Reduction of Polypropylene Extrusion Defects

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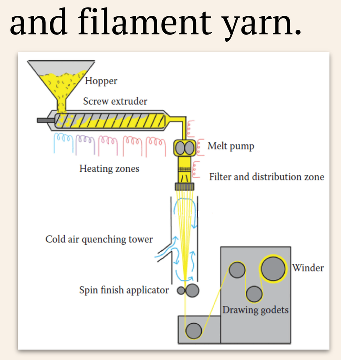
BACKGROUND

Drake Extrusion, located outside Martinsville VA, is a polypropylene extrusion company which services two main product lines, staple fiber and filament yarn.



Drake Extrusion is experiencing a specific defect called “blowouts” occurring on each of their 18 machines causing material loss and quality issues in its filament extrusion process.

Objective: Reduce Blowouts by >25%

QUANTIFYING THE PROBLEM

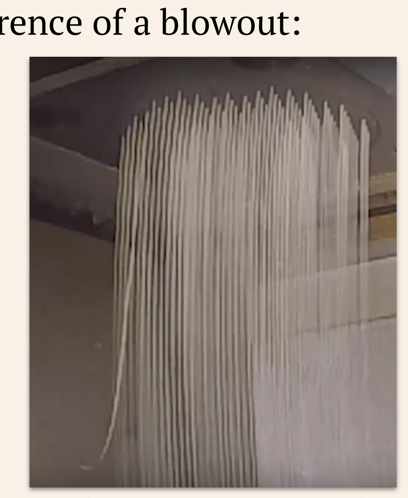
At the beginning of the project there was no data on the rate of occurrence of blowouts and their impact, only estimates. The team chose to spend time collecting data to understand the problem.

18 Machines	7 Variables	3 Weeks
• Validated on 1 machine • Expanded to all machines on 1st shift	• Color, machine, side, location on pack, date, time, weight	• >250 Occurrences • >1700 data points

A time study was conducted to determine the time to reset a line after a blowout. It was found it took the operators an average of <u>**7 minutes**</u> to reset the line; <u>**4 minutes**</u> to notice the defect and <u>**3 minutes**</u> to fix the line.

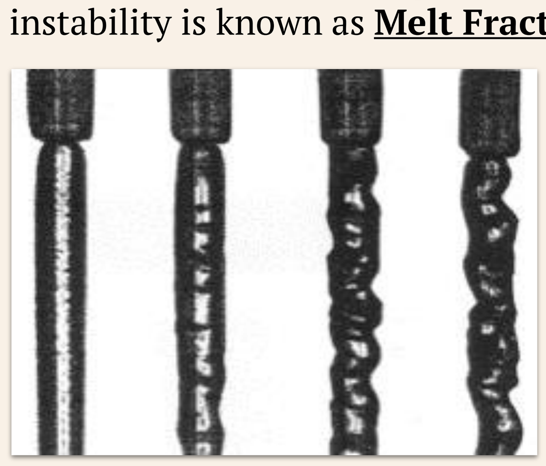
A GoPro was utilized to record the occurrence of a blowout:

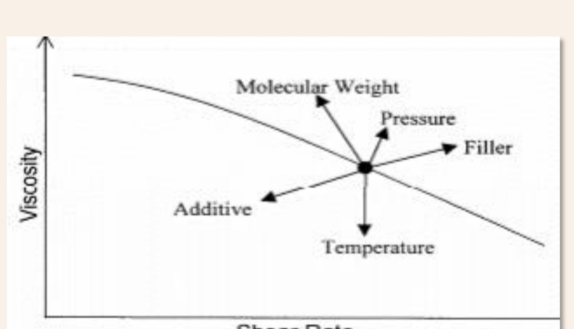
No Blowout



Blowout Occurred

From the video, it was determined the most likely cause of blowouts is the machine settings causing the material to have excessive shear stress at the point of extrusion. The strands were wavy and colliding with each other, resulting in the blowouts. This condition of material instability is known as <u>**Melt Fracture**</u>.





