

Mechanical Properties of Tedlar® PVF Films

Mechanical properties are important to the application and use of Tedlar® PVF films. The polymer is typically supplied in rolls and must be applied to a substrate using web processing. Proper selection of web handling parameters for reliable, high quality laminations depend on the mechanical properties of the film. These properties are also important to the durability of the film in its end application.

Tedlar® Film Classification

Tedlar® PVF films are available as either biaxially oriented or unoriented cast film. The biaxially oriented film is stretched to various degrees in both the machine and transverse direction during manufacturing, imparting a range of different mechanical properties on the product depending on the amount of molecular orientation. The amount of orientation is described by the film type, listed as the last digit on the product code. The unoriented film, also known as ‘SP’ film, is cast onto a PET carrier web and is sold with the PET web attached. The Tedlar® film can be easily stripped from the PET carrier web. Films of Type 1 through 5 are oriented, while Type 8 is unoriented. Table 1 provides a summary of the various film types.

Type 3 films are the most commonly used films due to the balanced properties, including good strength and moderate shrinkage at elevated temperatures. Type 5 films are used when additional formability is needed in creating formed parts after lamination that require deep draws. Type 8 films have the highest formability and lowest shrinkage due to the nature of the processing and are used in the most demanding forming applications. In both Type 5 and Type 8 films, the reduced orientation leads to lower strength. Type 1 films are sometimes used when higher shrinkage is required, for example, to match the shrinkage of an underlying substrate during manufacture.

Table 1. The typical mechanical properties of various types of Tedlar® PVF films.

Film Type	Orientation	Shrinkage at 170 °C	Elongation at Break	Strength	Typical Use
Type 1	High	High	Low	High	High shrinkage applications
Type 3	Balanced	Medium	Medium	Medium	General applications
Type 5	Low	Low	High	Low	High formability
Type 8 (SP)	None	Low	Very High	Low	Very high formability

Mechanical Properties of Tedlar® Films

Tedlar® PVF film is strong, flexible and fatigue-resistant. Its resistance to failure by flexing is outstanding. Since the surface aesthetics are imparted by the film formulation, the aesthetics do not change when stretching the film for most film types.

The mechanical properties of Tedlar® depend on the specific film, including the amount of orientation and the additives or pigments in the film. The most important factor in the mechanical properties of Tedlar® is the amount of molecular orientation. The stress versus strain curve for film with various levels of orientation are shown in Figure 1. Highly oriented Type 1 films have the highest strength and lowest elongation at break. Balanced Type 3 films have a moderate level of performance. Low orientation Type 5 films have the lowest strength and highest elongation to break, making them exceptionally formable. Unoriented Type 8 films, also known as ‘SP’ films, have approximately the same strength as Type 5 films but with much greater elongation to break, making them exceptionally formable. The Type 8 films also have an extended region of elongation at constant stress, making them prone to elongation by necking rather than uniform stretching.

Aside from orientation, other film properties such as additives, pigments, and thickness can have small effects on the mechanical properties of the film. The typical mechanical

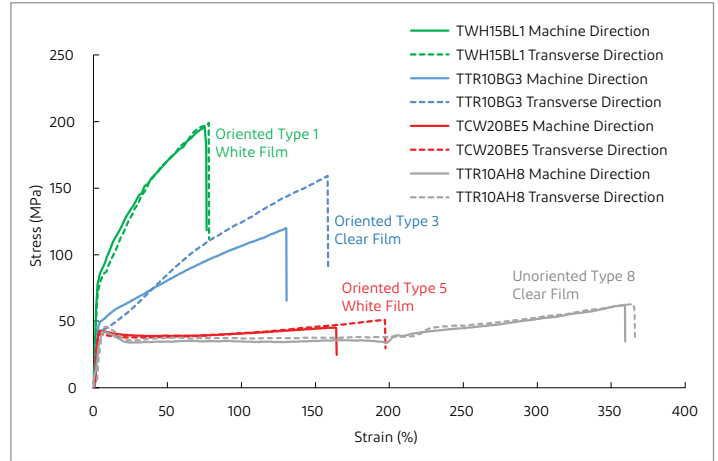


Figure 1: Typical stress versus strain curves for a variety of film orientations. Lower orientation causes lower strength but greater formability.

properties of some white and clear films, both 1 and 2 mil thick, are shown in Table 2. Minor variations in strength and elongation result from the composition and thickness of a specific film type. It is also important to note that PVF films contain no plasticizers, so mechanical properties remain stable through thermal processing and aging.

