How Many Layers Are Enough?

Properties of Multi-Layer Stretch Films Compared

Ever since pallet stretch wrap was introduced, the number of layers in high-performance films has been steadily rising. But how many layers does a film need in order to form a stable load unit? Polifilm Extrusion asked itself this question and compared films with 11, 13, and 55 layers.

High performance stretch films for stable load units and safety on the roads (© Polifilm)

Polyolefin stretch films are essential for the tertiary packaging of goods in global trade. Only when the packaged goods have been joined into a unit, usually on euro pallets, is the requirement for a stable and safe load unit satisfied. The main task of stretch film consists in holding the load unit together securely, so that the packaged goods can survive the shipping and storage processes undamaged. The mechanical properties of the film are the most important ones for securing a load unit. However, in addition to high holding power, bonding performance is required in order to achieve secure layer composition when the goods are wrapped.

The task of stretch film consists in holding the goods together as a load unit, forming a stable connection between the packaged goods and the pallet, and preventing the goods on the pallet from slipping, shifting, and falling apart, as well as protecting them against moisture, dust, and other environmental influences. The film manufacturers are faced consequently with a great responsibility, on the one hand, to develop suitable wrapping films and produce them in consistent quality. On the other hand, they have to obtain information regarding the types of load units, the variety of wrapping methods, as well as wrapping equipment and transport processes, and even simulate conditions of storage and transportation. »

Fig. 1. Different-shaped load units: straight and flush with the pallet (left: type A), with protrusions above and/or below (middle: type B) and very unevenly arranged goods (right: type C) (© Polifilm)

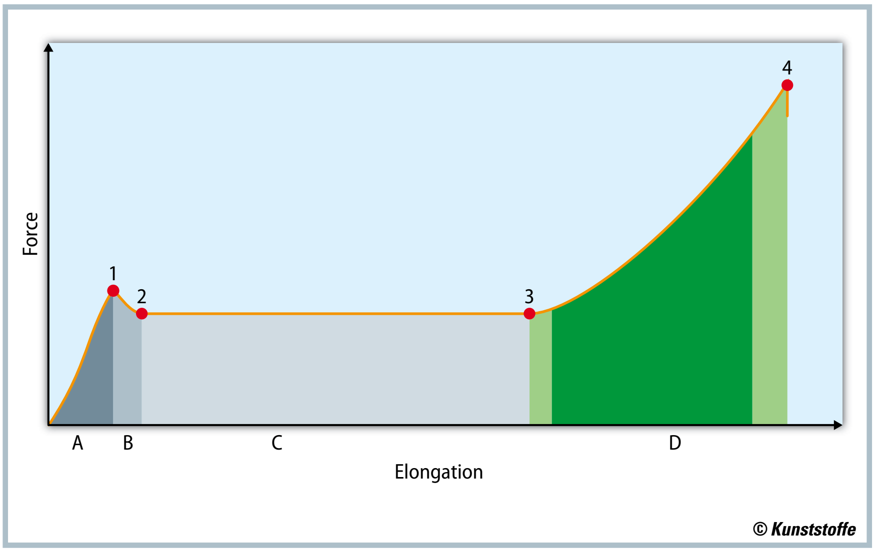

Fig. 2. Elongation behavior of a stretch film with mainly elastic zone (A), plateau (C) and working zone (D) (source: Polifilm)

Types of Load Units and Stretch Wrapping Methods

When stretch film is used, attention must be paid to the type of pallet and goods to be stretch-wrapped. This requires that the shape of the load unit is known (**Fig. 1**): Is it straight and perhaps flush with the pallet (type A), do the goods protrude at the top or bottom (type B), or do the commissioned goods have an uneven shape on the pallet (type C)? Moreover, weight and shape stability exert strong influence on the load unit. Thus, the decisive question is whether the goods on the pallet keep their shape dimensionally stable and stay relatively rigid, or they are soft and can deform under too-strong shrinking forces.

In addition to the large number of different kinds of load units, there is a wide variety of wrapping lines and methods on the market. Depending on the wrapping process, there are semi- to fully automatic wrappers, as well as hand wrappers. They differ in terms of speed, pre-stretching, and load on the film during wrapping. Thus a free arm wrapper in a fully automatic wrapping line at a beverage bottler wraps at markedly higher speed than a semi-automatic rotary turntable wrapper. Every system uses a special pre-stretching unit to define the pre-stretch and thus prepare it for the particular job (**Fig. 2**). Only when the film has been stretched beyond the so-called plateau range is the zone reached where stretching it further causes its holding force to increase. At this point, the polymer chains are oriented in the direction of stretch (Machine Direction, MD) and thus exhibit maximum holding forces.