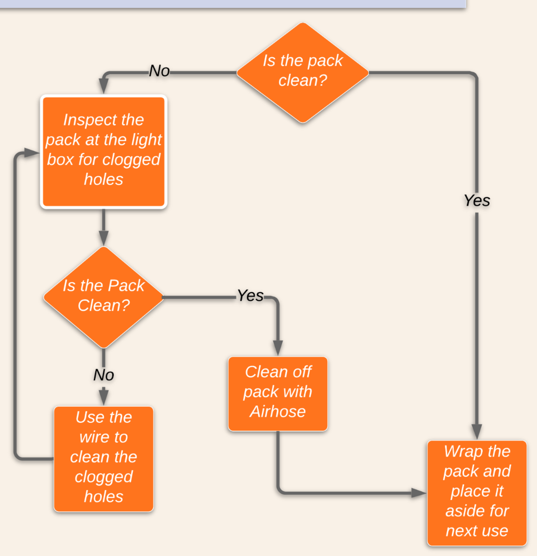
The team hypothesized that altering the viscosity using the variables temperature and pressure would alter the shear stress and therefore the occurrence of blowouts. Testing in the form of a <u>**Design of Experiments (DOE)**</u> needed to occur to determine the most optimal settings. <u>**Standardization of the process**</u> before testing was crucial to the validity of tests.

CURRENT STATE

Blowouts currently cost Drake an estimated <u>**30.24 hours**</u> of lost production time per day. Over time, microscopic defects can form in the extrusion holes of the spinnerets, which can cause the blowout defect, among other issues. As Drake does not track packs, it is impossible to tell which packs are good quality and which ones need to be replaced. Drake is in the process of etching all spinnerattes with numbers for tracking.

Impact of Blowouts	
~2.5	Defects per Hour per Machine
~1080	Defects per Day
24%	Of Defects Causing Downtime
19%	Of Defects Causing Material Waste
~30.2	Hours of Downtime per Day

High potential for variation in pack cleaning process: operators have to make a lot of decisions based and each has a different process. Any error in cleaning can potentially cause defects down the line in the extrusion process. Operators retrained in the importance of following standard work procedures.



DESIGN OF EXPERIMENTS

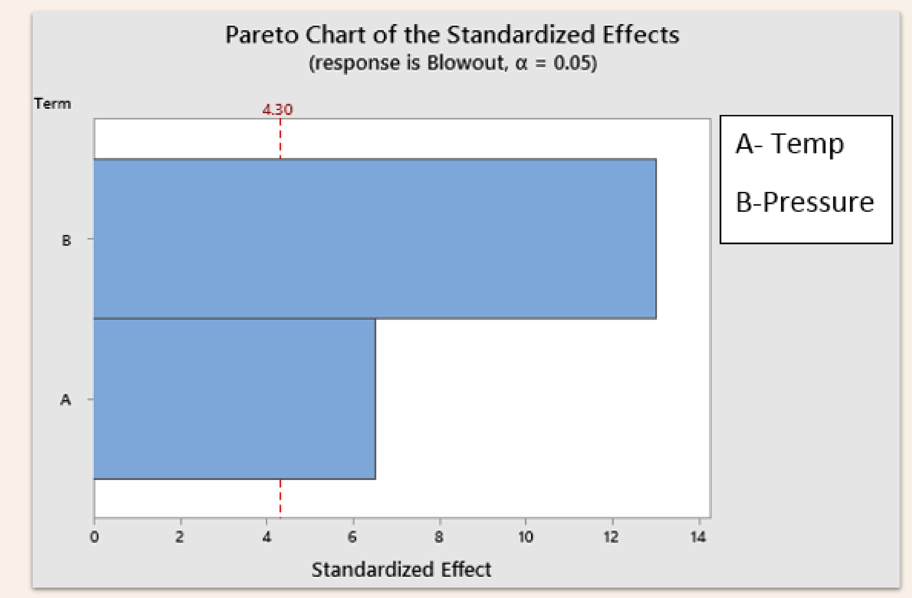
A full factorial DOE was the best option to statistically prove if suboptimal temperature or pressure were at fault for the blowouts. Change in colors was minimized as much as possible. However, unforseen production changes resulted in a single change from the “Smoke” color to the “Honey’ color.

