



Thermoforming Conference[®]

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In-line Co-extrusion and Thermoforming Technology for Bicolor PP Cups with Mineral Fillers Fitting Existing Lids



Requirements of the client:

Goal No. 1:

Fitting existing lids on newly designed drinking cups which have to be produced with following characteristics:

1. Two different volumes meaning two different weights/ thicknesses
2. Each cup size/volume has to be produced with a different material formulation:

2.1 Monolayer with transparent virgin Polypropylene material



2.2 Co-extrusion A-B-C

- A. Virgin Polypropylene + red masterbatch
- B. Regrinded Polypropylene (in-line) + Polypropylene with mineral charges
- C. Virgin Polypropylene + white masterbatch



How to prevent lid fitting problems due to different material shrinkage and different thermoforming machine parameters?

Requirements of the client:

Goal No. 2:

Optimize material composition by defining and rationalizing:

- Material thickness to guarantee good and constant rim-rolling
- Percentage of calcium carbonate or talc filler in order to ensure good top load
- Masterbatch percentage on white and red layer ensuring at the same time good color coverage



Implications:

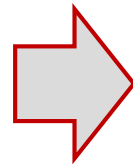
Different material contraction on different cup sizes while maintaining the lid geometry and specifications.

How to solve the problem?

1. Possibility to control the production process in order to obtain the same diameter using materials with different shrinkage dimensions.
2. Control rimming process temperatures and the positioning of the rimming screws.
3. Defining optimal material mix by dosing the compound composition.

How can we guarantee the offered solution?

Pilot mold testing **single cavity** ≠
multiple cavities on machine



Solved by studying following parameters on testing bed in order to eliminate the unknown variables:

- Cycle times
- Temperatures (mould + sheet)
- Mould design

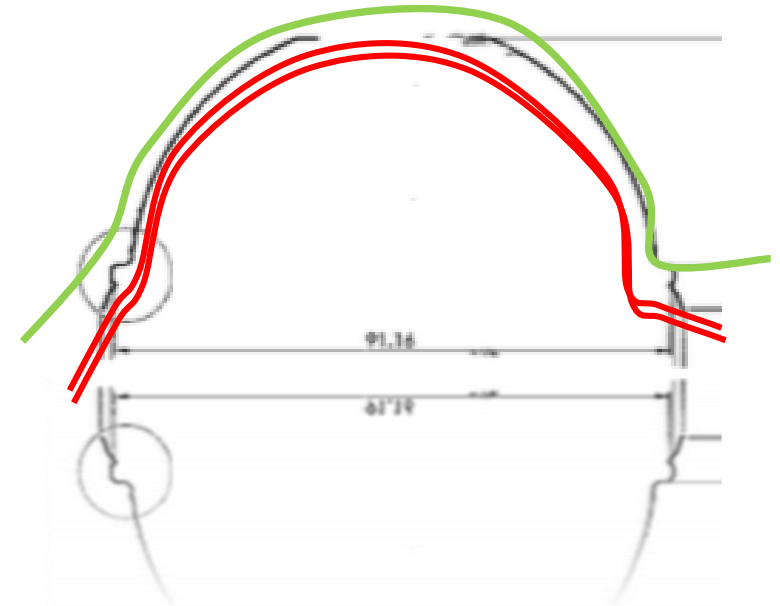
- 1) Cutting diameter had to be defined
- 2) Material shrinkage on primer virgin Polypropylene material (variable according material of the supplier)
- 3) Material shrinkage on co-extrusion with mineral filler (depending on the % and type of the filler)
- 4) Rim rolling parameter (design and position of the screw + temperature setting) to compensate different final diameters.
- 5) Thermoforming parameters (sheet temperature, cooling time, down holders, plug assist activation, etc.)

In order to control the final diameter, residual material on the U-rim maintaining good cycle times and material distribution of the cup.



