TAGA NextGen

# Advancing Cutting Table Estimation with the Help of AI

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# Presentation Overview

- Background and Context
- Research
  - Equipment
  - Testing Process
  - Results
- Summary
- Conclusions
- Future Directions

# Background and Context

- Why is this necessary?

- Industry connection.

"We are still working on that…"

"It depends on the week!"

"It is loosely based off prior jobs we have completed."

"We guess!"

"What do you mean by estimate?"

# Prior Work

- To Determine Cut Time:
  - Estimate the circumference of the object.
  - Total circumference (based on number needed).
  - Calculate cutting time (based on knife speed).
  - Add a complexity factor.

- Account for setup time.
- Estimate cost.

| Cutting Table Production Standards (hourly rate: $115.00) | | | | | |
|---|---|---|---|---|---|
| Setup time | | Cutting tool base rates per linear inch | | Shape Complexity | Time increase |
| single sheet | 5 min first sheet; 1 minute per additonal | serigraphy knife | 1100 in/min (2794 cm/min) | simple | 4x |
| step & repeat per piece | 5 min first sheet + .25 minutes per piece | high frequency knife | 900 in/min (2286 cm/min) | medium | 8x |
| milling | 10 min first piece; 1 minute per additonal | milliing knife | 236 in/min (600 cm/min) | high | 12x |
| kiss cut | add 5 minutes | | | very high | 20x |

# So What?

- Prior work
  - Simple – 4x
  - Moderate – 8x
  - Complex – 12x
  - Very Complex – 20x

- Estimate this job given existing methods…
  - 13.79” x 3.1415 = 43.32”
  - 43.32/900 = .048 minutes or 2.88 seconds
  - 2.88x20=57.6 seconds
- Actual cut time – 9 minutes, 51.3 seconds

# Prior Results

| Shape | Complexity | Speed | Cut Distance | Old Method | Actual Cut Time | Difference |
|---|---|---|---|---|---|---|
| 1 | Simple | 16.4 in/sec | 43.8” | 11.76 sec | 6 sec | +5.76 sec |
| 2 | Simple | 16.4 in/sec | 45.35” | 7.2 sec | 7 sec | +.2 sec |
| 3 | Simple | 16.4 in/sec | 73.5” | 11.52 sec | 31 sec | -19.48 sec |
| 4 | Moderate | 16.4 in/sec | 81.45” | 24.48 sec | 1 min 1 sec | -36.52 sec |
| 5 | Moderate | 16.4 in/sec | 60.25” | 20.64 sec | 1 min 27 sec | -1 min 6.36sec |
| 6 | Moderate | 16.4 in/sec | 50” | 22.56 sec | 36 sec | -13.44 sec |
| 7 | Complex | 16.4 in/sec | 112.44” | 25.92 sec | 46 sec | -20.08 sec |
| 8 | Complex | 16.4 in/sec | 167.43” | 25.2 sec | 1 min 49 sec | -1 min 23.8sec |
| 9 | Very Complex | 16.4 in/sec | 363.37” | 56.4 sec | 7 min 17 sec | -6min 20.6sec |
| 10 | Very Complex | 16.4 in/sec | 480.29 | 57.6 sec | 9 min 51 sec | -8min 53.4sec |