Trial	Date	Temp. Level	Temp. (F)	Pressure Level	Pressure (bar)	Color	Blowouts
1	3-Mar	+	275	/	120	Smoke	5
2	4-Mar	/	270	+	125	Smoke	10
3	4-Mar	+	275	+	130	Smoke	Process Issues
4	26-Mar	-	265	/	120	Honey	2
5	26-Mar	/	270	-	115	Honey	0
6	26-Mar	-	265	-	110	Honey	1
7	27-Mar	+	275	-	110	Honey	4
8	27-Mar	-	265	+	130	Honey	Process Issues
9	27-Mar	/	270	/	120	Honey	2

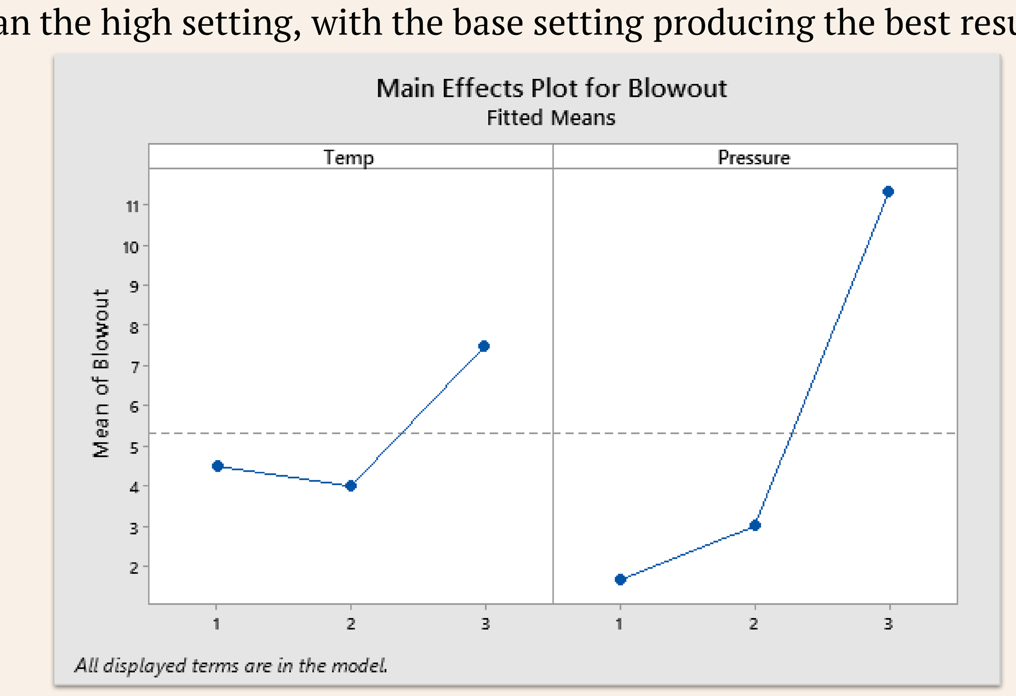
The DOE test was conducted as a <u>**2-factor, 3-level test**</u>, resulting in 9 tests on the variables temperature and pressure, pre-extrusion. Before the test could occur, a number of variables were noted to cause <u>**variation in the process which were held constant**</u>; number and shape of holes (72 vs 144, Delta vs Round), age and number of packs, burner and burner time. In conjunction with Chemical Engineering professors and the Drake team, the settings decided for the test were determined to alter temperature by <u>**+/- 5 degrees**</u> and pressure altered by <u>**+/- 10 bar**</u>. The tests were run for 2 hours at each specified setting and the tester was prompted to note every blowout by location and time. “Process Issues” signifies that too many defects were occuring to leave the machine running. This can be viewed as a very high occurrence of blowouts.