That is why customized films are needed that exhibit the properties required for the particular combination of goods and pallets in the particular wrapping technology.

Types of Stretch Films

In general, stretch film can be distinguished according to the above mentioned requirements among the following types (**Fig. 3**):

- film with low elongation and high holding force,
- film with medium elongation and moderate holding force, and
- film with very high elongation.

But does the great variety of films have to have many layers? In the market, there is a heated discussion about how many layers a stretch film has to have in order to create a stable load unit. In the past, mainly mono- and three-layer films were used. Nowadays, 5-, 7-, and 9-layer films are the technical standard. However, the trend is toward 11 or 13 layers, and systems already exist that can produce 27, 33, or as many as 55 layers.

Some terms still circulating in the market, such as multi-layer or nano-layer film, are poorly defined, since there is no universally accepted definition of the point at which a film becomes a multi-layer or a nano-layer film. One key question is whether more layers result in better properties. For instance, given the same film thickness, does a 55 layer film achieve better properties than a 13 layer film? To get to the bottom of this issue, 13 and 55 layer films were cast on identical latest-generation lines.

Investigation of Versatility and Complexity

Together with the companies SML Maschinengesellschaft mbH of Lenzing, Austria, and Dow Packaging & Specialty Plastics of Midland, MI/USA, Polifilm produced and measured films with 12, 15, and 23 µm film thicknesses. SML PowerCast XL lines worked with seven extruders (2x90/33; 5x75/33), a Chill Roll with 1600 mm in diameter and 5000 mm wide, an automatic wide slot die (4800 mm), and reached a top speed of 850 m/min. The two identical lines differed only in respect to their feedblock configuration (layer divisions in **Fig. 4**).

Stretch films in the stated film thicknesses and with 500 mm width were then produced using the same production parameters. The stretching and holding forces in their formulations were varied in order to reflect the commercial spectrum (**Table 1**). The high-performance film requirement was filled by Dow polyethylenes, such as Elite AT 6111 (ethylene octene copolymer manufactured with Elite AT technology).

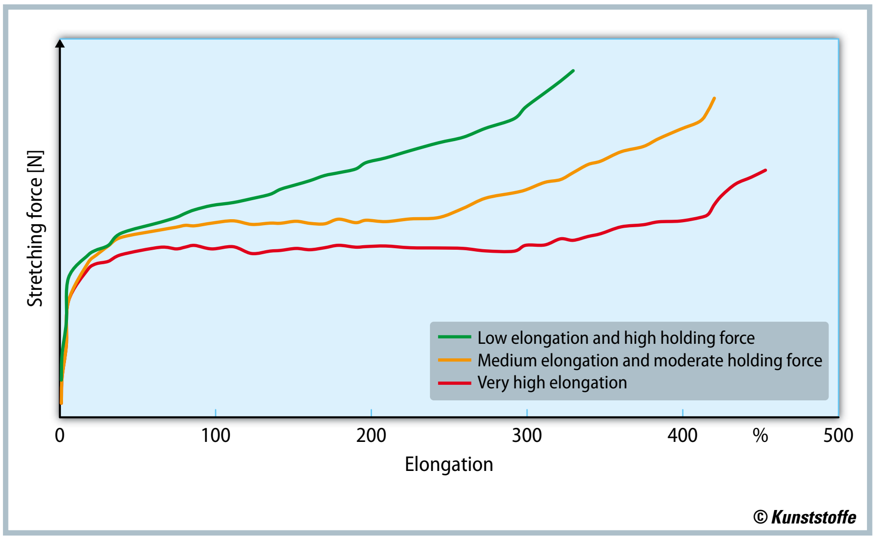

Fig. 3. Stretching force-elongation diagram of films with low elongation and high holding forces, medium elongation and moderate holding forces and very high elongation (source: Polifilm)

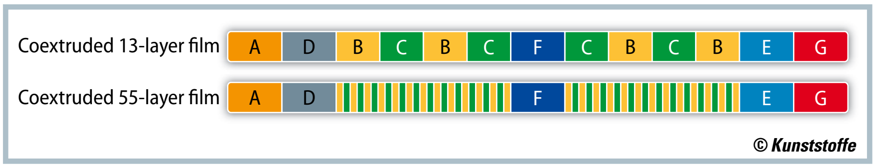

Fig. 4. Layer structure of coextruded 13- and 55-layer films: Extruder A, D to G in each case 10 % of overall thickness, Extruder B and C each 25 % of overall thickness (source: Polifilm)

Tests

An FPT-750 film testing system from ESTL of Deerlijk, Belgium, was used to test the films (**Fig. 5**). Measurement of the maximum possible prestretch elongation, as well as puncture and shock resistance was performed at various levels of prestrechting and at various test speeds. A common wrapping speed of 4000 mm/s was chosen.