- Analyzing the lid thermoforming process
 - negative vs. positive male mold: Two different material thicknesses
- Internal dimension of the lid is influenced by material thickness and thermoforming process.
- Customer has to define which range of the final cup diameter is fitting on the existing lid.
- Customer defined a range from 92 to 92,2 mm

Dome lid



Plane lid



SECOND STEP



Produce mono-cavity mold for testing:

- A. Real monolayer Polypropylene raw material shrinkage
- B. Real multilayer Polypropylene sheet with mineral filler shrinkage

WM had to define cutting diameter on mold testbed taking into consideration :

- Final diameter of the contraction after rim rolling
- Polypropylene (PP) standard shrinkage 18/1000
- Final diameter 92 mm after rim rolling with virgin Monolayer Polypropylene

Third step

While the test mold was in production, WM Thermoforming Machines produced:

- Sheet extrusion line
- Rim rolling unit

Advantage: possibility to extrude the material and rim the cups on a WM in-line machine for better process controlling.



- WM detected that the supplied virgin Polypropylene material from the customer had less shrinkage.
= **15/1000 instead of standard 18/1000**
- WM determined a shrinkage % being affected using mineral filler
= **12,5 /1000 with 15 % of talc in the sheet material.**
- WM defined the diameter contraction on the rim rolling process using different temperatures and screw configurations in order to determine the gap adjustment process.
= **possibility to adjust the standard rim rolling contraction + 9% OR – 18 %**
- Having an external diameter of 92,37 mm, it will be possible to adjust the rim rolling process in order to obtain an external diameter of 92,17 mm
- If we have an external diameter of 91,95 mm it will be possible to adjust the rim rolling process to obtain an external diameter of 92,05 mm

Results of rimmed cups

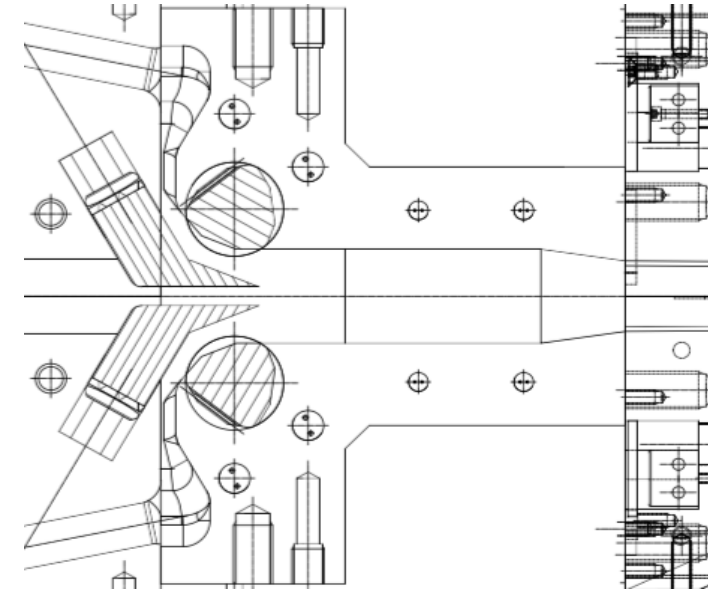
Cutting diameter	material w/shrinkage %	Diameter virgin PP	Diameter PP w/ talc
94,85 mm	18	92,00	92,47
	17	92,15	92,59
	16	92,29	92,71
	15	92,43	92,83
	14	92,57	92,95
94,70 mm	18	91,86	92,33
	17	92,00	92,45
	16	92,14	92,56
	15	92,29	92,68
94,55 mm	14	92,43	92,81
	18	91,71	92,18
	17	91,86	92,30
	16	92,00	92,42
94,40 mm	15	92,14	92,54
	14	92,28	92,66
	18	91,57	92,04
	17	91,71	92,15
94,25 mm	16	91,85	92,27
	15	91,99	92,39
	14	92,13	92,51
	18	91,42	91,89
94,50 mm	17	91,56	92,01
	16	91,71	92,13
	15	91,85	92,24
	14	91,99	92,37
94,50 mm	18	91,67	92,13
	17	91,81	92,25
	16	91,95	92,37
	15	92,09	92,49
	14	92,23	92,61

- All the final diameters marked in yellow are matching previous range specification from the client – 92-92,2 mm.
- The customer required to have a wide range of material selection looking to use their existing material with 15/1000 shrinkage on transparent cups and all the range up to 18/1000 for Bicolour cups.
- Without having the possibility to carry out these tests, the only possibility was to select the cutting diameter and obtaining the 92 mm with maximum shrinkage through post forming + rimming with virgin Polypropylene between 94,25 mm and 94,85 mm.
- After carrying out all the tests, WM decided to produce the final mould with a 94,5 mm cutting diameter in order to give the client more flexibility during the material selection.

