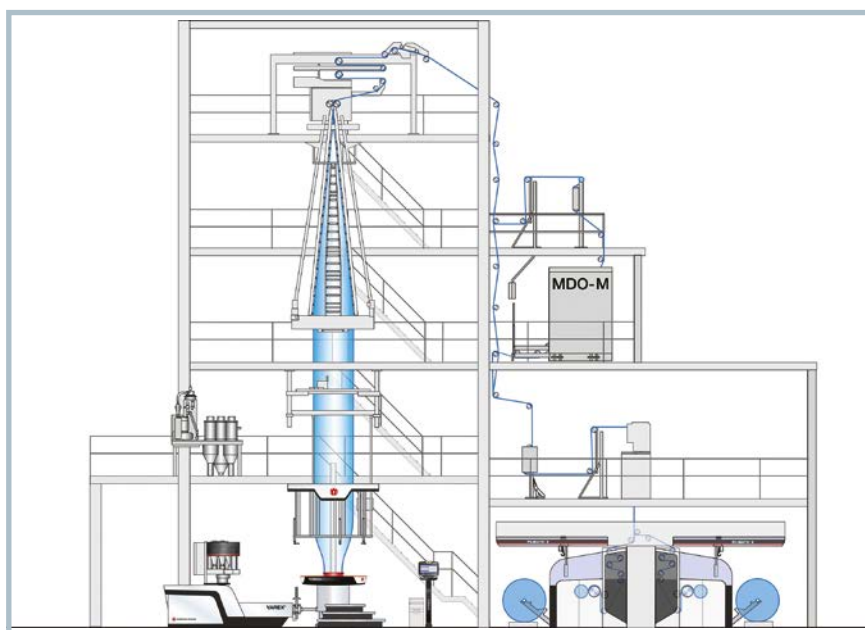


Fig. 1. Schematic layout of a blown film line featuring in-line MDO (figures: Windmöller & Hölscher)

fore wind-up. These edge trims can each be up to 150 mm wide lowering net output from the line.

Strategies for Reducing Neck-In

There are various ways to reduce or compensate for neck-in. A key parameter is the stretching gap. The narrower it is, the less neck-in occurs. The problem is that the minimum gap width varies with the material, structure and the application of the film to be stretched. Best results are therefore obtained with a stepless gap adjustment set-up.

A further important parameter is the positioning of additional nip rollers

against the temperature-controlled rollers in general and against the rollers in the stretching gap in particular. These nip rollers not only enhance heat transfer between the temperature-controlled rollers and the film, they also fix the film on the rollers, thereby ensuring a defined degree of stretching, which in return has a positive effect on overall stretching.

Furthermore, modern processes that selectively control film thickness in in-line MDO applications offer more potential for material savings. These modify the film thickness profile of the primary film via the extrusion line's profile control system, yielding a defined film profile after the stretching process. This strategy »

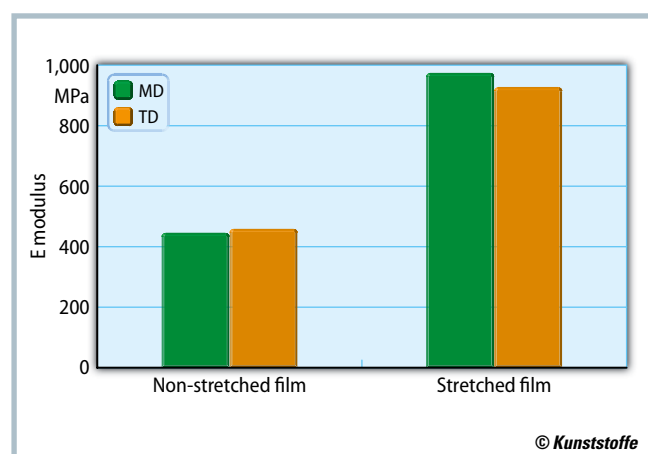


Fig. 2. The mechanical properties of stretched film are far superior to those of its unstretched counterparts (example: high-barrier films having 7 layers and a thickness of 40 µm)