Table 2: Typical mechanical properties of three different Tedlar® films.

Property	TTR10BG3 1 mil transparent type 3	TWH15BL3 1.5 mil white type 3	TWH20BS3 2 mil white type 3	TTR10AH8 1 mil transparent unoriented	Method
Tensile Modulus MD (GPa)	2.2	2.3	3.0	1.8	ASTM D882-18
Tensile Modulus TD (GPa)	2.1	2.3	2.7	1.8	ASTM D882-18
Yield Stress MD (MPa)	36	30	34	28	ASTM D882-18
Yield Stress TD (MPa)	31	28	34	30	ASTM D882-18
Yield Strain MD (%)	2.0	1.8	1.6	1.9	ASTM D882-18
Yield Strain TD (%)	1.9	1.7	1.7	1.9	ASTM D882-18
Ultimate Strength MD (MPa)	103	65	130	56	ASTM D882-18
Ultimate Strength TD (MPa)	157	86	72	66	ASTM D882-18
Elongation at Break MD (%)	131	155	130	358	ASTM D882-18
Elongation at Break TD (%)	154	107	195	375	ASTM D882-18

Shrinkage of Tedlar® Films

Tedlar® oriented films will shrink when they are subject to heating without constraint. The amount of dimensional change depends most strongly on the temperature and orientation, with higher temperature and higher orientation causing the greatest shrinkage. This behavior is illustrated in Figure 2 and Tables 3 and 4 for some white and clear films with different orientation types. In general, film shrinkage increases as the type decreases from Type 8 to Type 1 films. In some instances, the films will expand slightly with initial heating in one of the two orthogonal in plane directions, then contract at higher temperature. This behavior will impact web handling through heated zones and precautions may need to be taken to properly spread and laterally tension the film during processing.

The force required to prevent the film from shrinking in either direction is relatively small. For example, at 180 °C, the typical force required to prevent shrinkage in 1 mil films are shown in Table 5.

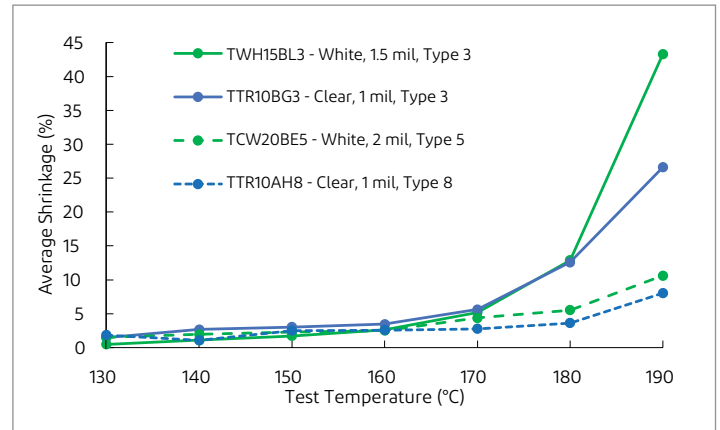


Figure 2: Typical machine and transverse direction shrinkage for white and clear films of Type 3, 5 and 8. The values provided are averages of machine and transverse direction shrinkage.

Table 3: Typical shrinkage as a function of temperature in both machine and transverse direction for three different white films.

Test Temperature (°C)	TWH15BL3 White, 1.5 mil Type 3		TWH20BS3 White, 2 mil Type 3		TCW20BE5 White, 2 mil Type 5	
	MD	TD	MD	TD	MD	TD
130	2	-0.8	3	0	3	0.5
140	3	-0.3	0	0.1	3	1
150	3	0.1	3	-0.1	3	1
160	4	1	4	-0.1	3	2
170	6	4	4	4	4	5
180	13	13	7	4	5	6
190	39	48	15	20	9	12

Table 4: Typical shrinkage as a function of temperature in both machine and transverse direction for three different clear films.

Test Temperature (°C)	TTR10BG3 Clear, 1 mil Type 3		TGP10BG3 UV Blocking Clear 1 mil, Type 3		TTR10AH8 Clear, 1 mil Type 8	
	MD	TD	MD	TD	MD	TD
130	4	-1	3	1	2	2
140	5	0	4	3	2	0
150	6	-0.1	4	3	2	3
160	7	-0.2	6	6	3	3
170	10	2	16	17	3	3
180	16	9	38	45	3	4
190	28	25	68	74	9	8

Table 5: Typical force required to prevent shrinkage in the machine directions for two different films at 180 °C.