FINAL MOLD DESIGN HAS BEEN DEFINED

Material specification:

- Material structure and composition has to be defined before building up the extrusion section .
- During the selection process, the customer asked us to have the following material structure :
 - A Virgin Polypropylene material + Masterbatch RED 5 % – **Total 22,5 %**
 - B 10% Virgin material + Regrinded Polypropylene from process **37 % + 8%**
(PP with 70 % calcium carbonate)
 - C Virgin Polypropylene material + Masterbatch white 5 % – **22,5 %**
- WM did built up the feed block taking into consideration previous specification but leaving the opportunity to improve the process .



Material savings :

Prior to receiving the final mold for carrying out the trials, WM calculated the material cost savings considering the customers' standard requirements and with the goal to improve the efficiency of the line in terms of material costs.

Lowering the production material costs was possible by reducing the color masterbatch % and/or increasing the compound with mineral filler.

Reducing masterbatch %

1. The quality of the cup has to be maintained and the quality of the masterbatch has to be verified in order to understand how to proceed within the process.
1. Reducing external layer increasing % of masterbatch
2. Reducing external layer increasing masterbatch quality and so pigment concentration

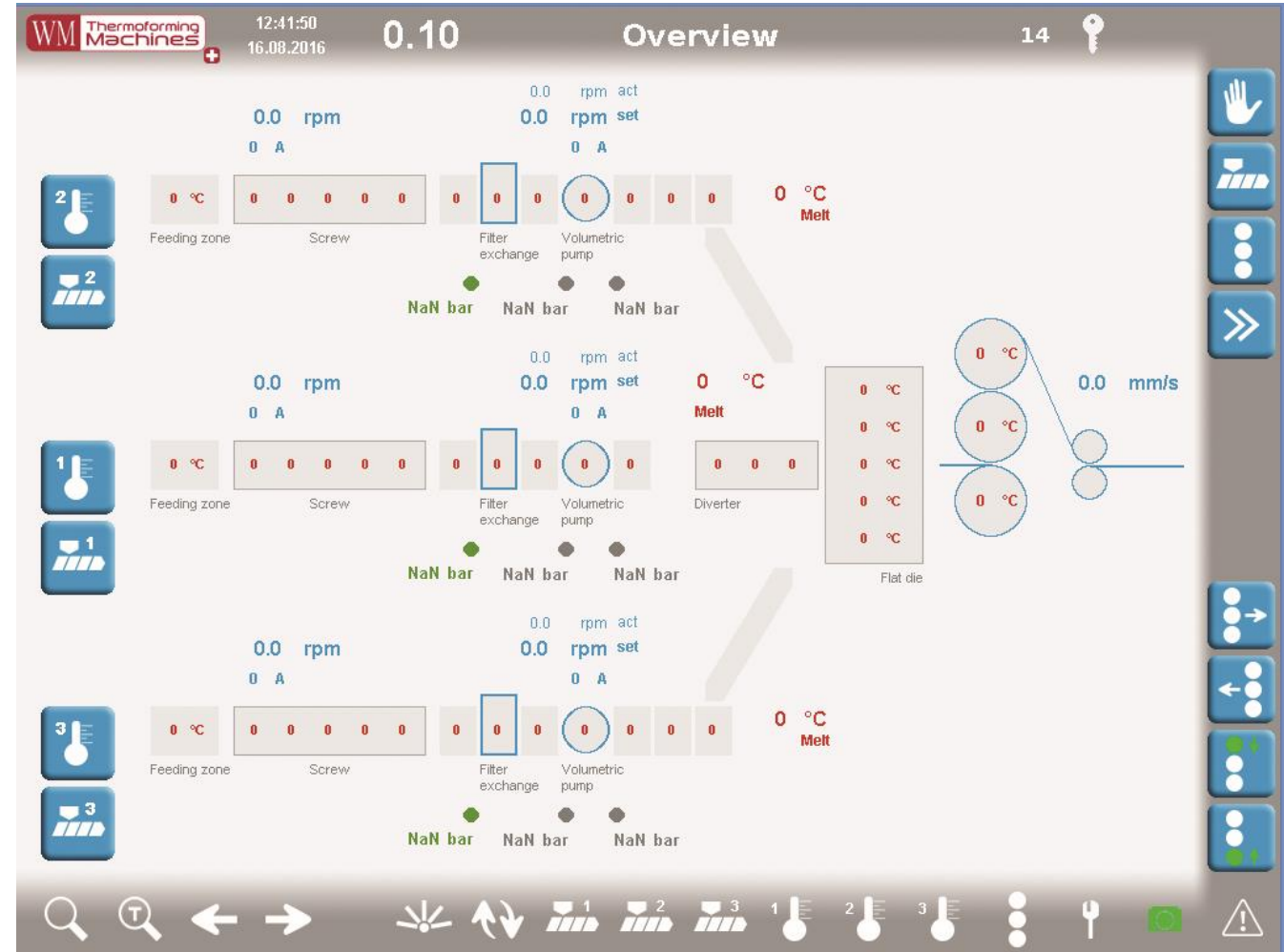


Compound with mineral fillers (CaCo_3)

1. Using more fillers means more wearing on machine and molds
2. Using more fillers maintaining the same product weight and generating reduced sheet thickness
3. Thermoformability and mechanical characteristics of the cups are to be checked

Goal 2: Cost efficiency through optimizing material composition

