

# TECHNICAL BULLETIN: CONSIDERATIONS ON COF



## 1 Introduction

The coefficient of friction (COF) is a dimensionless parameter that indicates the resistance that makes the surface of a slip of a material object.

In the conversion processes (Printing, Lamination, Cutting) and packing (Form, Fill and Seal [FFS]), the plastic films in contact with many surfaces (rollers, guides, collars, etc.), on which are generated friction forces that oppose the posting of the same.

As the sliding resistance is higher (high values of COF), one can observe the presence of defects in processing the following:

1. Generation of surface scratches and marks that affect the appearance of the film and especially its luster.
2. Deformation and thinning of the film, being more evident this defect in the loss of color overlay printing (losing record).
3. Rupture of the film with the subsequent interruption of the production process.

To prevent these defects, slip additives are incorporated between the materials used in the manufacture of films for automatic packaging applications, reducing the coefficient of friction.

In the polyethylene, the addition of slip agents to reduce the value of COF of 0,7 – 0,8 to 0,1.

Normally the automatic packaging process (FFS) requires dynamic COF values of the movie-movie around 0.2.

Slip additives are substances partially compatible with the EP, which causes him - during the recrystallization of the polymer - the slider is driven to migrate or the free surface of the film.

In general, the polyethylene films can be classified according to their coefficient of friction:

Type	Content slider (ppm)	COF
Without sliding	0	0.7 a 0.8
Low Slip	500	> 0.4
Medium Slip	1000	0.2 a 0.4
High Slip	1500	0.1 a 0.2

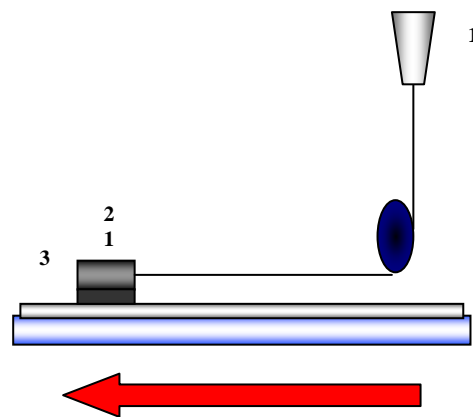
Note: Thickness of film: 25 microns

## 2. Measurement the COF

Typically, two indices are reported friction material:

- Static: Indicates the level of resistance that makes the material to initiate movement of an object.
- Dynamic: Indicates the level of resistance that makes the material to keep an object moving at constant speed.

The friction coefficient is obtained based on the guidelines of ASTM D1894 or British Standard BS824. In both standards is measured the resistance of the film to the displacement of flange dimensions and weight standard.



**Figure 1: Schematic of the device for determining the coefficient of friction of plastic films (1: load cell, 2: Skate rubberized, 3 film).**

Both rules differ on the following factors:

Parameter	Units	ASTM D1894	BS 824
Weight	g	200	700
Speed	mm/min	150	800
Displacement	mm	150	500

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Because of these differences, both test methods yield different results. The friction coefficient values measured by BS 824 are between 7% and 120% higher than those obtained with ASTM D1894.

## 3 Additives sliding

A wide variety of substances that can be used as promoters in polyethylene sliding. Among these are:

- Amides
- Silicones.
- PE waxes.
- Teflon

Commercially, the amides (especially oleamide and Erucamide) are the substances most widely used as additives for polyolefins sliding.

Below are listed the main types of amides used as slip.

Amida	Formula	Meeting Point (°C)
Oleamide (OR)	$C_{17}H_{33}C(O)NH_2$	66 - 72
Erucamide (ER)	$C_{21}H_{41}C(O)NH_2$	75 - 82
Stearamide (SR)	$C_{17}H_{36}C(O)NH_2$	96 - 102
Behenamide (BR)	$C_{21}H_{44}C(O)NH_2$	108 - 112
Oleyl palmitamide	$C_{18}H_{35}NH(O)C_{16}H_{31}$	60 - 66
Stearyl Erucamide	$C_{18}H_{37}NH(O)CC_{21}H_{41}$	70 - 75
Ethylene bisestearamida (EBS)	$C_{17}H_{36}C(O)NH(CH_2)_2NH(O)CC_{21}H_{36}$	140 - 145
Etilenbisoleamida (EBO)	$C_{17}H_{33}C(O)NH(CH_2)_2H(O)CC_{17}H_{33}$	115 - 120

The addition of 500 ppm Erucamide reduces the COF of LDPE film to values close to 0.1, while an equivalent dose of Behenamide give a COF of 0.8. This difference is attributed to the linear structure of the molecule Behenamide allows crystals to form larger surface resistance.

