Lab 4.1

Winder Machine Throughput Problem

**Learning Outcomes**

Upon completion student will understand the relationship between angular and linear speed, and experience real-world problem solving.

**Introductory Exploration**

To explore and understand the relationship between change in radius and change in circumference, lay a ruler on the end of a roll of paper towels so that it aligns with the center of the tube and is perpendicular to the outer edge of the roll. Then use a marker to draw a radial line from the tube out to the outer wrap, making sure to apply lots of ink so that the ink mark seeps down into the roll a little ways. Finally, unroll about 10 sheets of paper towels as one long strip then measure and record the distance between each pair of consecutive ink marks. One circumference wrap happens between each pair of marks.

What do you notice about these circumference distances? Why is this occurring? Explain. Describe the relationship you see among the data. Based on the data/relationship, calculate the thickness of the paper and the total number of wraps found on the roll.

Project Objective

A manufacturing operation wants to save money by producing rather than purchasing a special ribbon material that is a component in their product. They must determine the minimum number of machines that they need to build in order to be able to produce the 50,000 yards per day of ribbon required for manufacturing their product. The ribbon material is 2 inches wide by 0.01 inches thick. The completed ribbon is wound in 500-yard lengths onto a 3-inch diameter tube. The motor that turns the tube is an inexpensive model that runs at a constant 20 RPM. There are downtimes when the machine is not running: 10 minutes after each 500-yard roll is completed in order to remove the full roll and start a new one, and 3 hours of each 24 hour day in order for the operator(s) to take breaks.

**Plan of Attack**

Step 1 – Understand the problem.

You can’t hit the target if you don’t know what/where the target is. In your own words, describe the type of solution being sought and give an example solution (does not need to be accurate numerically, just focus on what a solution should “look” like.)

Step 2 – Understand the parameters that will control your resulting solution.

This is the most important step of the plan, and if you mess up here you will definitely mess up on step 3, which will throw off your entire result.

Discuss how this problem’s objective will be similar to the introductory exploration and how it will be different.

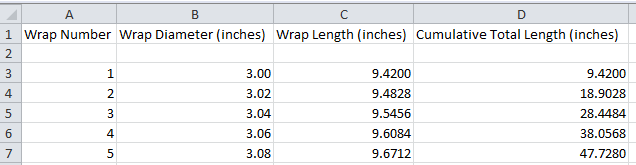
Step 3 – Determine the number of wraps to complete one roll.

As you (should have) discussed in step 2, for this problem cannot directly measure the outer radius to calculate the number of wraps. But we do know the total length and the material thickness. So we must “back-into” the number of wraps.

I want to see two methods here:

A) Use an MSExcel spreadsheet.

The following screenshot shows the needed columns and the first few rows. Simply extend the spreadsheet until the Cumulative Total Length reaches one completed roll of ribbon. Note: the only cell with a hard-typed number is A3, all the other cells must contain cell-referencing computational formulas….and I will check your formulas, not just the numbers!



B) Create and solve an algebraic equation.

Let X = the number of wraps, and build a formula that computes the total inches wound by X wraps. Then set this formula equal to the total number of inches in one roll. Finally, solve for X. Note: the total inches wound by X wraps will be a *sum,* so you will need to look back at our work in series. In particular, you will need the formula for the Sum of a Finite Arithmetic Sequence.

Step 4 – Use the information found above to finish creating a solution. Things to consider/calculate:

i) The machine run-time per roll.

ii) The machine clock-time per roll.

iii) The daily yardage throughput per machine.

These are relatively simple applications of conversion factors once you’ve achieved step 3.

**Putting it all together**

The inexpensive, constant-RPM motor of this problem causes a variable linear speed of the ribbon through the processing machine.

Why? Explain.

A variable linear speed is not a problem when the ribbon manufacturing process is not speed-sensitive. However, depending on the materials and type of processing involved, the process may be speed-sensitive. If the process is speed-sensitive, the motor must have variable RPM.

Why? Explain.

This type of speed-sensitive machine is more expensive to build because of the added sensors and controls needed for maintaining constant linear speed by varying the RPM’s of the motor.

Extension problem - determine the minimum number of machines necessary to handle the required daily throughput if the machine motor controller is capable of maintaining a constant 10 yards per minute. Assume the same amount of set-up time per roll and daily break time as before.

**Expected Results to be Graded**

Submit two electronic documents:

1) A typed, professional-looking document (MSWord) that presents your answers to all the questions found throughout the lab, your mathematics work utilized in achieving the objective, your final results for the objective, and the extension work.

2) A spreadsheet (MSExcel) showing your work for step 3A, which must include cell-referencing computational formulas in all numeric data (i.e. not column label) cells except the starting cell in the upper left corner of your data.

Name these two files each as: **winderlab*-lastname***

Due by the date indicated on Moodle

Value: 100 points

# Algebraic Solution

# We need to find the number of wraps, call it , needed to wind the entire 18000-inch (500 yds times 36 inches per yard) roll. Since each wrap will add 0.01 to each “side” of the tube then the diameter grows by 0.02 inches each wrap, which will increase the length wrapped each revolution.

Remembering that , we find the length of each wrap and sum them:





3

3.04

3.06

3.02











Since this is the sum of a finite arithmetic sequence with common difference of , then applying the sum formula, using , and simplifying gives us:



Setting this sum equal to the total inches for a complete roll and using the quadratic formula gives us:

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Ignoring the negative result, we have 622 wraps to run one roll. Thus, the run time to wind one roll is:



Including the 10 minutes setup we have 41.1 minutes clock time per roll. Thus the daily machine throughput is:



Now we can find the number of machines needed is:



So we need to have 4 machines to handle the 50,000 yards throughput per day.

For the “extension”: 50 run-time minutes per roll will lead us to 10500 yards per machine-day making us need 5 machines to handle the daily throughput.