Connecting Industry to Mathematics Instruction

NSF ATE Award # 1954291

Analyzing Production of an Automotive Adhesive

In partnership with

WAKE TECH

WAKE COUNTY PUBLIC SCHOOL SYSTEM

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Background

Parker LORD won a significant contract to manufacture a new adhesive for automotive use. Production started and was ramping up. During early testing, the customer observed high pressure alerts when trying to pump the adhesive through their factory tubing. They noticed that the "PX" values, measuring the force (in PSI: pounds per square inch) required to pump the adhesive through the tube, was too high. The acceptable range of "PX" was between 150-210 PSI throughout the 120-day shelf life of the adhesive. Your job is to figure out what the Parker LORD manufacturing plant data is showing and come up with recommendations to solve the problem.

Data Collection

Two months of data were collected on 20 batches of adhesive, made from three distinct raw materials (RMs). Initial PX values were recorded at time of adhesive manufacture. Retains (small containers of each batch that were kept at the Parker LORD facility) were rechecked at various dates after manufacturing, and PX was recorded. Various batch characteristics were also recorded.

The included Excel file "PX-data.xlsx" contains this data. The variables included in the spreadsheet are defined as follows:

Batch – Batch number (unique number to identify the batch)
Mfg Date – Date of manufacture of the batch
Batch Size – Weight of the batch (pounds)
RM1 %H2O – Percent water present in the first raw material
RM2 %H2O – Percent water present in the second raw material
RM3 %H2O – Percent water present in the third raw material
Mfg Shift – Work shift (time of day) when the batch was manufactured (0: 1st shift, 1: 2nd shift, 2: 3rd shift)
Avg Dew Point – Average dew point (°F) in the manufacturing facility on the date of manufacture
Total %H2O in Batch – Percent water present in the batch (after combining raw materials)
PX Initial – PX of the batch (PSI) at time of manufacture
PX Recheck – PX of the batch (PSI) at time of recheck
PX Recheck Time – Number of days elapsed since the batch was manufactured
Tested Location – Site where the batch PX values were tested

Part 1 – Confirming the Problem

1. Compare the original PX measurements with the PX recheck measurements. Does there appear to be a drift (change) in PX for these batches over time? Why or why not?

2. Using the original spec limit of 150-210 PSI, what percent of these batches would be rejected by the customer based on their PX recheck values?

3. We need to identify which variable(s) may be correlated to this increase in PX.

   - Read the descriptions (previous page) of each variable recorded in the spreadsheet. Choose and list two of the variables that you think would be strongly related to each other, and two variables that you think would not be related at all.

     Strong relationship between:

     No relationship between:

   - Investigate your choices from part (a) by computing the correlation coefficient (r) and/or coefficient of determination (r^2). Do these statistics confirm your thoughts? Why or why not?

Part 2 – Modeling PX Drift (Change)

4. Assume that the drift in PX follows a linear pattern. In a new spreadsheet column, calculate the **total drift** (PSI) by computing the difference between the initial PX and the rechecked PX for each batch in the sample. In a second column, divide each difference by the number of days since manufacture to calculate the **average drift per day** (PSI per day) for each batch.

5. Scientists and engineers hypothesize that an undesirable water reaction is causing the batches' PX values to drift (change). Investigate the relationship between the total batch water content (independent) and drift per day (dependent). To do this, you should:

   a. Create a scatterplot comparing total batch water content (horizontal, %H2O) and drift per day (vertical, Units/day).

   b. Determine a linear regression equation. Define each variable in the equation.

   c. Determine the correlation coefficient (r) for the model. How strong is the relationship between water content and drift per day?

6. Determine the predicted drift per day values for each batch. In a new spreadsheet column, calculate the residual values for each batch and create a residual plot. Which batch had the largest difference between its actual and predicted drift per day values? Does a linear relationship seem appropriate?

Part 3 – Applying the Linear Drift Model

7. How many days will it take the first batch in the spreadsheet (#11958383) to reach the maximum allowed PX of 210 PSI? This is called the *shelf life* for the batch.

8. Shelf life of a batch of adhesive is the number of days that the batch will remain within the PX requirements. In a new spreadsheet column, determine the shelf life for each batch at the original maximum PX of 210 PSI. Will any of these batches reach the customer's expected shelf life of 120 days?

9. There may be room for negotiation with the customer about the spec limit. Determine the shelf life for each batch at a higher spec limit of 270 PSI. Would this be an acceptable change to the spec limit?

10. Your customer has agreed to the higher PX spec limit of 270 PSI for a slightly lower price but needs to maintain the 120-day shelf life. Your manufacturing manager has determined that it is possible to make the adhesive with a lower starting PX (as low as 145) and a lower initial water content (either 0.04%, 0.05%, or 0.06%). For each of these options, use your regression line to calculate the expected drift per day, then the expected shelf life (assuming a beginning PX value of 145 and higher spec limit of 270 PSI). Which initial water content (0.04%, 0.05%, or 0.06%) do you think would be the best choice? Why?

11. These batches of adhesive were rechecked after roughly 20-60 days from the date of manufacture. The adhesive must be shipped to the consumer (usually takes at least 3 weeks), so the PX measurements in the first 20 days are not as important as the measurements between 60-120 days. How useful is your linear model for predictions beyond the 60-day mark? What could your company do to develop a more accurate model?

Part 4 – Extension

12. A later batch (#12000465) was rechecked four different times, and the results are included in the table below. For this new batch, calculate the drift per day at each recheck (compared to the initial PX of 172 Units). How does the drift per day for this batch change over time?

Batch	%H2O Total	PX	PX Recheck	Days after Mfg
12000465	0.0294%	172	177.3	7
12000465	0.0294%	172	191.15	14
12000465	0.0294%	172	199.8	28
12000465	0.0294%	172	205.1	55

13. Use the linear regression model you made in Part 2 to predict the drift per day for a batch that has a %H2O Total of 0.0294%, like batch #12000465. How does this predicted drift per day compare to the observed drift per day at each recheck time? If this batch were to be checked again after even more time, what would you expect the drift per day to be? Why?