Sample	Force (N/cm)
TGP10BG3 – Clear, UV blocking, 1 mil, Type 3	0.6
TWH15BL3 – White, 1.5 mil, Type 3	0.5

Mechanical Properties at Elevated Temperature

There are several thermal transitions present in PVF film which can affect the mechanical properties. The lowest thermal transition temperature occurs in the glassy polymer at -80 °C and is associated with local amorphous relaxation on short chain segments. At -15 to -20 °C, a lower glass transition occurs which is believed to be related to relaxation of amorphous regions free from restraint of crystallites. An upper glass transition temperature occurs at around 40 to 50 °C due to relaxation of amorphous regions which are under restraint by crystallites. Another transition occurs at around 150 °C due to pre-melting relaxation in the crystallites. Finally, the polymer exhibits peak melting around 190 to 210 °C.¹

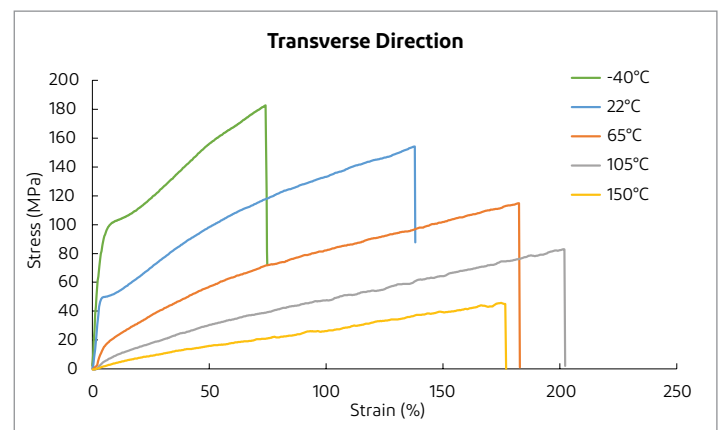
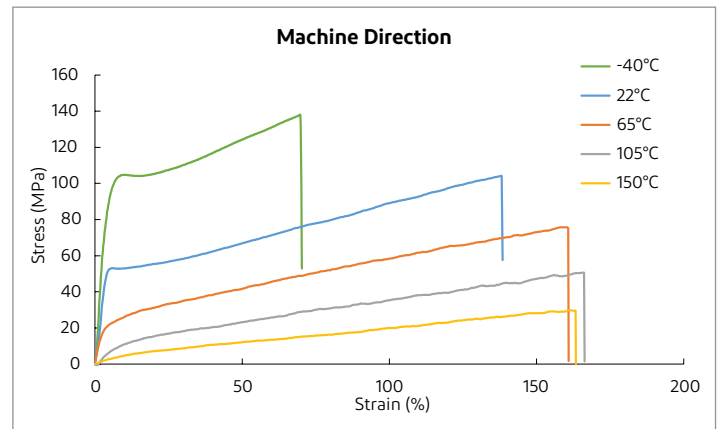
Tedlar® PVF films performs well in temperatures ranging from approximately -72 to 107°C (-98 to 225°F), with intermittent short-term peaking up to 204°C (400°F). Lower temperatures increase the strength and elastic modulus, and decrease the elongation of the film. Higher temperatures soften the Tedlar® film and decrease the amount of elastic response. The elongation of the film increases slightly with temperature, up to a maximum at around 100 °C, and then the elongation typically decreases with increased heating. Since Tedlar® films contain no plasticizers, the mechanical properties are stable throughout exposure at elevated temperatures. The typical mechanical properties as a function of temperature from -40 °C to 150 °C are shown for a Type 3 clear, UV blocking film (TGP10BG3) and a Type 3 white film (TWH15BL3). The properties are shown from 22 °C to 150 °C for a variety of other white and clear films with various thickness and orientation, summarized in Table 6.

Table 6: Films with typical mechanical data at various temperatures shown below.