Some references report that the combination of oleamide Erucamide and lets you enjoy the synergistic effect of the

mixture, however, studies report that this type of mixture has a lower rate of decay of the COF with respect to time and, additionally, to the extent which increases the proportion of oleamide, increases the tendency to block the film.

## 4 Influence of additives

The presence of other additives in the formulation of PE affects the operation of the sliders.

### 4.1 Anti-lock

In general, anti-blocking additives alter the regularity of the film surface. This alteration of surface properties of the film has been shown to contribute to reducing the COF.

The synthetic silicas are highly porous materials that have the capacity to absorb the amides, reducing their ability to promote slippage. It is found that the addition of 3000 ppm of synthetic silica in LDPE can completely eliminate the default slider Erucamide 500 ppm.

Some types of powders used as anti-blocking agent, has a synergistic effect when combined with Erucamide.

### 4.2 Antistatic

Commonly used on glycerol monostearate (MEG) and antistatic agent for movies. Because the antistatic agent's action requires, as in the case of sliding, migration of the compound to the surface of the film, the combined presence of both additives produces a phenomenon of competition to reach the free surface of the film. The direct consequence of this mechanism of competition is that both the sliding and antistatic agent, are diminished its effectiveness.

As an example, below shows the COF values obtained in a film of LDPE with different formulations of Erucamide and glycerol monostearate (MEG).

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Erucamide Content (ppm)	MEG Content (ppm)	COF @ 10 hrs
500	0	0.12
500	1000	0.38
500	2500	0.50
500	5000	0.70
0	5000	0.85

## 4.3 Molecular Structure

Especially affects the density of slip properties of the polyethylenes. As the density increases polyethylene increases the fraction of material that is incorporated into crystal structures, which reduce the coefficient of friction, both the material in its natural form as an additive to slide.

Other molecular parameters to a lesser extent affecting the COF are:

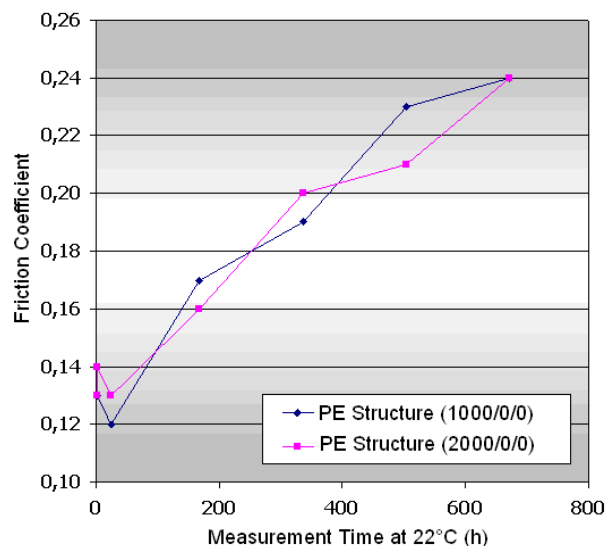
- Linearity of the molecule: For resins of the same density and melt flow rate, the LLDPE has a higher COF than LDPE (0.85 vs. 0.77).
- Catalytic system: The linear polyethylene obtained by metallocene catalysts exhibit higher COF values compared to products obtained with Ziegler Natta catalysts.

## 4.4 Combination of Materials

Different combinations of materials (mixing, lamination, coextrusion, coating, etc.). Induce varied effects on the performance of sliding of the film.

In coextruded structures, the additive slider has the additional option to migrate to the interface between the materials making up the film to be absorbed by the adjacent layer. Figure 2 shows the evolution of the COF for two-ply coextruded structures of PE, in which were incorporated in 1000 and 2000 ppm only one of the external surfaces of the structure.

The increase of the COF in the examples can only be explained by the migration of slip additive to the layers that compose without this structure.



**Figure 2: Variation of COF with coextruded structures (Layer A with the addition of 1000 and 2000 ppm Erucamide).**

Studies have shown that in coextruded structures with layers of ionomer as seal, migration takes place not only to slip free surface of the film, but also between the layers to which they have not been added the additive.

Following the affinity of polar amides with polar polymers such as ionomers, coextruded structures with these materials exhibit the following effects:

- Preferential migration of the amide to face contact with the polar resin, when the additive is incorporated into non-polar material (eg PE).
- Preferential migration of the amide to the outer surface of the polar material, when the additive was incorporated into the material comprising this layer.

Following the migration interlayers, some scholars suggest that the coextruded film with ionomers should not be rolled before 5 days of extruded, or after 20 days.

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It is found that the variation of COF with the storage temperature is higher in coextruded structures with non-polar polymers (eg PE or PP) than in those that incorporate polar products (eg, Ionomers, polyesters, polyamides, copolymers acids).