RESULTS

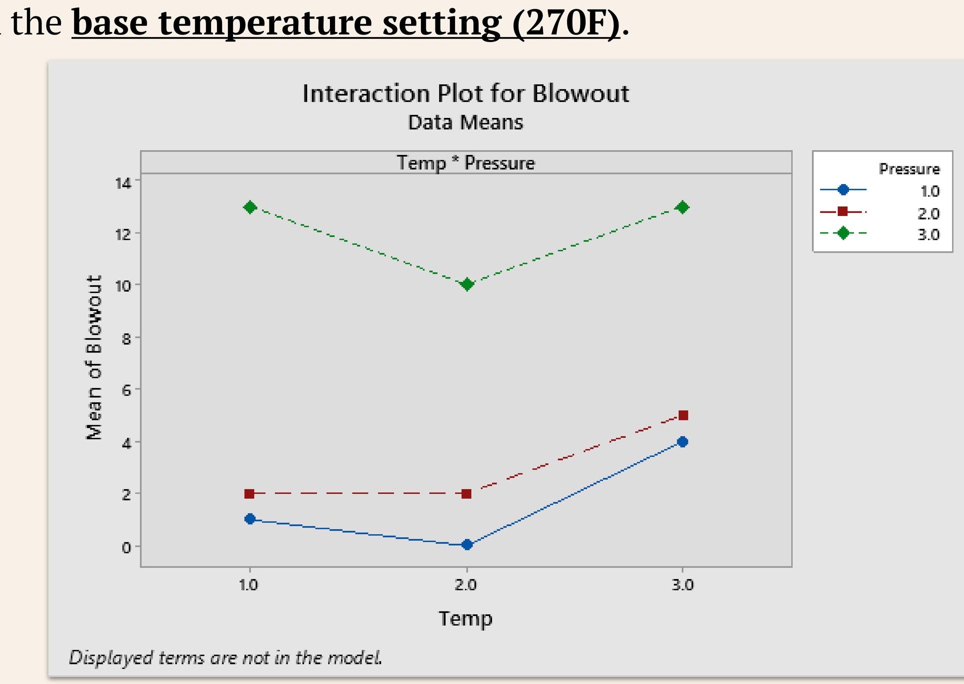
With P-Values less than the significance level of .05, the variables <u>**temperature (P=0.023)**</u> and <u>**pressure (P=0.006)**</u> both have a statistically significant effect on the resulting number of blowouts. The interaction P-value was not able to be calculated due to the two missing data points and lack of degrees of freedom The pareto chart below shows that pressure has more than twice the Standardized Effect on the blowout rate.



The main effects plot below shows the effect each individual variable has on the blowout rate on each settings (1=low, 2-base, 3=high). It can be seen that as the pressure decreases, the blowouts rate decreases. The effect temperature has on the blowout rate is not as consistent. However, both the low and base settings produce far less blowouts than the high setting, with the base setting producing the best results.



The plot below demonstrates the interaction between the variables temperature and pressure. This demonstrates that the best setting for pressure is the <u>**low setting (110 bar)**</u>. In addition, the low pressure setting produces the lowest number of blowouts when it is combined with the <u>**base temperature setting (270F)**</u>.

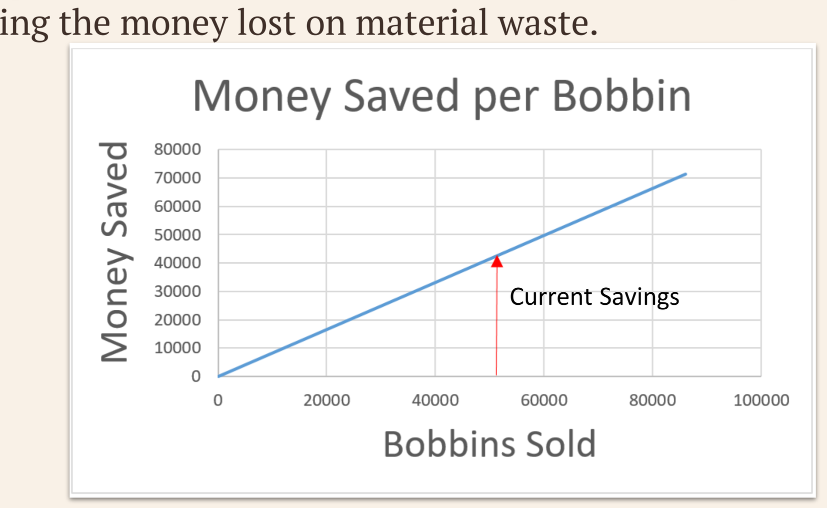


Each machine consists of two sides, each with four packs extruding product. A 1-Sample t test was conducted on the number of blowouts by pack location, which showed with 99% confidence that the <u>**difference in occurances was not due by chance**</u> and are a result of an additional variable.

