Section A-Research Paper
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Comparative Analysis of Machine Downtime for Biaxially Oriented Polypropylene Films during Manufacturing

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Abstract

Downtime plays an important role in efficiency and profitability of any machine which is being utilized. In this research, a thorough analysis of different factors and their sub-factors contributing to the overall downtime of a BOPP film manufacturing machine is done. The data collected is divided among two different factors which are further divided among the sub-factors accordingly. Process-downtime and Engineering-downtime are the two basic factors on which the downtime of the machine depends. Further research study shows that the Engineering downtime causes much more halt as compared to the Process -downtime and it can be countered most effectively with the help of Preventive maintenance.

Keywords: Biaxially Oriented Polypropylene, Cast-oriented Polypropylene, Consumer-Packaged Goods, Machine Direction Orientation, Transverse Direction Orientation, Pull Roll Stand, Programmable Logic Controller.

Introduction

Manufacturers constantly strive to prioritize their productions in this cutthroat marketplace. In this context, production effectiveness is essential. Even with new technologies, unplanned downtime is the main cause of profit loss. Unexpected downtimes are caused by equipment failure, delayed materials, breakdowns, and flaws (Nallaperuma et al, 2018). When a piece of machinery or equipment is not working or functional, it is said to be in a "Downtime". Downtime is the interval between the first piece of equipment to fail and the start of full operation. Profits are lost without a doubt if production is ever unable to deliver high-quality prints. Reducing machine downtime immediately improves industrial production output and efficiency. The efficient use of equipment, tools, etc., is essential to overall productivity. Unplanned events are the main cause of equipment downtime. Businesses have prioritized operational efficiency in order to increase profits (Priyadarshini, 2015). However, the unplanned stops are the most common unexpected factors that effect on the overall productivity. The requirements of outstanding performance force, companies need to reduce their total downtime frequency. Downtime is the interval between the first piece of equipment to fail and the start of full operation. Profits are lost without a doubt if production is ever unable to deliver high-quality prints (Nwanya et al, 2017). Reducing machine downtime immediately improves industrial production output and efficiency. Machine downtime has many different root causes, each of which is unique. These can include issues with the physical equipment, such as failures or jams, as well as issues brought on by external circumstances, such as an unavailability of the machine operator, a lack of materials, and planned or unforeseen maintenance. Personal allowances, planning, and meeting scheduling are other factors. A fundamental component of efficient downtime management is accurate information. The major obstacle to establishing a trustworthy downtime management system for plastic manufacturing companies is inaccurate data or a lack of it. Accurate and useful information about the scope of downtime and its causes depends on reliable data. In this research we will study about the downtime related factors during the manufacturing of BOPP films. So, in order to minimize the downtime related to any machine first one should find out the different factors that are behind the downtime and after analyzing them one can prepare a counter plan in order to minimize those causes and moving the machine a step closer to ideal-working. Waste is produced during the production of BOPP films as a result of process or quality issues. The company has a facility that turns garbage into RPGs (Reprocessed Granules), which are raw materials. One of the main issues that must be resolved in order to realize a long-term vision of a green economy and zero waste is the quality of recycled materials (Saw & Gopekar, 2014).

PP films are clear, high gloss, flexible plastics with an excellent tensile strength. The propene or propylene monomer used in their production. Among all common plastics, this linear hydrocarbon resin is the lightest polymer. PP is available as a copolymer or a homopolymer and can be significantly strengthened with additions. A form of polyolefin that is a little bit tougher than polyethylene is polypropylene (PP). It is a common plastic that has a strong heat resistance and a low density. The many PP film varieties include PET (polyethylene terephthalate), BOPP (Biaxially Oriented Polypropylene), and others. In BOPP film, the term "biaxially-oriented" refers to the production technique that stretches the film in two directions, increasing its strength and transparency. Although BOPP is a more widely used polypropylene film, CPP (Cast-unoriented Polypropylene) is steadily gaining favor in a number of different industries, including food, medicine, flowers, textiles, and many more. The usage of CPP in the food, pharmaceutical, floral, textile, and other industries is steadily gaining favor, despite the fact that BOPP is a more widely used polypropylene film.

