SHEET EXTRUSION FOR THERMOFORMERS

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Abstract

Thermoformers can achieve many advantages by producing sheet in house. Sheet extrusion systems for in-line thermoforming and off line use are available in a wide range of sizes to suit almost any consumer or industrial thermoformed product application.

The benefits of in-house sheet extrusion will be reviewed. Thick cut to length, thin roll stock, and in-line applications will be discussed.

The methods of determining the size of the required sheet extrusion line and the capital equipment requirements will be used to determine the cost per pound of extruded sheet to enable you to calculate your savings.

Discussion

As a thermoforming company grows in volume it will reach a critical mass where it can consider extruding its own sheet. Typically this occurs somewhere around the 2,500 to 4,000 metric ton per year (5,500,000 to 8,800,000 pounds per year) sheet consumption level. This quantity is typical of a sheetline with a 114mm (4-½ inch) extruder.

The general range of outputs of various size extruders is shown in Table 1. Exact rates will depend on the polymer, width, and thickness of the sheet being run. The cooling capabilities of the rollstand and linear line speed may limit the top extruder rate.

Typically one high output sheet extrusion system can supply enough sheet for 2 to 4 small thermoformers.

In addition to the lower cost of in-house extruded sheet there are many additional benefits. With the ability to schedule your sheet production to match actual thermoforming orders you can reduce warehouse inventory levels significantly especially if many different colors are required. This flexibility will also allow you to quickly respond to meet short delivery requirements.

Sheet quality levels specific to your end products can be established and maintained. If selling by the piece and not by weight you can set gauge targets close to the minimum allowable thickness. This can result in significant material savings over the course of the year.

Regrind from the thermoformers can be quickly reprocessed in house at full value instead of being sent back to some remote processor thus saving on freight and material losses en route.

Figure 1 shows a 114 mm (4 ½ inch) sheet co-extrusion system designed to produce 1.5 - 4 mm (0.06-0.160 inches) thick HIPS sheet 1240 mm (49 inches) wide at a rate in excess of 900 Kg/hr (2000 lb/hr). The vented extruder is followed by the following equipment. A hydraulic slide plate screenchanger which is used to filter out any foreign matter that may be in the melt. A melt pump that will deliver a constant volume of melt to the coextrusion feedblock. The satellite extruder is not shown for clarity.

From the sheet die the melt web goes into the bottom nip of a 3-roll gear driven stack. The reason we go up-stack for this application is to keep the height of the extruder and die closer to floor level. Other reasons would be to keep the surface produced by the center roll facing upwards for easier inspection and away from contact with the conveyor rolls. Each roll is individually temperature controlled by a high volume circulating system located beneath the conveyor. Soon after the sheet leaves the last cooling roll the thickness is measured using a gamma backscatter thickness gauge. The sheet is then cooled some more on the conveyor before being trimmed to width and covered on one side to protect the surface. The sheet is then automatically counted and stacked on pallets. (Hopefully on twin walled thermoformed plastic Pallets)

Figure 2 shows another 114 mm (4 ½ inch) sheet coextrusion system but instead of producing cut to length sheet it is making 1.5 meter (5 foot) diameter rolls to be used to feed offline thermoformers. The top roll on this stack is smaller than the center and bottom rolls to allow for closer die approach when polyester is run.

Figure 3 shows a much shorter 114 mm (4 ½ inch) coextrusion system producing sheet for direct inline thermoforming. On this line the sheet is cooled only enough to have sufficient strength to be transferred into the thermoformer.

This results in the need for less reheating of the sheet in the thermoformer and a more uniform through the sheet temperature profile because the center is now hot. This results in energy savings and a thermoformed product with less residual stress. This will result in a lower tendency for a polypropylene container to warp when being hot filled.

In line thermoforming also does not require edge trimming so the quantity of regrind is reduced plus you can reuse skeletal regrind immediately saving storage space and manpower plus it minimizes the possibilities of contamination and other material losses.

Another advantage of forming sheet in-line is that problems with forming the sheet can be detected immediately and corrected where before several shifts worth of rolls could be made and the problem not detected until the first roll was thermoformed off line.

In-line thermoforming systems are in production with sheet outputs into thermoformers of 2700 Kg/hr (6000 lb/hr). Todays larger and faster thermoformers where product volumes justify their output produce much larger efficiencies when compared to the several small off thermoformers supplied by a single high output sheet extrusion system. Smaller in-line systems 500 kg/hr (1100 lb/hr) and up will also provide many of the above benefits.

Selecting a sheet extrusion system is fairly simple if you are currently thermoforming and know the yearly weight of sheet used. You may want to add an additional amount to cover future growth.

The yearly requirement should be divided by 5000 nominal hours for a 5 day workweek or 7000 hours for a 7 day work week. Both hourly numbers assume a conservative uptime of 80%. This allows for changeovers, maintenance and other reasons for downtime.