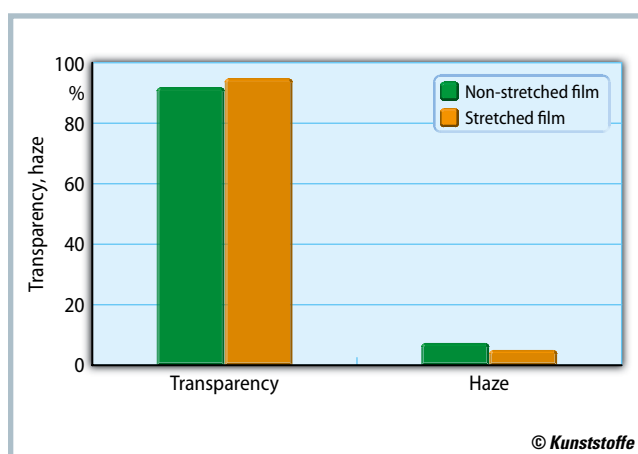


Fig. 3. Stretching also benefits the film's optical properties (example: high-barrier films having 7 layers and a thickness of 40 µm)

Fig. 4. Stretched films create better barriers (example: high-barrier films having 7 layers and a thickness of 40 µm)

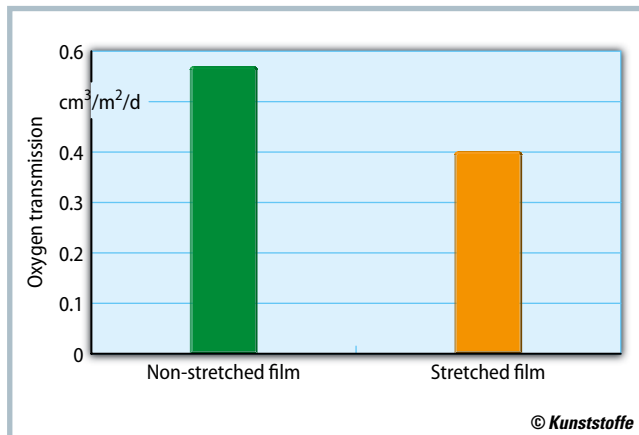


Fig. 5. The use of modern control and drive technology boosts efficiency and economics

Table 1. Overview of MDO technology

Configuration	In-line or off-line
Film width	Up to 3,600 mm
Number of temperature-controlled rollers	Up to 14
Number of stretching gaps	1 or 2
Stretch ratio	Up to 1:12

can reduce the extent of edge trimming by up to 50 % and so significantly improve the economics of stretching.

Selective Property Modification

Since MDO enhances mechanical properties and boosts the barrier effect, it presents all kinds of film applications with huge potential for reducing thickness. In addition, the excellent optical properties of stretched films widen the scope for packaging differentiation at the point-of-sale. However, the possibilities of MDO go beyond that. For example, film stretching can be used to selectively modify shrink

or tear-opening properties and even breathability. To illustrate, a selection of film applications in which MDO is already established is presented below.

One attractive application for MDO is packaging film for compressible goods, such as rock wool and hygiene products (e.g. diapers). The product is compressed and wrapped in stretched film of low extensibility. The improved tensile strength and low elasticity of MDO film can lead to substantial reductions in material and package volume.

MDO is also used to make film for labels. Uniaxial stretching affords a way of specifically adjusting the shrink proper

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ties of shrink sleeves, for example. For their part, self-adhesive labels based on stretched polyethylene films gain enhanced optical and mechanical properties. In particular, high stiffness and good flatness make further processing easier. As well, optimizing the film thickness can generate savings on the raw materials.

Breathable films find application in hygiene products and roofing underlayments. The breathability is obtained by stretching mineral-filled film. The polymer matrix separates from the filler particles during stretching and forms a fine network of micropores. These allow gases to pass through the film, but are impermeable to liquids.

Conclusion

Uniaxial stretching with MDO can be used to selectively modify the properties of all kinds of polymer films. Advances in machine and control technology boost efficiency substantially, especially that of in-line MDO (Fig. 5). As a result, not only can existing MDO applications be rendered more efficient, but also new application fields for this technology can be developed in the future.

Windmöller & Hölscher KG, Lengerich, Germany, has an extensive MDO portfolio (Table 1) and many years of experience in the stretching of blown and cast film. W&H is ideally positioned to provide expert advice on tailoring the stretching process for each application. ■