Film	Type	Temperature Range (°C)
TGP10BG3	Transparent, UV blocking, 1 mil, Type 3	-40 to 150
TWH15BL3	White, 1.5 mil, Type 3	-40 to 150
TTR10BG3	Transparent, 1 mil, Type 3	22 to 150
TTR10AH8	Transparent, 1 mil, Type 8 (SP)	22 to 150
TWH10BS3	White, 1 mil, Type 3	22 to 150
TWH20BS3	White, 2 mil, Type 3	22 to 150
TCW20BE5	White, 2 mil, Type 5	22 to 150

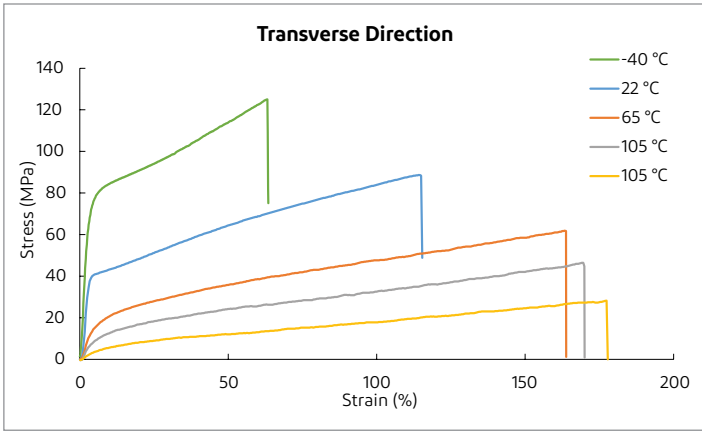
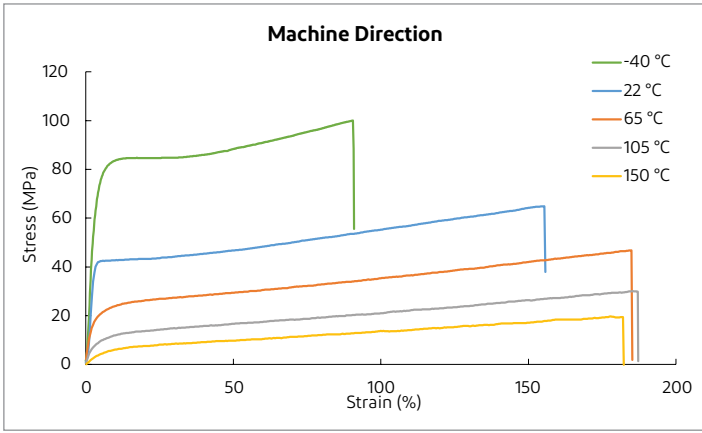
The mechanical properties at elevated temperature make the material excellent for thermoforming and texturing. High elongation at elevated temperatures allow the material to adopt the shape of a thermoforming mold without breaking, even for deep draws. The film will also take a texture at high temperature, such as from a textured roller or pressed mold, and hold the texture upon cooling.

TGP10BG3 (1 mil UV blocking transparent film, type 3 orientation):

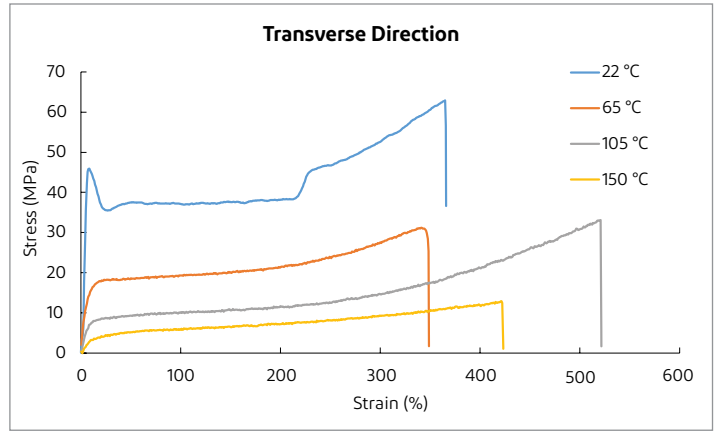
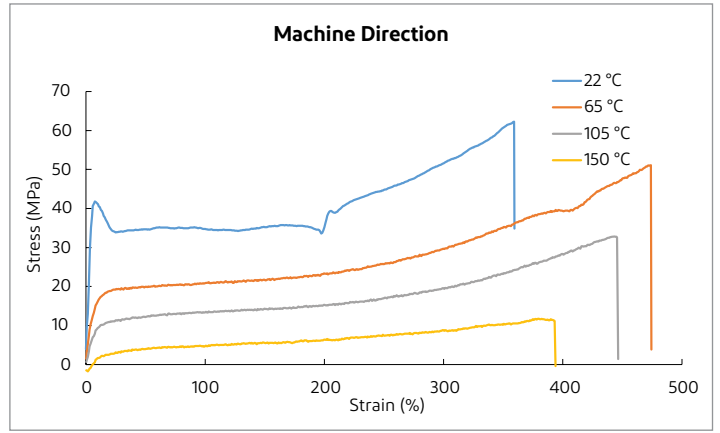