IMPACT

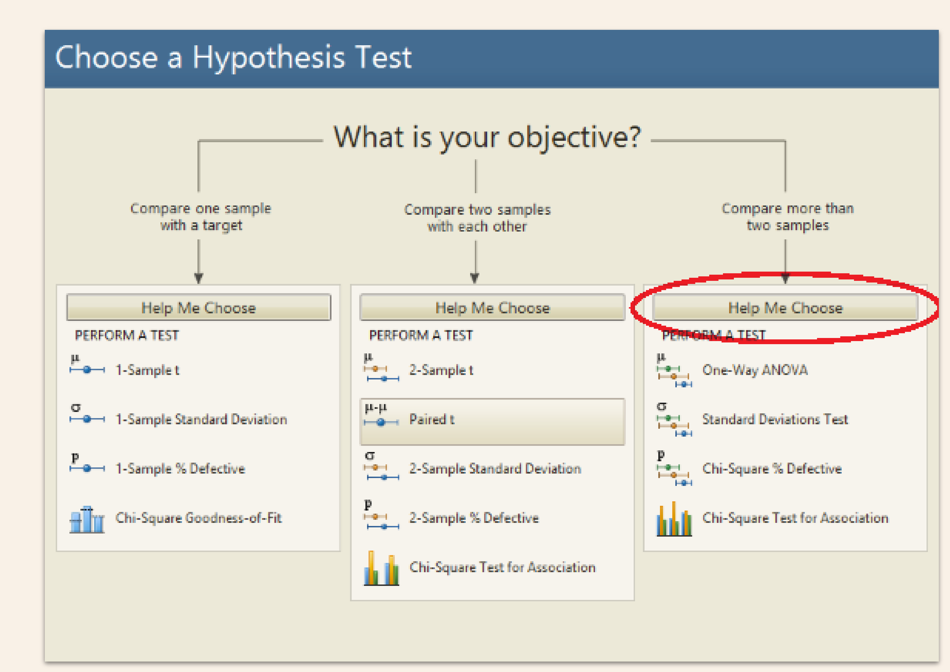
Annual Savings = $40,917

Drake currently sells the finished product in containers called bobbins. Each bobbin of smoke/honey coloring cost $18. At the current defect rate Drake is losing $1.26 per bobbin due to machine downtime and material loss. The results of the DOE show us that we can reduce the occurrence of blowouts by <u>66%</u>. This reduction leads us to say that over one year reducing the blowouts by 66% will save Drake <u>**$40,917**</u> per year on the smoke/honey colors. Due to only testing two colors we cannot say whether these numbers will hold true across the board for all colors; however if the rate of reduction remains the same we estimate that Drake will save <u>**$0.83 on each bobbin produced.**</u> In addition, the time to detect the defect will be reduced by a rate we cannot predict which will also lead to decreasing downtime and decreasing the money lost on material waste.



CONTINUATION PLAN

The team has created a step by step report to allow Drake to continue testing and utilize MiniTab. With these tools, Drake will be able to analyze their other filament yarn colors, and determine manufacturing settings that will result in higher quality products. Additionally, they will be able to continue testing the products examined during the project to further optimize their production settings. These tools include documentation on performing the DOE with a statistical software package, and recommendations for software packages to utilize. The team additionally recommends a slight changes to the DOE; rather than testing 2 factors at 3 levels with no replications, we recommend transitioning to a 2 factor, 2 level test with 2 replications.



Furthermore, the team recommends Drake invest time into pressure testing their packs. Pressure testing involves collecting a weighing the amount of polypropylene extruded from each pack in order to determine if there is a statistical difference between how much product each pack is outputting. A difference in pack output would validate the theory of packs having an effect on the blowout rate and would require pressure regulation.

ACKNOWLEDGEMENTS

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