ANALYSIS OF DEGRADATION OF PET FILMS DURING MANUFACTURING

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Abstract

This study focuses upon the various reasons that are responsible for generation of B-grade production of the films during manufacturing of A-grade quality films. A total of eighteen different reasons that are solely responsible for downgraded manufacturing which ultimately results in low revenue generation than the desired one. It shows that winding which is a crucial part of film manufacturing is the most effective reason of all and it contributes an average of 18.6% of the total Down-graded production while manufacturing. Thus, it should be the one which should be foreseen above all other reasons in order to regulate degraded production and overall waste generation during film manufacturing.

Keywords: -PET Film, BOPET Film, MLP, Manufacturing, Winding, Gauge, Die Lines

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Introduction

PET films, often referred to as BOPET films, are a very adaptable kind of plastic film utilised in a number of applications. High-quality resin and cutting-edge technology are used in the production of BOPET films. Ropes made of twisted polyester (PET) yarns have been replacing traditional steel ropes and chains as mooring lines for offshore platforms in deep-sea environments. In order to optimise rope manufacture and the design of mooring systems, a thorough understanding of the material's mechanical behaviour is necessary (Lechat et al, 2011). The resin is first melted and extruded through a small slit die to begin the process. The film is subsequently stretched to attain the appropriate thickness and characteristics in both machine and transverse directions. The film is heat-set in the final step to enhance its dimensional stability and other characteristics. BOPET films produced using this technique have remarkable mechanical and thermal resilience, making them a popular substrate for a number of uses.There are several different types of BOPET films, each with special qualities and advantages.

By gathering BOPP packaging, the possibility of recycling the trash can be maximized and a form of the polymer mixture can be established in order to produce a homogenous mass. They may be specifically designed to assess several formulations via essays, determining the optimal composition by combining their characteristics and examining potential uses (Rodrigues et al,2020).Use of co-extruded clear and ultra-clear films is common in applications that demand the highest level of gloss and clarity. Films that have been chemically treated offer great printability and barrier qualities. High-strength yarn grade films are employed in textile applications, whereas opaque white films provide high opacity and outstanding printability. Balanced shrink films are a great option for packing products with unusual shapes since they produce uniform shrinkage. Security applications use holograms, whereas ornamental applications use base films for hot stamping foil. The electronics sector favours electrical grade films because of their superior electrical insulation.The remarkable mechanical and physical characteristics of BOPET films enable the substance to perform above expectations while using less material. BOPET films provide the only practical option for the use of food contact approved recycled material in flexible packaging at an industry scale, building on the best in class mechanical and chemical recycling options currently available.

This helps brand owners and retailers fulfil their sustainability commitments and increase the circularity of plastic packaging.The production of plastics has increased rapidly worldwide due to its versatility and use in many different sectors of the economy. The annual generation of millions of tonnes of plastic garbage places pressure on methods of managing plastic waste to keep it from building up in the environment. Recycling still faces obstacles, but it is an appealing disposal option that supports the idea of a circular plastic economy.For PET, several waste management strategies are used, including energy recovery, chemical recycling, and mechanical recycling.

When sorting is too costly or complex, energy recovery is chosen instead of primary recycling, which calls for high-quality garbage (Jones et al, 2021). Although,due to its tremendous growth in application over the past 20 years, virgin PET is regarded as one of the most significant engineering polymers. It is a highly appreciated substance that finds extensive use in the production of bottles and other liquid containers. It is reasonably thermally stable and possesses good tensile and impact strength, chemical resistance, clarity, processability, and colour ability. Post-consumer PET recycling is a technology that involves multiple scientific domains and is a cross-disciplinary practice. These include production engineering, process engineering, and polymer chemistry and physics (Awaja& Pavel, 2005).