The practical test was performed using a test pallet on a turntable wrapper from Highlight Industries Inc. of Wyoming, MI/USA. The films were wrapped using a standard wrapping program and evaluated with respect to the holding forces at the corners and in the surface of the pallet, as well as the puncture resistance of the stretch film connection of the packing scheme selected.

In addition, the films were laboratory tested for Dart Drop (DD, ASTM 1709-01) and Elmendorf Tear (ASTM1922-00) in machine direction.

Evaluation

Using the production and testing methods described above, 3800 data points were detected and evaluated for their formulations according to **Table 1**. For all properties comparisons (puncture resistance, shock resistance, tear strength, elongation, Dart Drop, Elmendorf Tear, application test, and holding forces) between the 13 and 55 layer films of different types and film thickness, it turned out that there are no significant differences within the statistical deviation, no matter whether the film formula- »

Fig. 5. Test equipment and process: FPT-750 from ESTL (left) and practical test on the test pallet (center) with puncture and plate test (right) (© Polifilm)

Formulation	Elongation	Holding force
Easy flow film	high	medium–high
High elongation film	high	medium–high
Strong film	medium	high

Table 1. Overview of the formulations tested on the 13- and 55-layer line (source: Polifilm)

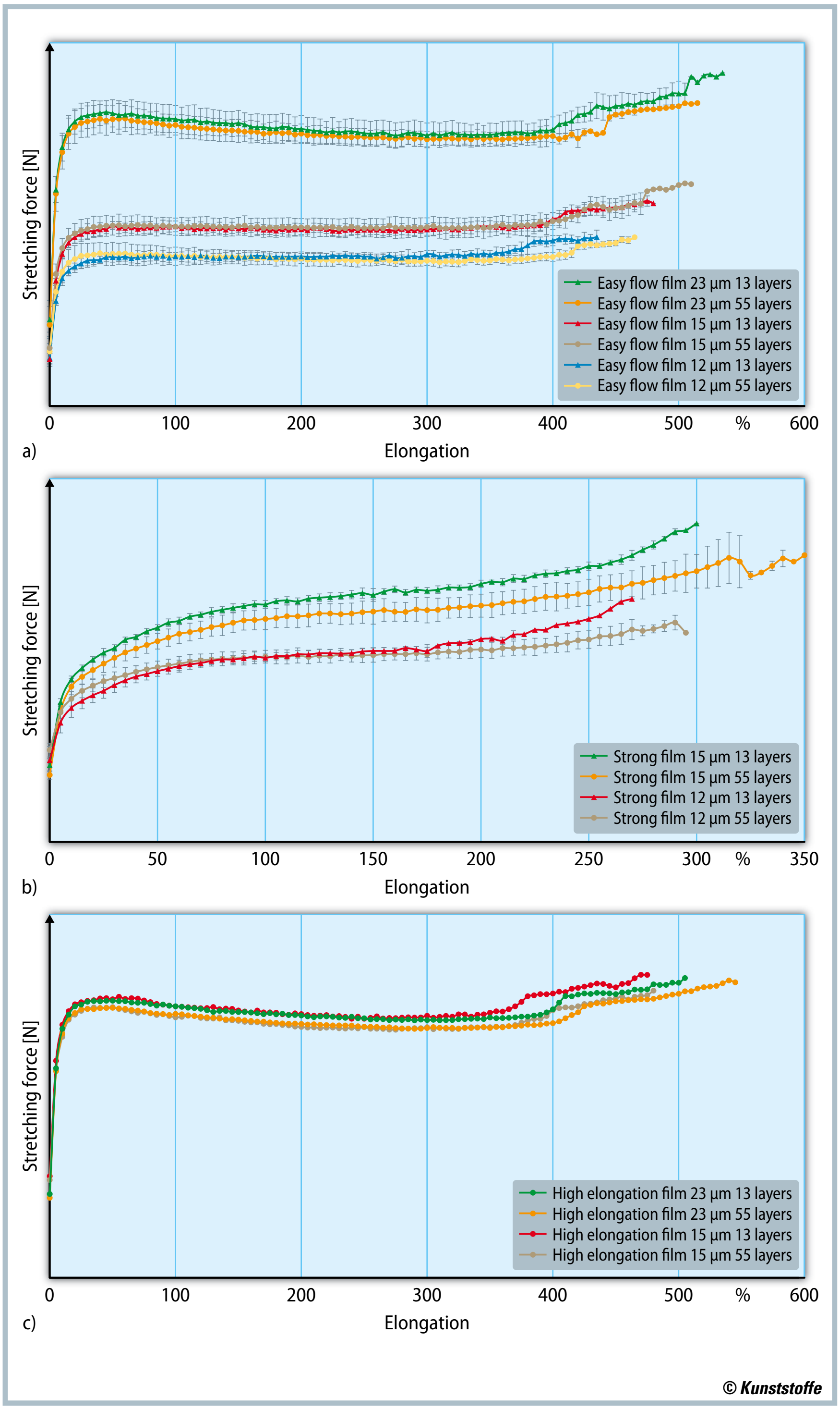

Fig. 6. Stretching force-elongation diagram of films from the 13- and 55-layer line: a) easy flow film with 12, 15, and 23 µm thicknesses, b) strong film with 12 and 15 µm and c) high elongation film with 15 and 23 µm (source: Polifilm)

tions were produced on the 13 or the 55 layer line.

Comparison of the relationship between stretching forces and elongation recorded by the "Ultimate Test" procedure delivers similar results. The "Ultimate Curves" of the 13 and 55 layer lines are compared for one thickness and formulation each for the easy flow film (**Fig. 6a**) and the strong film (**Fig. 6b**). No significant difference could be detected between films with different layer structure either in terms of maximum elongation or holding forces. Standardizing the holding forces to film thickness results in thickness dependent curves, so that films with