The BOPP is stretched both transversely and longitudinally, resulting in two different directions for the orientation of the molecular chains. The orientation makes the film's overall stiffness and tensile strength stronger. It also offers good flex-crack and puncture resistance against a wide temperature range. These are exceptionally glossy and fairly transparent. Actually, they can be metalized, clear, opaque, matte, or glossy. These are very efficient against oxygen and moisture prevention. These are also used in manufacturing labels (Teresa, 1998).

White-BOPP labels are the most popular and are non-toxic, incredibly strong, and moisture-resistant. It adheres nicely to a variety of surfaces thanks to its potent permanent adhesive. White BOPP material is preferred by producers of cosmetics, personal care, and health items for their labels and packaging. Clear and White one of the most resilient products for the Consumer-Packaged Goods (CPG) sector is BOPP labels. Shrink wrap for food packing and labelling both employ the inexpensive biaxially oriented polypropylene material. Because BOPP labels in white and clear are flat, they easily adhere to containers. This is especially true for products with irregular shapes, like fresh meats, or packaging with unique shapes, like spheres.

The other type of these used as labels is Clear BOPP. The clear BOPP label material is virtually invisible in addition to being tough and moisture-resistant. When used, clear BOPP makes it seem as though there is no label, allowing your product to stand out. Even glass bottles and containers with dark colours can be used with clear BOPP. BOPP provides a competitive price point, is tear-resistant, and accommodates a variety of ink formulas. Thus, it is a great material option for surfaces that can become wet or filthy because of its moisture resistance and adhesive properties. Moreover, due to their advantageous features and inexpensive price, BOPP films are replacing cellophane in applications including snack and cigarette packaging. Thus, they are also used for food packaging widely these days. Oriented films can be heat-set to give dimensional stability or utilised as heat-shrinkable films in shrink-wrap applications. In BOPP films, heat sealing is challenging, but it can be made simpler by either coating the film with a heat-sealable substance, like polyvinylidene chloride, after processing, or by coextrusion using one or more co-polymers prior to processing to in order to generate layers of film. All film companies need a permanent R&D facility due to the wide range of biaxially oriented film types and the dynamic market environment. The majority of biaxially oriented film is made up of BOPP films, which have a global consumption of over 6 million tonnes (Breil, 2011). The applications, which span both the food and non-food industries, are extremely varied and can simply be categorised as packaging applications. These applications can be categorised according to the thickness range and the number of layers. For electrical applications, such as capacitor film, the thinnest films with a thickness of at least 3 µm are needed. The synthetic paper industry offers the thickest films, up to 180 µm.

Due to their low hydrophilicity, biaxially oriented polypropylene (BOPP) films are poorly suited for ink printing and adhesive wetting. The amount of surface layer oxidation directly relates to the corona treatment's energy (DeMeuse, 2011). As a result, the surface is altered to enhance wettability and adhesion. Corona treatment is the most popular technique for surface modifying BOPP and other polyolefin films, and it has the advantages of continuous, inline operation and cost efficiency. Polar functional groups including hydroxyl, carbonyl, and carboxylic groups are added to the film surfaces during corona treatment. The film surface free energy increases when certain functional groups are present (Ebnesajjad & Landrock, 2015). The main problem, however, is that surface grafting after corona treatment necessitates extra processes that greatly delay the procedure and raise the cost of the film. Technology has been created to add organic grafting materials to the corona process natural air-based atmosphere. It has been successful to introduce Acrylic-Acid monomer vapour into the corona.

Research Objective

To analyse various factors and the sub-factors that contribute to overall downtime of a Biaxially Oriented Polypropylene film manufacturing machine.