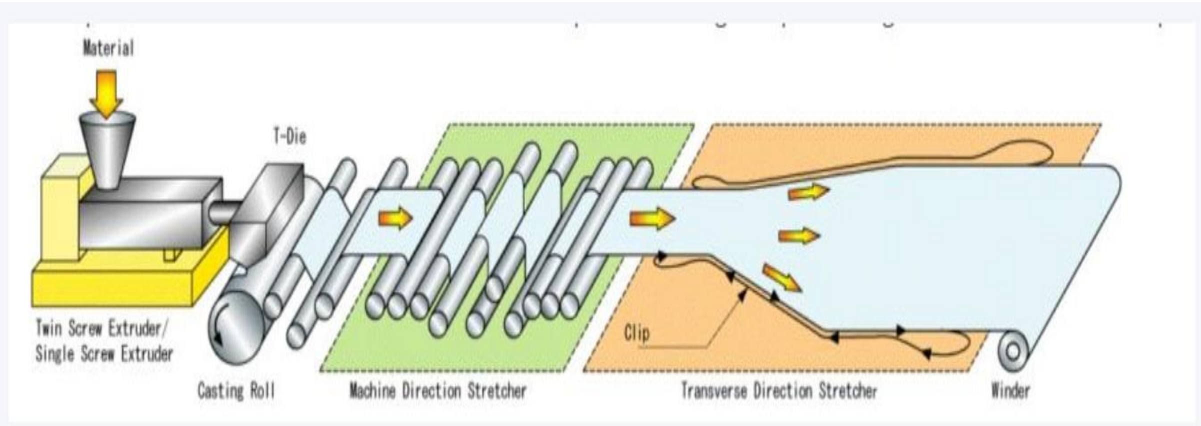

Fig.1 BOPET Film Manufacturing Line

As shown in Fig.1 the film is produced by extruding a film of molten polymer into the shape of a chill roll. After then, biaxial orientation occurs and it is quenched into an amorphous form. Either a sequential or simultaneous drawing method is used to achieve orientation. The procedure that is most frequently employed is usually the sequential method. In this case, the machine direction and transverse draw ratios are roughly 3 to 4. After the drawing process is complete, the film is heat set by subjecting it to strain and a 200°C oven temperature. This orientation ensures great strength and stiffness in the finished BOPET film.The film can also be drawn concurrently in both directions, but this requires slightly more complicated equipment. Draw ratios are usually between three and four in each direction.The film is "heat set" or crystallised under tension in an oven at temperatures normally above 200 °C (392 °F) when the drawing is finished.

The film's molecular orientation in the film plane is locked in during the heat setting process, which also prevents the film from contracting back to its original, unstretched shape. Biaxially oriented PET film's high strength and stiffness are a result of the polymer chains' orientation.When good processability, mechanical strength, chemical and thermal stability, and gas barrier qualities are needed, polyethylene terephthalate (PET) films are utilized. Since PET is utilized in many applications with predicted lifetimes of up to decades e.g., for use in buildings, textiles, or solar back sheets, hydrolysis leading to embrittlement of the material is a major problem. Consequently, it is crucial to have a thorough grasp of the degradation processes and how they affect the molecular mass distribution (Oreski et al, 2023).

These BOPET films often suffers quality deviation which results in manufacturing of product with an inferior quality as compared to the standard which is manufactured by the company. These films are termed as B-graded BOPET films. These films are often sold at lower prices than the A-graded or the films which met all the standards for the product quality. These B-graded films are not intentionally produced during the manufacturing process but are produced unintentionally or due to certain factors or reasons. But as discussed above BOPET films have excellent properties of recycling and reprocessing thus are reprocessed or are sold at lower rates depending from industry to industry.

In order to reprocess the films, the respective B-graded films are again sent to the extruder for the process of manufacturing to start from the beginning. The films are melted again in extruder and complete process is revised in order to manufacture them again with all the standards up to mark. In this research these factors are studied that causes the B-graded PET films while manufacturing A-graded PET films. A-graded PET films are the films which basically meets all the industrial standards.

By supplying essential functionality to end markets including consumer electronics, automotive, green energy, and medical devices, to name a few, BOPET films have allowed many aspects of our modern lifestyle. However, flexible packaging structures see by far the most use of BOPET film, where its special combination of attributes has made it possible for it to serve as the foundation for high performance MLP (multi-layer plastic) structures.Although BOPET films only account for 5–10% of the total volume by weight in the flexible packaging industry, they outperform their weight in terms of the number of packaging structures that rely on their special combination of characteristics, with up to 25% of packs using BOPET as a crucial component.

Research Objective

To study various factors which are responsible for down-gradation of quality of BOPET or PET films & the overall amount of B-graded film production while manufacturing PET films.

Research Methodology

There are basically six different lanes on which the BOPET films are manufactured. For each different lane the amount of B-graded production is calculated.This B-grade generation or production can be understood by studying various factors which are responsible for the B-grade film production. The percentage values for each different factor are calculated.