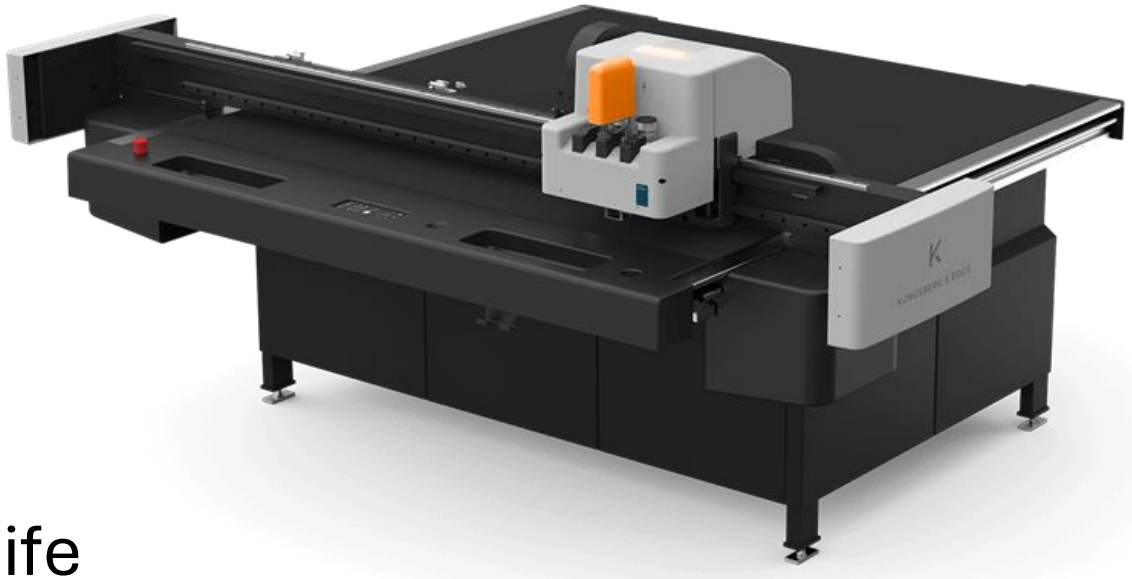
# New Study

- What did prior research not consider?
  - Start/Stop/Lift/Adjust/Restart

- Use Original Shapes to test AI
  - Cut “critical corners” based on shape.
  - Record CAD table cutting and have AI count the “lifts”.

- Factors Considered
  - Total cut distance and nodes/points (identified in Adobe Illustrator).
  - Accel speed of CAD table
  - Stopping time

# Equipment Used

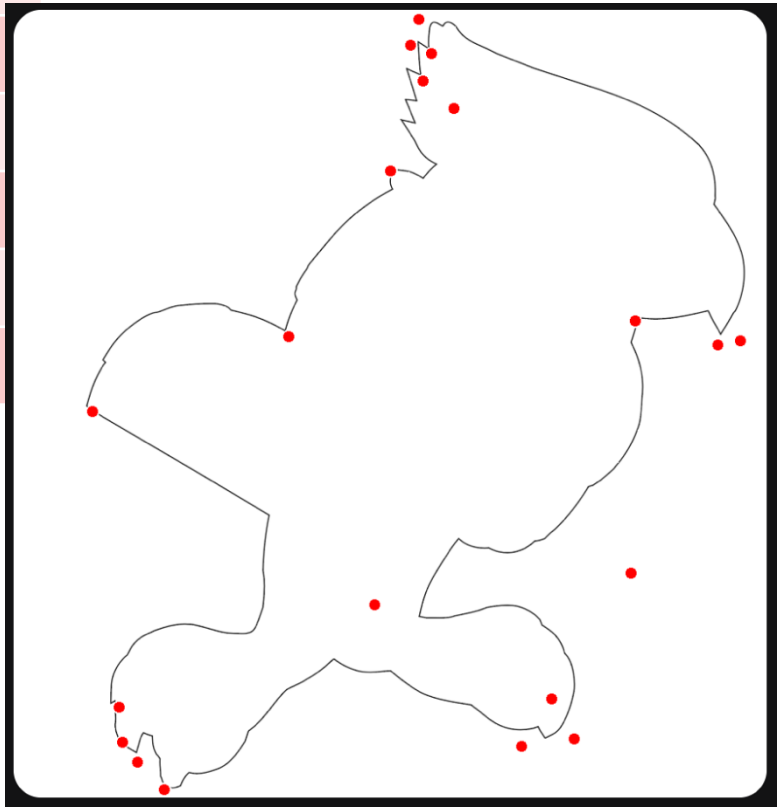


- Kongsberg X20 CAD Table

High-Frequency Vibracut Knife Tool SR6224 Blade

# What Didn’t Work – Critical Corner Count

| Shape | Complexity | AI1-CS | AI2-CS | AI1-CC | AI2-CC | Illustrator |
|---|---|---|---|---|---|---|
| 3 | Simple | 16 | 16 | 16 | 16 | 16 |
| 4 | Moderate | 38 | 40 | 56 | 32 | 81 |
| 5 | Moderate | 32 | 17 | 20 | 23 | 224 |
| 6 | Moderate | 21 | 0 | 12 | 7 | 54 |
| 8 | Complex | 35 | 26 | 56 | 12 | 143 |
| 9 | Very Complex | 0 | 0 | 316 | 94 | 656 |
| 10 | Very Complex | 0 | 0 | 445 | 214 | 833 |