¹ Boyer, Raymond F., Glass Transitions in Semicrystalline Polymers, J. Poly.Sci.: Symposium No. 50, 189-242, 1975

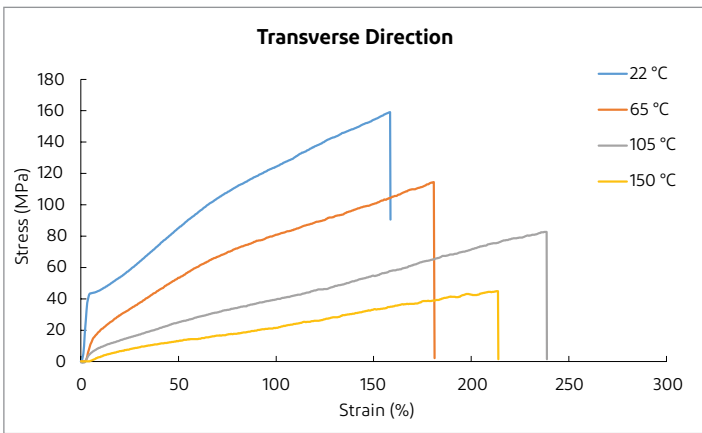
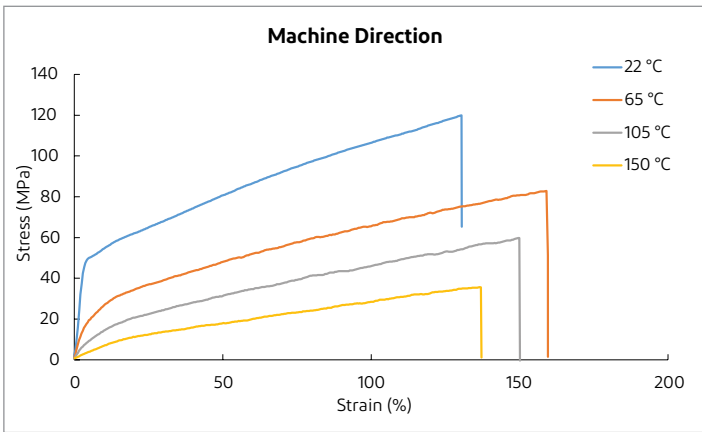
TWH15BL3 (1.5 mil white film, type 3 orientation):



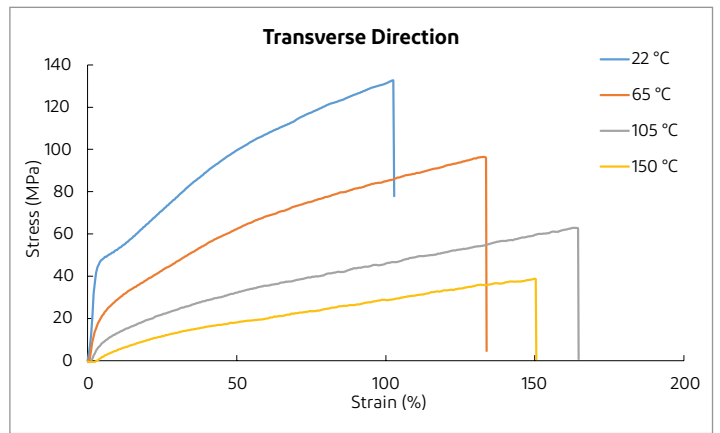
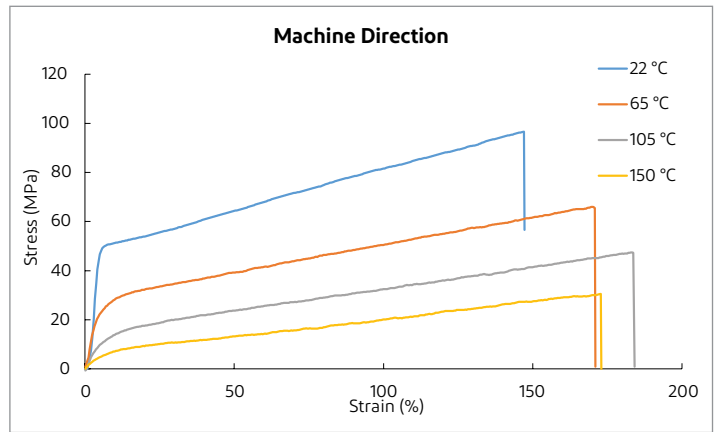
TTR10AH8 (1 mil UV blocking transparent film, unoriented):