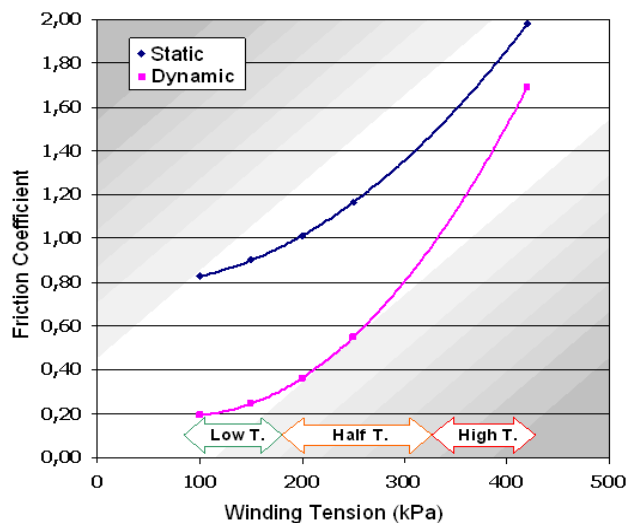
## 5 Processing conditions

### 5.1 Extrusion

The extrusion variable that shows the greatest effect on the COF is winding tension.

Work carried out show that the COF (both static and dynamic) has a ratio of second order with respect to the winding tension, as can be seen in the figure.

The phenomenon of inhibiting the migration of slip generated by the increased tension produced by the effect of reducing the free energy of exothermic separation caused by high pressure between the faces of the film. Thus molecules sliding, instead of migrating to settle on the faces of the film, migrate from one surface to another, reducing the effective concentration of sliding required to have the desired COF.



**Figure 3: Variation of the COF of a three layer coextruded structure with the addition of Polyethylenes Eruamide 2500 ppm and 5000 ppm of silica.**

Based on this mechanism can also anticipate that those lines of extrusion, coextrusion, lamination, cutting, etc., Which have central voltage windings (Center Winders) lead to a heterogeneous distribution of slip, with the highest COF the extent to which progress towards the center of the coil.

Given the evidence of landslide problems arising from the winding tension is recommended:

- Reducing the voltage applied by the winder to a level that would prevent the occurrence of defects in the coil, such as the effect type telescope.
- Reinforcing additive resin base with a concentration of slip agent, adding small doses (200 to 250 ppm).

Finally, it is worth recalling that the extrusion temperature has an influence on COF extremely low, so we do not recommend altering it

### 5.2 Corona Treatment

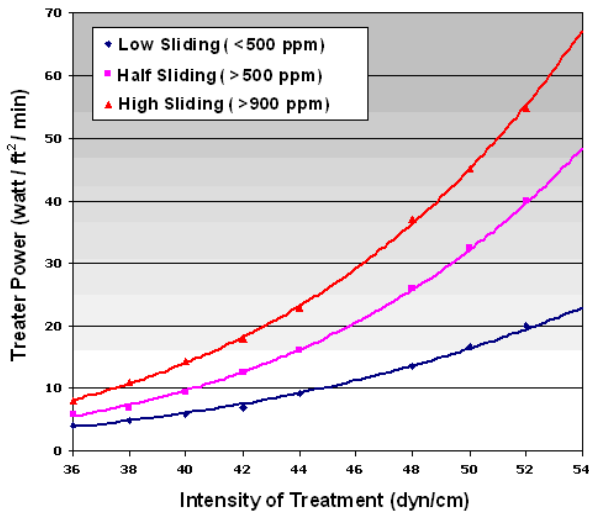
Treating the film surface tends to increase the COF, due to:

- Generation of polar groups that increase the attraction between layers.
- Steaming or burning slide additive migrates to the surface.

Because of these effects, the basic rule in the film surface treatment (corona or flame) is the unit designed for this purpose is located as close as possible to the extrusion head. In this way, take advantage of the time required for the additive to migrate to the surface of the film.

Figure 4 shows a guide for establishing the power level to be used in the treater, to compensate the loss caused by the sliding treatment.

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LDPE or LLDPE Blown	Use data plotted
HDPE	Power x 0.75
Polyester	Power x 0.75
Nylon	Use Low Sliding curve
Paper or cardboard	Power x 0.75
Blowing PP	Use Middle Sliding curve
BOPP Copolymer	25 w/m <sup>2</sup> /min
BOPP Homopolymer	55 w/m <sup>2</sup> /min
Pearl BOPP	25 w/m <sup>2</sup> /min
LDPE and LLDPE flat	Power x 1.50
EVA	Use Low Sliding curve x 1.5
Metallized film	20 w/m <sup>2</sup> /min
Metallized paper	20 w/m <sup>2</sup> /min

**Figure 4: Guidelines for adjusting the power of the Crown Tratadora as the level of treatment required and the slide content.**

## 5.3 Lamination

The heat applied by roller mill can contribute to increasing the value of the COF. For example, we found that the COF of a lamination film composed of two coextruded HDPE / EVA / ionomer increases from 0.25 to 0.5 after rolling at 65 ° C (150 ° F).