Research Methodology

The research is based on two-different factors that contribute to machine downtime that are Process-related & Engineering-related. These two factors are further characterized in different sub-factors. The films used in this research are basically the BOPP and the PET films. Both of these films were running over 8 different lanes and thus the data was collected from each different lane for the same set of film. Each time the machine was stopped or came to halt total downtime reading was taken in minutes per day per line(M/D/L). Now these readings were further characterized according to the reason behind the halt.

Now after classifying these halt reasons among two different factors, it was compared to the preset targets by the company and their counteracts were made in order to further minimize them in future.

Data Collection and Analysis

The data collection was done on a regular basis for over a month. The data was divided among two different factors which are- Process Downtime and Engineering Downtime for BOPP films.

Table 1.1 Various Sub-factors of Process-downtime of BOPP

Process-downtime of BOPP												
Sr. No.	Sub-factors	Target / Line	OPP 1	OPP 2	OPP 3	OPP 4	OPP 5	OPP 6	OPP 7	OPP 8	Total D/T	D/T
1	Die-lip/CR/MDO/PRS cleaning	15	32		60	30	9	39	43	11	224	28
3	Film Breaks (TDO/TUT)	4	28		56	17	9	43	25	46	223	28
2	Others	0	37		46	12	18	10	58	25	206	26
6	Line/Product unstable	0	39		13	0	1	9	89	30	182	23
4	Product / µ Change over	15	17		31	6	8	29	59	26	175	22
7	Filter change	6	7		14	16	21	22	41	15	135	17
9	Trim return/trap	0	10		51	2	7	14	4	38	125	16
5	Over Stocking	0	0		32	0	0	25	10	0	66	8
8	RPG	0	5		0	24	20	0	0	0	49	6
10	CT roll puncture repair	0	12		2	0	0	2	3	0	19	2
11	TOTAL	21	186	0	304	107	92	192	333	190	1404	176

The Table 1.1 illustrates this factor of process-downtime, which is further divided among ten different sub-factors with each sub-factor having its predefined target of downtime. Further, there are eight different lanes where the BOPP webs are channeled. For each different lane a different name is given namely OPP which abbreviates as Oriented Poly Propylene following its lane number. The first sub-factor here is the Die-lip etc. cleaning. The molten polyethylene is submitted over the edges of the die-lips or the edges of the die which are necessary for the extrusion thus a regular time to time cleaning is done in order to make sure that the machine works properly and the extrusion process do not get effected. This necessary cleaning results in addition to machine downtime.

The OPP 2 or the lane 2 here shows a null data as it was not in use for the period while the data was collected. The next sub-factor that contributes to the downtime is the film break. The web running throughout the machine can break due to various reasons which ultimately results to machine coming at halt. The web is then taken out of the different rollers and the web is then again installed and this process can take quite some time as the broken film may stuck in between the rollers and can became hectic to remove. Line or product unstable is generally the downtime which occurs when any product which was supposed to be run on a certain lane but is by mistake run over to a different lane, thus the time taken to remove the product from the wrong lane and get it back to the correct lane is counted in line or product unstable downtime. The product changeover downtime occurs when a certain product gets ready and now a new product is to be mounted for manufacturing.

So, in order to do that the respective lane is firstly cleaned and certain pre- processing tasks are performed to make sure that the machine is free from any technical faults and is ready for another go. This consists of checking all the vitals of the machine, whether they are working properly or not, feeding the raw material for the new product, cleaning the leftover of the earlier product from the extruder and the extrusion of the new product which generally takes approximately ten minutes or so.

The next is the filter change which is also a very essential process which makes sure that the overall process of manufacturing goes hassle free. The extruder consists of the solid polymer which gets melted and then only then it is transferred on to the line. But there is a small portion of it which don’t melts properly and in order to keep it away from the line a filter is present in the extruder which basically prevents this solid portion to get to the line. Thus, it also requires a time-to-time cleaning or replacing of the filter which is roughly 48 hours or so depending upon the condition of the filter.