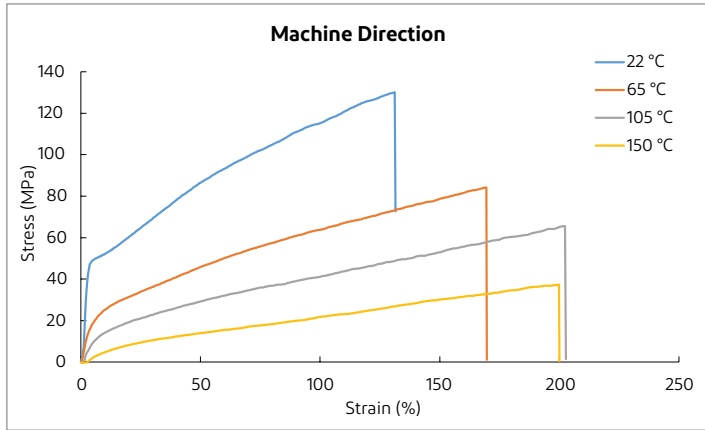
TTR10BG3 (1 mil transparent film, type 3 orientation):



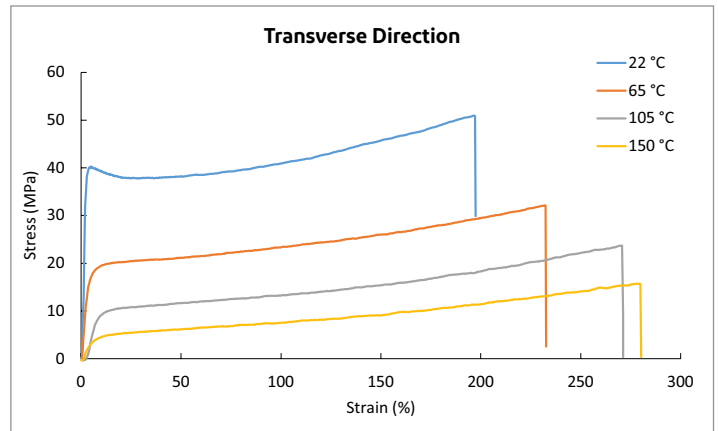
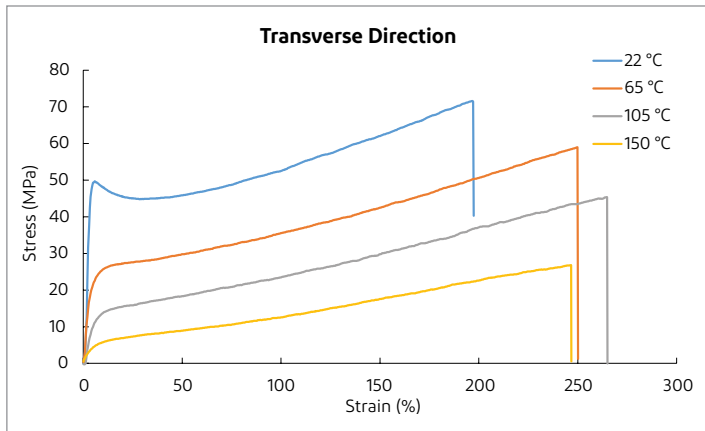
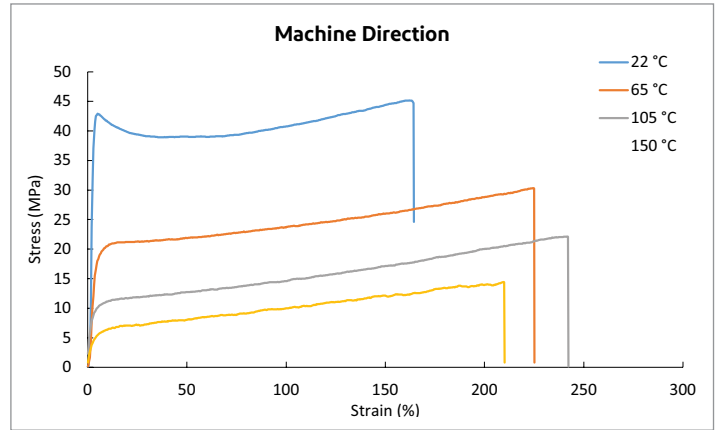
TWH10BS3 (1 mil white film, type 3 orientation):



TWH20BS3 (2 mil white film, type 3 orientation):



TCW20BE5 (2 mil white film, type 5 orientation):



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