In Profile

Since its founding in 1972, **Polifilm** has developed into a global market leader for extruded and protective films based on polyethylene (PE). The family-owned company today has 1600 employees and achieved a turnover of more than 550 million Euros in 2016.

↘ www.polifilm.com

Machine Hygiene

To ensure uniformly high-quality production, care should be taken to

- handle and transport the raw materials properly,
- utilize processing aids and dose them correctly,
- use appropriate screen packs,
- uphold maintenance and cleaning intervals, and to
- remove any contamination from the die in good time.

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↘ Read the German version of the article in our magazine *Kunststoffe* or at *www.kunststoffe.de* different thicknesses can be compared directly. Nor is there any significant difference for the high elongation film (**Fig. 6c**) with varying layer structure.

In further tests, it was investigated how analogous formulations behave under comparable production conditions on an SML 11-layer line. Here, too, the properties values recorded were nearly identical to those recorded for 13- and 55-layer lines (**Fig. 7**).

Conclusions

The extensive tests showed that stretch films for securing load units can be produced on 11-, 13-, as well as on 55-layer lines of the latest cast lines generation that exhibit the same properties given the same film thickness. Furthermore, during this work, we discovered that success depends on the raw materials, film formulation, and processing parameters used. Mastery of the line and its cleanliness are important for consistent quality.

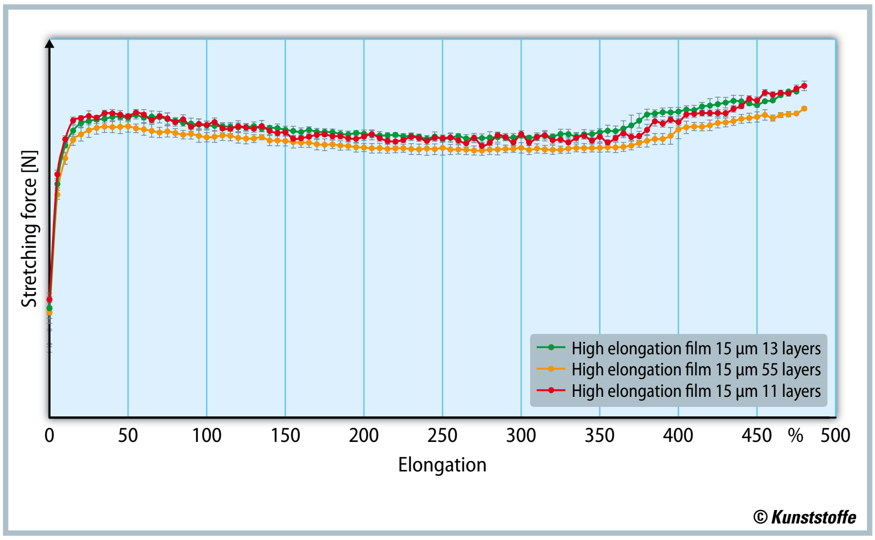

Fig. 7. Stretching force-elongation diagram of a 15 µm thick high elongation film from the 11-, 13-, and 55-layer lines (source: Polifilm)

Decisive for performance are formulations that fit the particular application – depending on the goods in question. Knowledge of the packing and transportation processes and high uniform quality are essential in order to serve the ever growing transport market with secure and sustainable load unit safety. ■