- Masterbatch percentage in recycled material
- Material thickness at a max.
- Total cost material



- Calculation of material feeding of the extruder depending on the variation of material density and composition (CaCo3 /Talc).
 - Calculation and setting of the rpm of the volumetric pump according required productivity and eventual load %
 - Auto self setting of the extruder, calender and thermoforming machine.

Goal 2: Cost efficiency through optimizing material composition:



First trials - Starting point - 16 Oz 6,5 grams 38 cavities 28 Cycles/minute

	Virgin PP	Masterbatch Red 5%	Masterbatch White 5%	Compound PP-70% Caco3	Regrind	
Euro /Kg	1,3	9	2,6	1	0	
% of the layer						
22,5	21,4	1,1	0	0	0	
55	10			8	37	
22,5	21,4		1,1	0	0	
Kg/h						
22,5	139	7,3				
55	65			52	240,5	
22,5	139		7,3			
Euro /h						Total
22,5	181	65,8				246
55	84,5			52	0	136,5
22,5	181		19			200
Total Euro /h						583

CaCo3 in the total sheet 12,2% - Low

Goal 2: Cost efficiency through optimizing material composition:

16 Oz 6,5 grams 38 cavities 28 Cycles/minute

	virgin PP	Masterbatch Red 5%	Masterbach White 5%	Compound PP-70% Caco3	Regrind	
Euro /Kg	1,3	9	2,6	1	0	
% of the layer						
20	19	1	0	0	0	
60	13			10	37	
20	19		1	0	0	
Kg/h						
20	123,5	6,5				
60	84,5			65	240,5	
20	123,5		6,5			
Euro /h						Total
20	160,55	58,5				219
60	109,85			65	0	175
20	160,55		16,9			177
Total Euro/h						571

- We try to increase % of masterbatch dosing but due to medium quality of the masterbatch the final distribution was not satisfying.
- CaCo3 in the total sheet: 15 % Material thickness less but we had good results on the forming
- 2% savings on total material cost = 82.000 Euro /year or 96,000 USD (based on 8.000 hours with 94 % efficiency)