The trim return or trap means when the trimmed unwanted part of the film is sent back to the extruder for reusage, it sometimes gets stuck or get trapped in the conveying mechanism resulting in machine’s downtime. Overstocking is another sub-factor which comes under Process-downtime which is generally caused when the extruder is run beyond its specified limits or when the raw material feeding is done beyond the capacity of it to melt it ideally. This results in partial melting of the raw material and again adding minutes to the overall downtime.

The RPG or the Reprocessed Granules are sometimes added to the extruder in order to promote recycling and also a very cost-efficient move made by different companies. But it sometimes results in extruder blockage or improper functioning of it. As the RPG are basically reprocessed granules thus, they have slightly different properties than the regular fed raw material and due to this there’s also a difference in the melting point of it too.

Corona Treatment is basically done to increase the dyne value of the films in order to increase their property to adhere ink more effectively. So, in order to do this the films are basically hit with electrons and the backing roller which keeps the sheets moving is made up of rubber and it gets punctured due to this. Thus, the complete process of installing a new roller takes certain amount of time and results in increase in the downtime for the machine.

The next factor which is responsible for the overall downtime of machine while manufacturing is Engineering-downtime. This is basically the downtime which is caused due to the technical mishaps occurring during a running machine. This factor also comprises various sub-factors under it namely power-supply, mechanical etc. unlike previous factor of Process-downtime this factor does not have any target values as it is completely unpredictable and thus cannot be determined beforehand.

Table 1.2 Various Sub-factors of Engineering-downtime of BOPP

Engineering Downtime						
Sr .No.	OPP line	Dept.	D/T (Min)	D/T (Min/day)	Prod. Loss in Min.	Details of D/T
1	OPP 1/3/4/5/6/7/8	Power	1809	76	97	Power dip
2	OPP 7	E&I	1216	64	64	Preheat LLF heater short-circuited
3	OPP 7	E&I	1185	62	62	Drive 6 converter faults
4	OPP 6	Mech	924	38	23	PRS nip roll no-1 gap set
5	OPP 7	E&I	715	38	38	PRS drive converter fault
6	OPP 6	E&I	634	26	16	TBR top corona motor change
7	OPP 7	E&I	521	27	27	plc server problem
8	OPP 3	Mech	445	19	17	MDO threading chain problem, chill roll movement problem
9	OPP 8	Mech	442	19	36	MDO Nip-roll (55min) &, TDO Track Cool-pump off (387min)
10	OPP 3	Mech	431	19	17	D/S EPC Malfunction/D/S EPC Change
11	**Total**		**8322**	**388**	**398**	

The first sub-factor is the Power related issues that occurs in the plant resulting in complete stoppage of machine. This effects each single lane running at the time and thus in the **Table 1.2** too all the OPP from 1 to 8 are shown to be affected by it. Another factor here is the E&I that is Electrical or Instrumental error.

For the lane 7 it is caused due to the short-circuiting of the pre-heating LLF heater which resulted in line instability and thus is countered by either repairing or changing the heater in order for smooth running of the process once again. The previous lane here again suffered electronics failure which resulted in the downtime for the machine. The drive encoder for the lane 7 malfunctioned which resulted in line stoppage and overall contributed to downtime.

Although this kind of malfunctioning can be countered by periodic checkup. In the lane 6 the Pull Roll Stand (PRS) had a mechanical failure, due to the nip roller's creating a gap between the set of other rollers, it is used for pressing the film against the Corona treatment roll and the Guide roll. It thereby helps to prevent the occurrence of air bubbles between film and cooling roll.