If you are just planning to get started in the thermoforming business you can calculate the required out put of the sheetline as follows.

For sheet fed thermoformers multiply the sheet thickness by the sheet width and length. Then multiply this volume number by the weight per cubic volume of the polymer you are using to obtain the weight of the sheet. Finally multiply the weight per sheet by the number of sheets of that thickness that the thermoformer will use per hour to obtain your required hourly extrusion output. Add approximately 5% to allow for edge trim.

Roll fed or inline-forming rates will be calculated in a similar manner. In this case the hourly rate requirement is calculated by multiplying the sheet thickness by the width and length of the molds' sheet requirement. Multiply this volume number by the weight per cubic volume of the polymer that you are using to get the sheet weight per cycle. Then multiply by the number of cycles per hour to obtain your hourly extrusion requirement. For producing rollstock add 5% to allow for edge trim. Inline formed sheet is generally not edge trimmed.

Knowing the hourly output requirement the size of the required sheetline can be determined by referring to the nominal extruder output rates listed in Table one.

If the product has a coextruded structure then the total output must be broken down into the amount required by each material in the structure before going to the table to select extruder sizes.

Your friendly consultive sheet extrusion sales engineer will be happy to assist you in selecting and pricing the proper size equipment for your application.

We are now ready to calculate the cost to produce in house sheet. For this example we will be coextruding a two layer high impact polystyrene sheet.

The equipment will be basically as shown in Figure 2. It will consist of a 114 mm (4 1/2 inch) 30/1 L/D primary extruder with controls and a 187 kW (250 HP) DC Drive followed by a hydraulic screenchanger and melt pump with an AC variable frequency drive.

The satellite extruder is a 90 mm (3 1/2 inch) 30/1 L/D with controls and a 112 kW (150 HP) DC Drive, hydraulic screenchanger and melt pump with an AC variable frequency drive.

Both extruders feed into a coextrusion feedblock and then into a 1830 mm (72 inch) wide die feeding into a rollstack that has 600 mm (24 inch) diameter cooling rolls in the bottom and center positions and a 450 mm (18 inch diameter top roll. The cooled sheet is edge trimmed and center slit into 2 webs before being wound into 1.5 meter (5 foot) diameter rolls on hydraulic powered winders.

The cost of the above equipment is approximately $ 1,200,000. A thickness gauge would cost $76,000.

Material handling, blending and edge trim grinding costs would be approximately $60,000.

The total equipment cost is $1,336,000 to which we add 10% ($134,000) for installation expenses for a capital investment total of $1,470,000.

The above does not include a water tower, air compressor or power substation which should be added if required.

We will now calculate operating costs for a 7000 hour operating year.

Factory floor space 370 square meters (4000 square feet) at $86.11 per square meter ($8.00 per square foot) calculates to $4.57 per hour.

The equivalent of 1 1/2 workers and 50% of a supervisor’s time at a total hourly cost of $50.00.

Electrical power 350Kw @ $0.11/Kw = $38.50 per hour.

Depreciation of the $1,470,000 installed capital equipment plus 30% for cost of money over five 7000 hour years gives an hourly cost of $54.60 adding 10% for maintenance costs produces a total hourly operating cost of $60.06 per hour.

The total operating costs for floor space, salaries, electrical power, depreciation and maintenance is $153.13 per hour.

The net output rate of this line for a 70% base layer with a 30% cap layer coextruded structure 1.5mm (0.060 inches) thick is 1110 Kg/Hr (2440 lb/hr). Assuming 95% efficiency the average hourly output becomes 1055 Kg/hr (2321 lbs./hr). Dividing the $153.13 hourly operating cost by this number gives you a cost of $0.145 per Kg ($0.066 per pound).

Adding the material costs of High Impact Polystyrene at $0.81 Per Kg ($0.37 per pound) which includes a 3% waste factored in. You obtain a projected sheet cost of $0.955 Per Kg ($0.436 per pound).

The numbers used in this example are approximate but indicate the savings that will be obtained by extruding your own sheet when compared to sheet that is purchased.

Following the above calculations with values for your own materials and plant location will yield your projected cost for in house extruded sheet.

TABLE ONE

Nominal 30:1 L/D Extruder Outputs

Material	65 mm (2-1/2 inch)		90 mm (3-1/2 inch)		114 mm (4-1/2 inch)		150 mm (6 inch)		200 mm (8 inch)	
	kg/hr	lb/hr	kg/hr	lb/hr	kg/hr	lb/hr	kg/hr	lb/hr	kg/hr	lb/hr
HIPS	190	400	490	1080	820	1800	1460	3200	2600	5700
PP Homopolymer	110	240	270	600	450	1000	800	1780	1420	3160
PP Copolymer	140	300	330	720	550	1200	980	2130	1740	3800
PET	200	430	380	840	640	1400	1140	2500	2020	4420
ABS	170	370	330	720	550	1200	980	2130	1740	3800