Goal 2: Cost efficiency through optimizing material composition:

16 Oz 6,5 grams 38 cavities 28 Cycles/minute

	PP virgin	Masterbatch Red 8%	Masterbatch White 8%	Compound PP- 70% Caco3	Regrind
Euro /Kg	1,3	12	2,9	1	0
% of the layer					
5	4,6	0,4	0	0	0
85	38			10	37
10	9,2		0,8	0	0
Kg/h					
5	29,9	2,6			
85	247			65	240,5
10	59,8		5,2		
Euro /h					
5	38,87	31,2			70,07
85	321,1			65	386,1
10	77,74		15,08		92,82
Total Euro /h					548,99

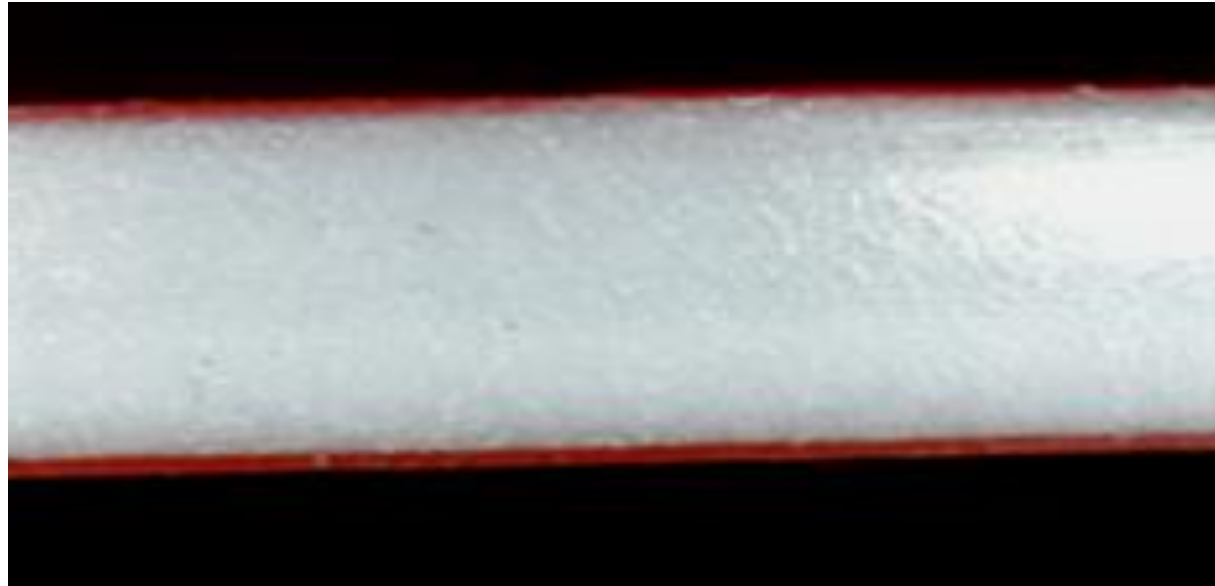
Increased concentration pigment Master Bach + New supplier with higher quality and price :

- + 33% Red Masterbatch costs
- + 11% White Masterbatch costs
- We increased dosing % from 5% to 8%
- CaCo3 in the Total sheet 15 %
- Material thickness is less but we had good result on forming without stressing too much the extruder and mold.