The lane 7 again had an instrumental error due to the encoder malfunction and it resulted in PRS drive convertor jamming. The PRS cooling roll drive motor of lane 6 came out to be faulty and was replaced with top CT (Corona Treatment) roll drive motor. But these kind of motor malfunctions in these units are basically countered using a spare motor. The PLC (Programmable Logic Controller) 's server of lane 7 had a communication problem due to the network switch's malfunction due to which lane was stopped and with the help of cable the communication was provided without using network switch. The lane 3 MDO (Machine Direction Orientation) had a threading chain problem due to the damaged guide ring and due to excessive wear & tear the gearbox which drives the chill rollers, the chill roll movements were seized.

On the lane 8 MDO's Nip-roll bearing was jammed and thus required installation of a new one. This lane also had cooling pump's shut-down because of pressure drop in the pump itself. There is a biaxial orientation process occurring while manufacturing the BOPP and heating to high temperatures is done in order for the polymer to be stretched first in machine-direction orientation and later in TDO (Transverse Direction Orientation) and requires cooling after that thus due to the cooling pump's malfunctioning the pressure had to be adjusted manually to the operational values.

Data Analysis

The downtime is basically divided among two categories which are Process-downtime and another is the Engineering-downtime.

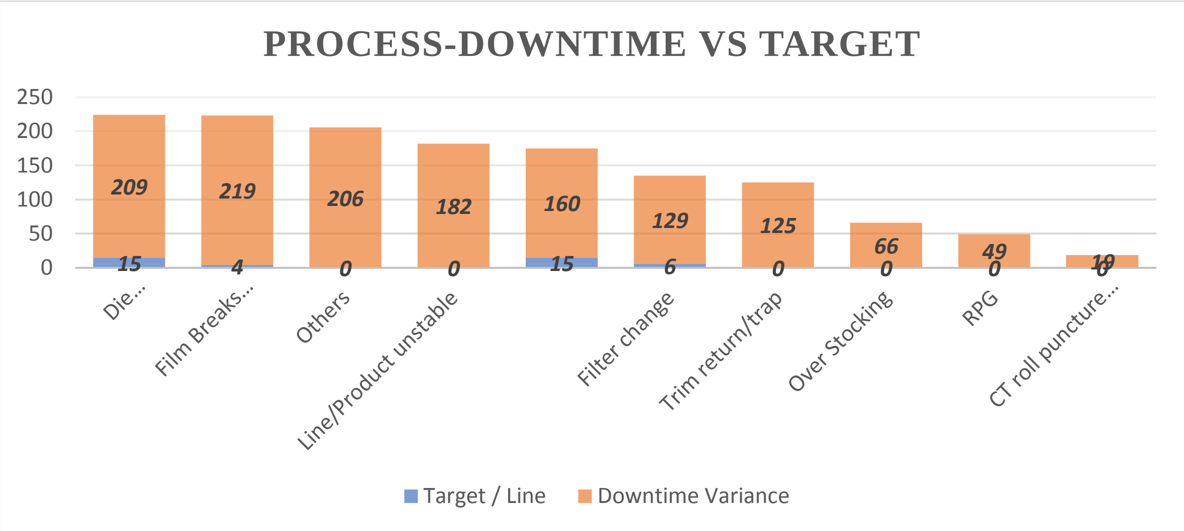

Chart 1.1 Process-downtime vs Preset Target for each downtime

The chart 1.1 basically shows the stacked graph plotted between the **Total-Downtime** in minutes over the Y-axis and various **Sub-factors of Process-downtime** over the X-axis. The blue part of the bar represents the target which is set by the company. The bar in orange represents the delta or the variance which comes in the downtime value for all these sub-factors. The graph shows that the maximum sub-factor that contributes to the downtime is the Die-lip cleaning whereas the least contributing factor is the CT roll repair. The most deviating sub-factor on the other is Film Breaks with maximum deviation value of 219 minutes than the targeted one.