All lanes have eighteen different factors based on which their B-grade production is determined. For each lane the grand total is calculated of the overall B-grade production by summing all the respective factors contributing to the B-grade film generation.Now by using this grand total of each lane, a percentage value for each different factor is also calculated.

Data Collection & Analysis

The complete data was collected on eight different lanes of a BOPET manufacturing machine. Different samples of various films were used to categorize the B-graded production into different factors respectively. In order to categorize the data in eighteen different reasons each degraded or standard-deviated product was inspected and thus was enlisted into different factors. The complete data is in metric-tonnes, for each different lane the total B-grade produced films is calculated which is further categorised among the different reasons in the Table 1.1.

The winding reason mainly comprises of the products wear and tear or other kind of degradation while winding the film in a roll. Extensive tension while winding can cause elongation defect of the film and even can led to tearing at a random point while winding.

Winding is the most common reason for the overall down-gradation of the manufactured film with an overall contribution of 18.6% in total.

Gauge bands are those that range in width from 3-5 mm to 20-25 mm and are not the result of a malfunctioning beta gauge or die bolt. They result from a non-uniform accumulation of broken polymer on the die lands, immediately above the die exit. An uneven gap forms between what would otherwise be two parallel plates as a result of this non-uniform growth. Even after a few hundred wraps on the roll, a ridge or a valley form in the location of the non-uniform gap, no matter how tiny.

Due to this an overall 18.1% of down-graded film production is contributed making it second most contributing reason of all. Accumulation of unwanted elements and particles can majorly affect the final output created. In order to manufacture an A-grade film, right proportions of each different elements are added in a right proportion. While mixing this any foreign particle's presence result in down-gradation in overall final product with an overall 14.7% effecting value.

Table 1.1 Factors Causing B-grade Production while Manufacturing BOPET Films

		B grade (%)							B Grade (MT)						
S. No.	Reasons	A	B	C	E	F	H	Total	A	B	C	E	F	H	Total
1	WINDING	10%	34%	34%	26%	13%	12%	18.6%	11.5	13.4	33.3	13.6	9.7	18.6	100
2	GAUGE PROBLEM	10%	4%	37%	46%	25%	3%	18.1%	11.7	1.6	36.5	24.3	19.0	4.1	97
3	PARTICLES	0%	0%	7%	0%	0%	45%	14.7%	0.0	0.0	7.2	0.0	0.0	71.6	79
4	DIE LINES / FLOW LINES	57%	0%	0%	0%	0%	4%	13.3%	64.2	0.0	0.3	0.0	0.0	7.0	72
5	HAZE / SHADE VARIATION	11%	4%	10%	12%	0%	0%	5.7%	12.7	1.4	10.1	6.5	0.0	0.0	31
6	SCRATCHES	3%	22%	2%	4%	9%	5%	5.4%	2.9	8.5	1.8	1.9	6.8	7.1	29
7	CREASES	3%	3%	0%	7%	20%	3%	5.2%	3.3	1.2	0.0	3.4	14.8	5.1	27.8
8	WRINKLES	1%	8%	0%	2%	11%	6%	4.2%	0.6	3.0	0.0	0.8	8.4	9.8	22.6
9	JOINTS	2%	0%	4%	0%	9%	5%	4%	1.7	0.0	4.1	0.0	6.8	7.7	20.3
10	DUST	0%	8%	0%	3%	8%	1%	2%	0.0	3.2	0.0	1.7	5.9	1.8	12.7
11	STAR MARKS	1%	0%	3%	1%	1%	2%	2%	1.7	0.0	3.3	0.3	0.5	3.1	8.8
12	PINNING LINE / HTWM	0%	1%	0%	0%	1%	5%	2%	0.0	0.3	0.0	0.0	0.9	7.3	8.6
13	SHORT LENGTH	2%	0%	1%	0%	2%	2%	1%	1.7	0.0	0.9	0.2	1.2	2.8	6.8
14	HIGH STATIC CHARGE	0%	16%	0%	0%	0%	0%	1%	0.0	6.2	0.0	0.0	0.0	0.0	6.2
15	COATING PROBLEM	0%	0%	0%	0%	0%	3%	1%	0.0	0.0	0.4	0.0	0.0	5.5	5.9
16	OIL SPOT / WATER SPOT	1%	0%	0%	0%	0%	2%	1%	1.6	0.0	0.0	0.0	0.0	3.8	5.3
17	PATCHES	0%	0%	0%	0%	1%	2%	1%	0.0	0.0	0.0	0.0	1.0	2.8	3.8
18	CORE DAMAGE	0%	0%	0%	0%	0%	0%	0%	0.0	0.0	0.3	0.0	0.0	0.0	0.3
Grand Total		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**114**	**39**	**98**	**53**	**75**	**158**	**537**