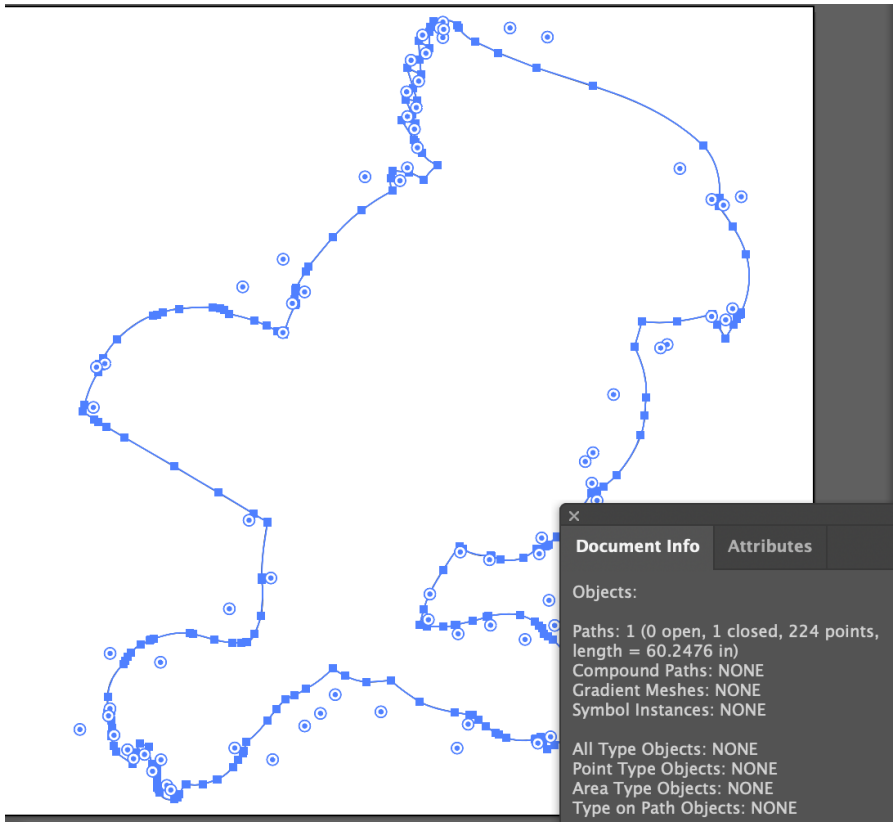
# What Didn’t Work – Video Count

| Shape | Complexity | CS | CC | AI1-CS | AI2-CS | AI1-CC | AI2-CC |
|---|---|---|---|---|---|---|---|
| 3 | Simple | 15 | 15 | 18 | N/A | 9 | 10 |
| 4 | Moderate | 63 | 62 | 38 | N/A | 9 | 5 |
| 5 | Moderate | 57 | 57 | 33 | N/A | 54 | 31 |
| 6 | Moderate | 28 | 28 | 23 | N/A | 12 | 18 |
| 8 | Complex | 70 | 70 | 35 | N/A | 7 | 14 |

- No Consistency outside of personal counts
- Some AI (free editions) couldn’t/wouldn’t accept the files
- Even after refinement of prompt, AI resulted in very low “lift” counts
  - Learning Example – Shape 3

# Stick to Math

- Utilize the total cut distance.
- Utilize the node/point count from Illustrator.
  - In each case .5 seconds stop/adjust speed




Carryover:

- Shape Complexity
  - Establish Accel Speeds based on Complexity
  - Consider nodes/points dependent on Shape
    - Stop at all or halve due to smoothness of shape?