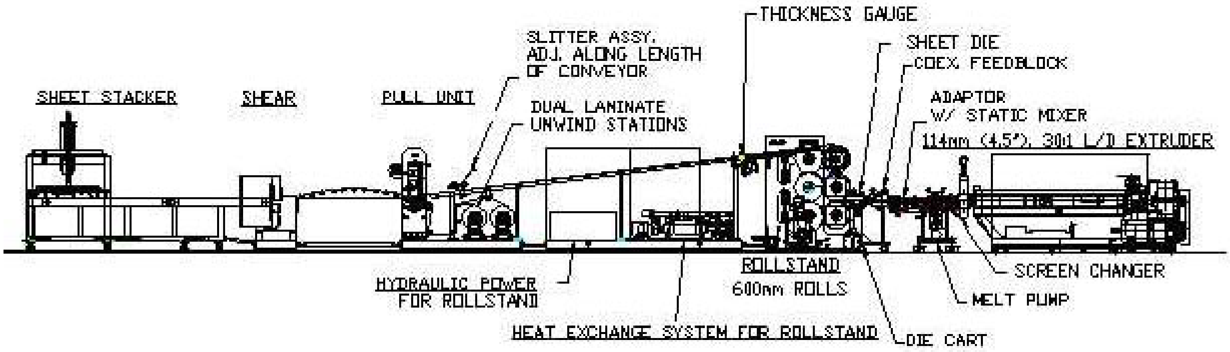

FIGURE 1
114mm (4½") SHEET EXTRUSION SYSTEM FOR CUT SHEET

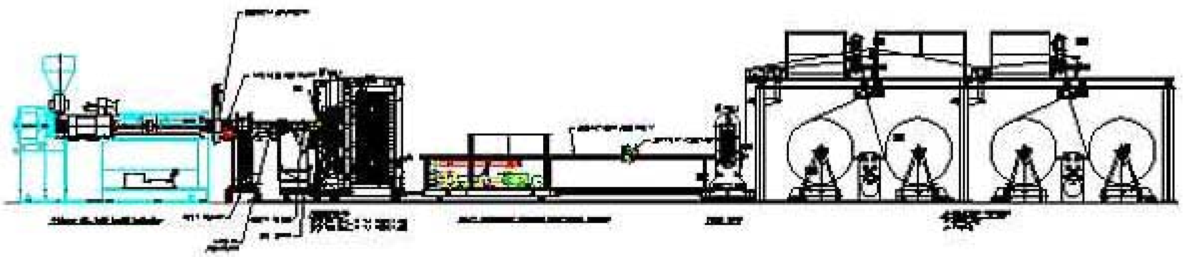

FIGURE 2
114mm (4 ½") SHEET EXTRUSION SYSTEM FOR ROLLSTOCK

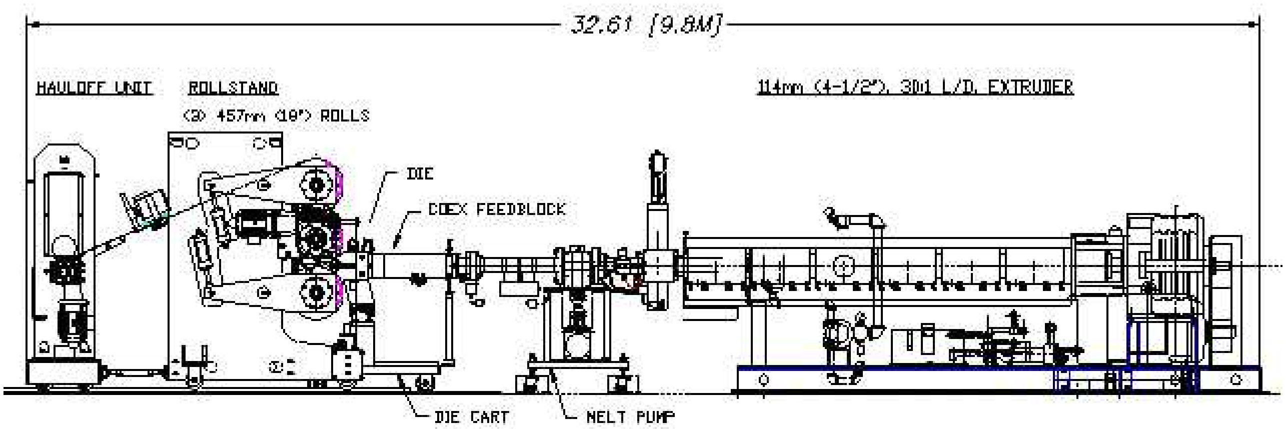

FIGURE 3
114mm (4 ½") SHEET EXTRUSION SYSTEM FOR INLINE THERMOFORMING

Keywords: Sheet Extrusion, In-Line thermoforming, sheet costs.