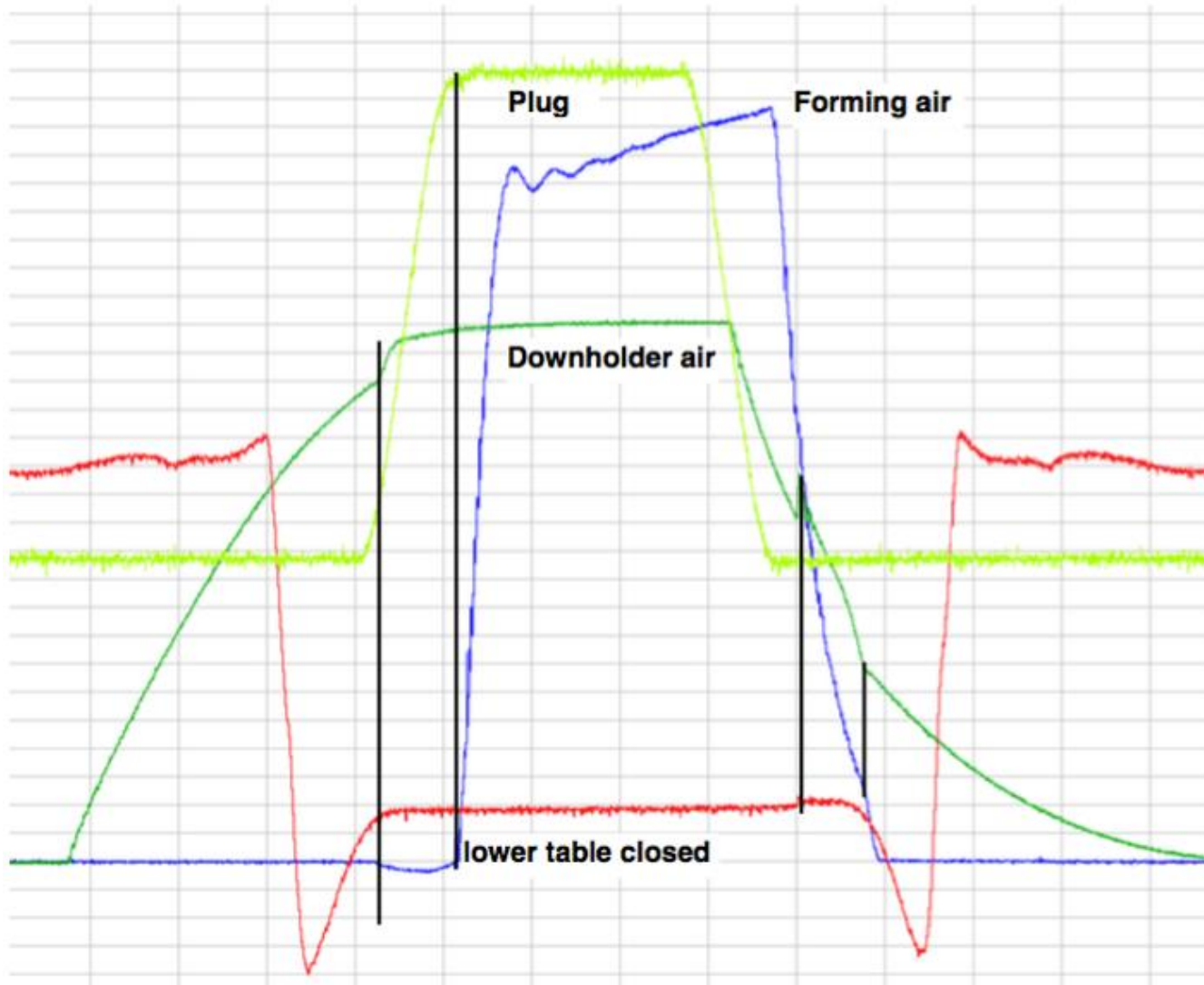
6% on total material cost =

235.000 €/year or 274,000 USD savings (based on 8.000 hours with 94 % of efficiency)

Goal 2: Cost efficiency through optimizing material composition:



Tooling: Cycle time parameters



Sensors inside the mold are showing to our technicians if we are forming with the right theoretical forming process .
In this way it's faster to find the right parameters when you have to change a lot of time material composition , thickness and weight to find.
The final material composition to safe money on your process !!!





- Forming time (= lower table closed) in [ms]
- Machine moving time in [ms]
- cycle time in [ms]
- cycle rate in [1/min]

- forming air 0..4 bar in [ms]
- venting time in [ms]
- max. forming pressure in [bar]
- average plug speed (70%) in [m/s]
- plug stroke in [mm]

- max. down holder air in [bar]
- down holder air 0...3,8 bar in [ms]
- down holder air during cutting in [bar]