# Shape Complexity

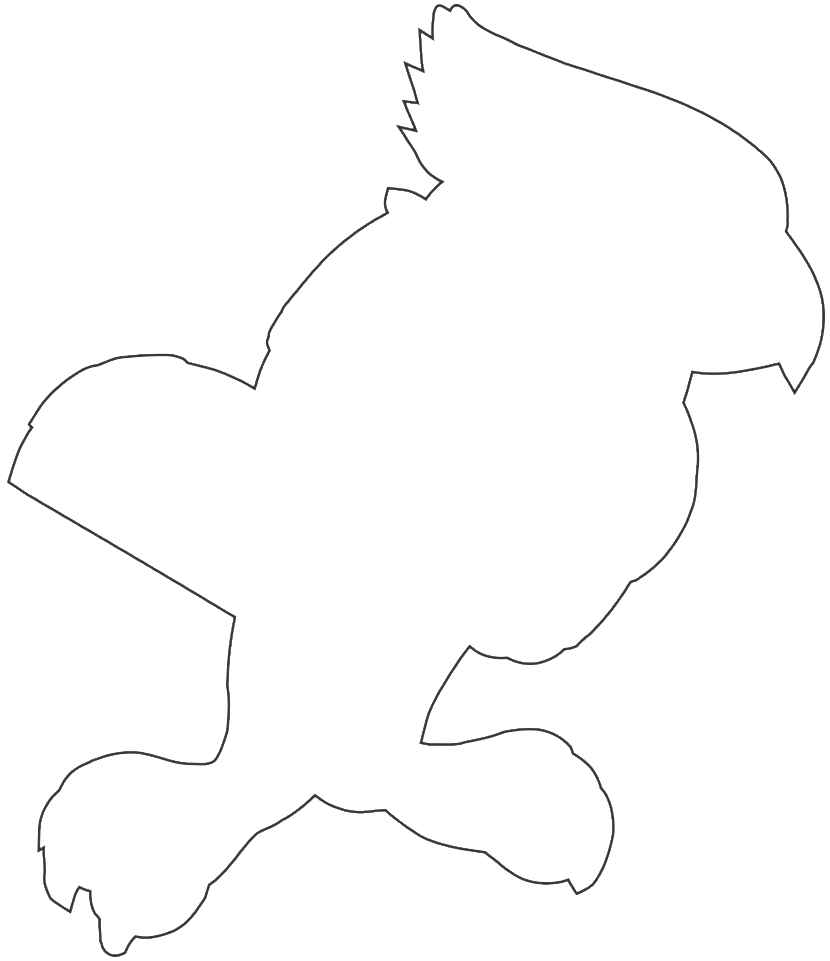
| Complexity Options | Accel Factor | Stop Time | Node Count | |
|---|---|---|---|---|
| | | | Majority Smooth/Majority Critical | |
| Simple | Fast – 300in/s$^2$ | .5 Seconds | 50% | 100% |
| Moderate | Moderate – 200in/s$^2$ | .5 Seconds | 50% | 100% |
| Complex | Slow – 100in/s$^2$ | .5 Seconds | 50% | 100% |
| Very Complex | Very Slow – 50in/s$^2$ | .5 Seconds | 50% | 100% |

# New Approach

| Shape | Complexity | Cut Distance | Nodes/Points | Prompt Specs |
|---|---|---|---|---|
| 1 | Simple | 43.8” | 4 | .5 seconds, fast accel (300in/s$^2$), 50% nodes |
| 2 | Simple | 45.35” | 4 | .5 seconds, fast accel (300in/s$^2$), 100% nodes |
| 3 | Simple | 73.5” | 16 | .5 seconds, fast accel (300in/s$^2$), 100% nodes |
| 4 | Moderate | 81.45” | 81 | .5 seconds, mod accel (200in/s$^2$), 100% nodes |
| 5 | Moderate | 60.25” | 224 | .5 seconds, mod accel (200in/s$^2$), 50% nodes |
| 6 | Moderate | 50” | 54 | .5 seconds, mod accel (200in/s$^2$), 100% nodes |
| 7 | Complex | 112.44” | 28 | .5 seconds, slow accel (100in/s$^2$), 50% nodes |
| 8 | Complex | 167.43” | 143 | .5 seconds, slow accel (100in/s$^2$), 100% nodes |
| 9 | Very Complex | 363.37” | 656 | .5 seconds, very slow accel (50in/s$^2$), 100% nodes |
| 10 | Very Complex | 480.29 | 833 | .5 seconds, very slow accel (50in/s$^2$), 100% nodes |

# Specific Prompt

- If I have a moderate shape with a total cut circumference of 60.25", and the cad table is cutting at a rate of 16.4 inches per second, how long would it take to cut? Assume the head effectively has to accelerate + decelerate between points and usually can’t get back to full speed. We also need to take into account the number of pivot points...illustrator indicates there are 112 points in the design. If we average .5 seconds per point additional to allow the cutting table to stop/lift/adjust/drop, how long in total can we expect it to take to cut this shape? Can you adjust this to factor in a moderate accel of about 200 in/s$^2$?