The Die-lines and the Flow-lines can damage the product film while manufacturing if the adequate pressure in not maintained in them. As the film produced are still delicate enough and if the die-pressure and flow-line is not maintained for different thickness of the films, results in overall down-gradation of the film with an overall 13.3% in total B-grade production of these films. The shade-variation is another reason for a A-grade manufactured film to be categorised as a B-grade production. The final outcome if deviates from the desired shade often leads to customer rejection further resulting in contribution to 5.7% of total B-grade generated film. Scratches are one of the most inevitable of all other factors. A scratched film results in instant rejection of it. A film can be scratched at any point where there is any pointed or coarse surface contact occurs. This abrasion causes an overall 5.4% of the overall B-grade production of the films. While manufacturing the film due to any reason if a joint has to be applied to make it of the desired length, then that film too can't be kept among the finest A-grade films. Its generally done if a very small part of film is damaged or when two or more films are required to be combined in order to get the desired length. This has an overall contribution value of 4% among the total. Wrinkles in a manufactured film also deteriorates its overall appearance and usability and thus wrinkled films are also considered among the Down-graded films with an overall value of 4.7% among the total.The next factors have a very minimal contribution to overall B-grade production.

Poorly attended film rolls are often deteriorated by these different factors. Dust accumulation, oil marks or water marks are among these factors. An efficient handling can minimalize these reasons.By ionizing the air, pinning methods provide an electrostatic action that pins the extruded melt film to the chill roll, minimizing air entrapment between the film and the roll. A faulty pinning mechanism leads to further poor manufacturing of the films. Further inadequate static charge generated among the film layers can lead to excessive adhesion force among the different layers which can result in wear and tear. A missing coating layer or wrong coating done over the respective film while manufacturing results in rejection of the manufactured film.

The core-damage is the least contributing factor which is almost negligible and only produced 0.3 metric-tonnes among the large value of 537 metric-tonnes thus has a zero value for percentage contribution after rounding of the value.

Results And Discussion

The research shows that there are different reasons that contributes to the Down-gradation of A-grade manufactured film to B-grade of which majority of film deterioration occurs while winding the film followed by gauge problems with least effecting reason to be core damage. Winding is an essential and the final process of manufacturing but when not taken care of properly for each different roll can lead to degradation of the final manufactured product. In this study an overall 100 metric-tonnes of film was categorised into B-grade production just because of faulty winding setups at each unit. Thus, an efficient winding system is must which can further decrease faults during winding thus saving a very large amount of manufactured product.

Conclusion

In this study it was found that an overall amount of 537 metric-tonnes of BOPET films are classified to down-graded or B-grade films due to various reasons and out of which 18.6% of the total that is one hundred metric-tonnes is only caused due to improper winding whereas the least contributing reason with an amount of merely 0.3 metric-tonnes from the total of 537 is caused due to core damage while manufacturing.

References

1. Rodrigues. M, Quevedo. S, De Souza. J, Farias. J. (2020), Waste Recycling in Biaxially Oriented Polypropylene,12449531, ISSN: 2250-3021, Pages 11-15.
2. Jones. H, Koutsos. V, Ray. D, Saffar. F. (2021), Polyolefins and Polyethylene Terephthalate Package Wastes: Recycling and Use in Composites, Energies-14217306, Pages 1-43.
3. Awaja. F, Pavel. D. (2005), Recycling of PET, European Polymer Journal, ISSN 0014-3057, Pages 1453-1477.
4. Oreski. G, Ottersböck. B, Barretta. C, Christöfl. P, Radl. S, Pinter. G. (2023), Degradation of PET – Quantitative estimation of changes in molar mass using mechanical and thermal characterization methods, Polymer Testing, ISSN 0142-9418, Page-108130.
5. Lechat. C, Bunsell. A.R. & Davies. P. (2011), Tensile and creep behaviour of polyethylene terephthalate and polyethylene naphthalate fibres, Journals of Material Science, Pages 528-533.