The laminating adhesives also have the disadvantage of "hijacking" the slider that migrates to the surface of the film, increasing the COF.

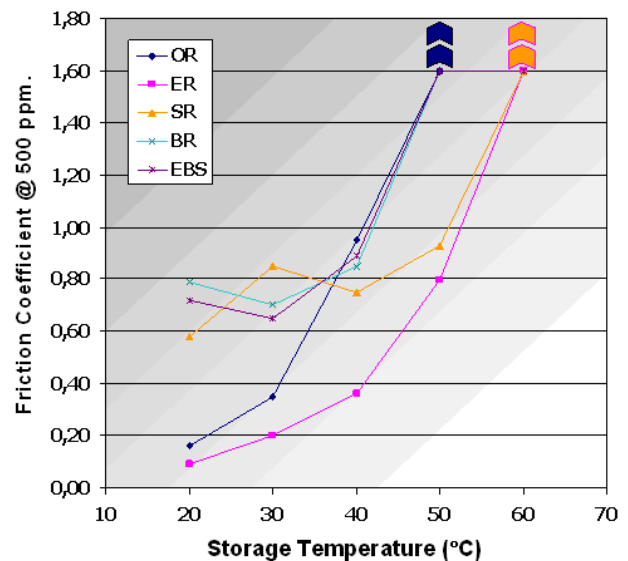
Laminations that have been made at room temperature show the COF values from 0.25 to 0.30, while those in which the grappler roller temperature is 80 ° C (176 ° F), there is an increase of the COF to 0.35 to 0.55 . Fortunately, this increase was reversed after a few days after conditioning.

## 6. Storage Conditions

Some works consider the storage temperature as the most influential factor on the COF of films.

Increasing storage temperature has the ability to increase the rate of solubility of the polymer additive, which reduces the fraction of it that stays on the surface of the film. Following this mechanism, it experiences increased COF.

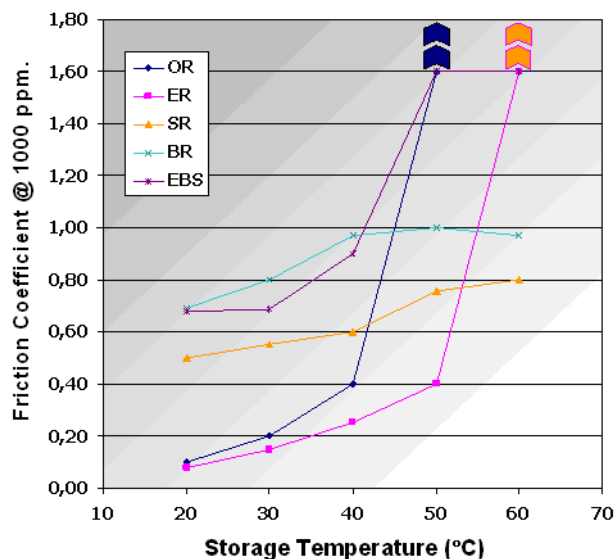
Figures 5 and 6 show the evolution of different sliding COF as a function of storage temperature of the film.



**Figure 5: Variation of COF with respect to storage temperature for different additives in LDPE Sliding dosed at 500 ppm.**

It is particularly interesting for the Erucamide, in which 1000 ppm dose attenuated the effect of increasing COF.

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**Figure 6: Variation of COF with respect to storage temperature for different additives in LDPE Sliding dosed at 1,000 ppm.**

At high temperatures (60 ° C), only beeamidas stearamide and are effective, because its structure saturated (no double bonds C = C) gives them a higher melting point.

In laminations sold in export markets, has been found that the value of the COF changes from 0.18 (measured after 10 days of rolling) to 0.40. Close monitoring of these firms showed that the upper layers of coils stored in the containers reach temperatures of 63 ° C (145 ° F), which is responsible for increasing the solubility of the polymer sliding and thus, the increase COF.

Because changing the storage temperature does not influence the total content present in the product slider, increasing at high temperatures experienced COF can be reduced or reversed by storing the film in less severe conditions. For example, in the case previously described, was achieved, with the storage of the rolls to room temperature, reducing the COF from 0.4 to 0.25 within ten days.

*This bulletin has been elaborated by the Marketing Management of Polinter, with the support of specialists of Investigación y Desarrollo, C.A. (INDESCA), and the Technical Services Management of CORAMER. It is intended to all the users of Venelene resins and we trust that the information herein contained will be useful.*

*In case of comments or suggestions, please write to [info@polinter.com.ve](mailto:info@polinter.com.ve) or contact our Commercial Agent at <http://www.coramer.com>*

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