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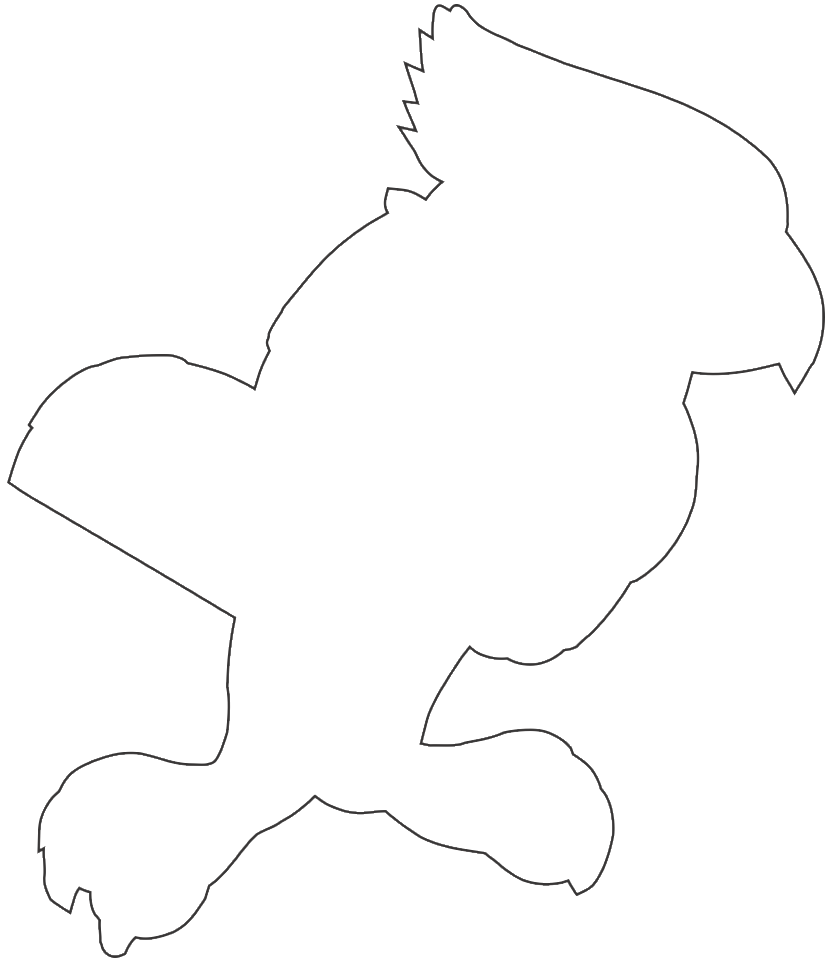