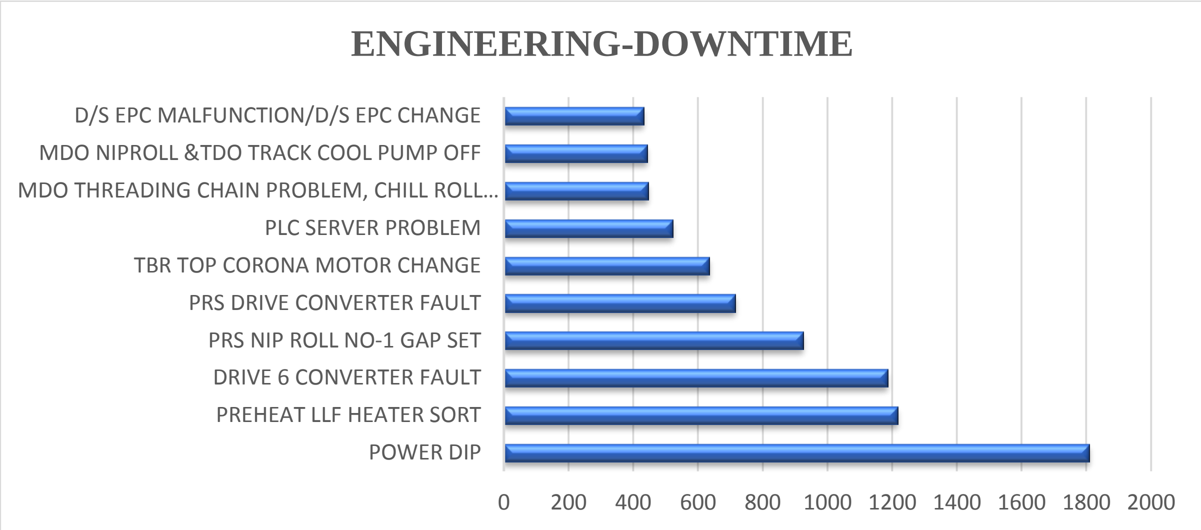

Chart 1.2 Values of Total-downtime for various subfactors of Engineering-downtime

The Chart 1.2 shows the overall comparison between the sub-factors of the **Engineering-downtime** vs the **Total-downtime Value** for each of them. It shows that the maximum downtime caused due to this factor is because of the power-dip or the uneven power supply provided to the machine itself. Whereas the least effecting sub-factor of Engineering-downtime is EPC malfunctioning or its change.

Results and Discussion

The research shows that the downtime of a BOPP manufacturing machine can be categorized among two different factors which are **Process-downtime** and **Engineering-downtime**. The machine consisted a total of eight Oriented Poly Propylene or lanes based on which the complete data is collected. The result shows that for the Process-downtime the overall value for downtime was 1404 minutes. The downtime taken for each day throughout the research was calculates as minutes per day for which the machine is stopped. The least effecting sub-factor in the Process-downtime was CT roll repair with a value of 19 minutes whereas the most contributing factor is Die-lip and other cleaning with a contributing value of 224 minutes. As for the Engineering-downtime the overall contributing value for it was 8322 minutes. The least contributing sub-factor in it is the EPC Malfunctioning with a value of 431 minutes whereas the most contributing downtime factor for the this and for the overall research was the Power-dip which resulted in a total of 1809 minutes of downtime contributed alone.

Conclusion

In this research it was found that there are basically two major factors among which the overall machine downtime depends. The first factor is the Process-downtime which basically covers the downtime related causes occurring during the various processes while the film is being manufactured with the least effecting sub-factor in the Process-downtime was CT roll repair and the most effecting one to be the Cleaning of various parts like Die-lip, Corona-Roll etc. While for the second major factor that is the Engineering-downtime had the most effecting sub-factor as EPC malfunctioning whereas the most contributing one as Power-dip. Furthermore, comparing these two major factors the Engineering-downtime came out to be more contributing factor for the downtime as compared to the Process-downtime.

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