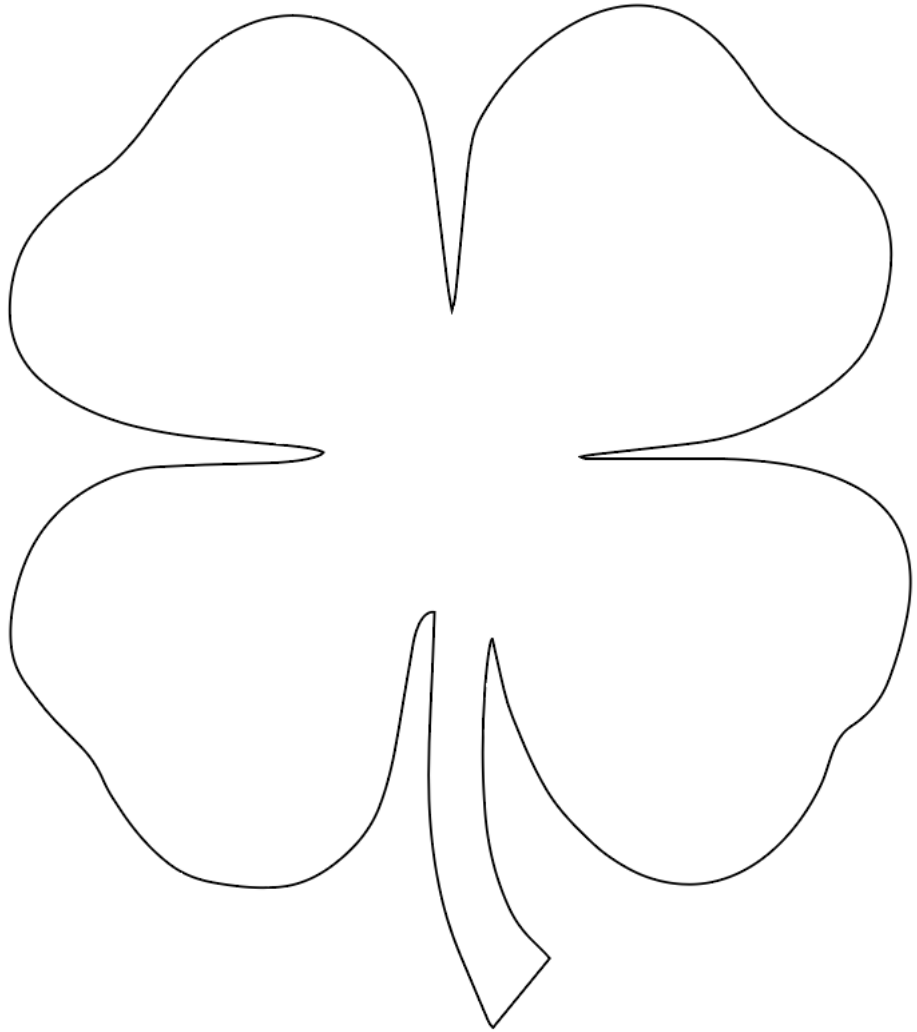
# Updated Results

| Shape | Complexity | Speed | Cut Distance | AI | Actual Cut Time | Difference |
|---|---|---|---|---|---|---|
| 1 | Simple | 16.4 in/sec | 43.8” | 3.8 sec | 6 sec | -2.2 sec |
| 2 | Simple | 16.4 in/sec | 45.35” | 5 sec | 7 sec | -2 sec |
| 3 | Simple | 16.4 in/sec | 73.5” | 13.8 sec | 31 sec | -17.2 sec |
| 4 | Moderate | 16.4 in/sec | 81.45” | 52 sec | 1 min 1 sec | -9 sec |
| 5 | Moderate | 16.4 in/sec | 60.25” | 1 min 8 sec | 1 min 27 sec | -19 sec |
| 6 | Moderate | 16.4 in/sec | 50” | 34.3 sec | 36 sec | -1.7 sec |
| 7 | Complex | 16.4 in/sec | 112.44” | 25.5 sec | 46 sec | -20.5 sec |
| 8 | Complex | 16.4 in/sec | 167.43” | 1 min 42 sec | 1 min 49 sec | -7 sec |
| 9 | Very Complex | 16.4 in/sec | 363.37” | 7 min 46 sec | 7 min 17 sec | +29 sec |
| 10 | Very Complex | 16.4 in/sec | 480.29 | 9 min 55 sec | 9 min 51 sec | +4 sec |


# Adding Shapes

# Specific Prompt

- If I have a moderate shape with a total cut circumference of 44.37", and the cad table is cutting at a rate of 16.4 inches per second, how long would it take to cut? Assume the head effectively has to accelerate + decelerate between points and usually can't get back to full speed. We also need to take into account the number of pivot points...illustrator indicates there are 41 points in the design. If we average .5 seconds per point additional to allow the cutting table to stop/lift/adjust/drop, how long in total can we expect it to take to cut this shape? Can you adjust this to factor in a moderate accel of about 200 in/s$^2$?



# Updated Results

| Shape | Complexity | Speed | Cut Distance | AI | Actual Cut Time | Difference |
|---|---|---|---|---|---|---|
| 1 | Simple | 16.4 in/sec | 43.8” | 3.8 sec | 6 sec | -2.2 sec |
| 2 | Simple | 16.4 in/sec | 45.35” | 5 sec | 7 sec | -2 sec |
| 3 | Simple | 16.4 in/sec | 73.5” | 13.8 sec | 31 sec | -17.2 sec |
| 4 | Moderate | 16.4 in/sec | 81.45” | 52 sec | 1 min 1 sec | -9 sec |
| 5 | Moderate | 16.4 in/sec | 60.25” | 1 min 8 sec | 1 min 27 sec | -19 sec |
| 6 | Moderate | 16.4 in/sec | 50” | 34.3 sec | 36 sec | -1.7 sec |
| 7 | Complex | 16.4 in/sec | 112.44” | 25.5 sec | 46 sec | -20.5 sec |
| 8 | Complex | 16.4 in/sec | 167.43” | 1 min 42 sec | 1 min 49 sec | -7 sec |
| 9 | Very Complex | 16.4 in/sec | 363.37” | 7 min 46 sec | 7 min 17 sec | +29 sec |
| 10 | Very Complex | 16.4 in/sec | 480.29 | 9 min 55 sec | 9 min 51 sec | +4 sec |
| N1 | Moderate | 16.4 in/sec | 44.37” | 26.5 sec | 22.54 sec | +3.96 sec |
| N2 | Very Complex | 16.4 in/sec | 250.41” | 5 min 16 sec | 5 min 19 sec | -3 sec |

# Conclusions and Future Directions

- AI can be helpful
- New method
  - Not perfect, but more consistent

- Expand Research:
  - Build in crease calculations
  - Test with different blades/speeds
  - Material comparisons

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# Thank you!

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