Bionic Wrench Production Report

DSGN 386 Final Report

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Product Documentation

This report is intended to provide production line documentation for the 8” Bionic wrench. The Bionic Wrench is a handheld wrench that automatically adjusts to fit many sizes of bolt heads for tightening fasteners. The design includes of two handles that are gripped like a pair of pliers and a head with six moving jaws. The jaws grip all sides of a bolt to evenly distribute the load and prevent stripping. The Bionic Wrench is available in three sizes, and this case study focuses on the 8” model, shown below in Figure 1.

The parts of the wrench include two interior and two exterior plates stamped from sheet steel and coated with black oxide, six steel jaws with are extruded and cut to length, a bent and coated steel spring, and two dip molded TPU grips. The wrench is assembled with three types of steel rivets. The relative position of the four plates during riveting is critical to allow for the unimpeded motion of the wrench. Detailed drawings of the wrench parts and assembly can be found in Appendix B: Part and Assembly Drawings.

Figure 1: A Packaged 8” Bionic Wrench

Final Bill of Materials

Table 1: Bill of Materials

Item	Description	Qty	Part #	Indiv. Cost USD	Total Cost USD
Pins, Various Jigs	1” x ¼” diameter Steel Dowel Pins, Bright Finish	18	98381A542	7.31 / 25 pins	
Main Body Jig Track	Wear Resistant AR400 Carbon Steel 6 x 12 x ⅛ inches	1	1607T112	31.79	
Jaw Jig	Low-Carbon Steel Sheet with Decarb-Free Surface 4 x 4 x1 inches	1	1388K504	37.66	
Pins for Base Plate Alignment and Jig Track Interface	Alloy Steel Low-Profile Socket Head Screw ¼”-20 Thread Size, ¼” Long	1 pack of 10	92220A181	7.86	
Interior and Exterior Flip Plates	Low-Carbon Steel with Decarb-Free Surface 8 x 12 x 3/32	1	1388K351	54.26	
Cylinder Alignment Feature: Main Body Jig	6061 Aluminium Rod	1	1610T11	4.50	
Acrylic: Spring Jig, Jig A, Jig B (Rivet Placement Jigs), Packaging Jig	⅜, 7/32, ¼” Thick Acrylic Sheets		8560K435 x2 8560K224 8560K242	99.66 40.96 27.67	267.95
					411.67

Above Materials Ordered from McMaster-Carr

Estimated Materials Cost

Table 2: Materials Cost

Item	Description	Total Cost
Raw Materials	Materials Found in *Bill of Materials*	411.67/fixture set
Manufacturing / Tooling + Labor Outsourced	USL Laser Machine Table, Manual Milling Machine, Haas CNC Milling Machine	800/ fixture set
Labor (direct)	Labor towards processes of the plant: Assembly Workers, Inventory Worker	500,000 / year
Waste / Scrap	Based on unused raw materials due to fixed quantity orders of raw materials	150 / fixture set
Other Costs		

Final Quality Standards

Given that the Bionic Wrench is a commercial product that will be used by consumers, it is important that they meet certain quality standards. These standards can be split into three broad categories.

Wrench

The wrench should not bind, and be free moving. There should be no witness marks on the body of the wrench or the jaws around the rivets. Overall, there should be no visible blemishes on the wrench.

Rivets

The manufactured rivets should be on the same side, so that in packaging the factory rivet heads can be on the front. The rivet heads should be of good quality, and meet the golden standard. All wrenches should have 13 rivets.

Handles

The handle grips should match up once they are on the wrench, both going up to the same point on each handle. The handle grips should not fall off while the wrench is in use.

Production Line Balancing

Based on the provided annual demand forecast (info found in Appendix __: Demand Forecast) the takt time for the line during a high production month (200,000 units over two shifts, six days a week) must be

$$\frac{1\ min}{9.25\ units} * \frac{60\ sec}{1\ min} = 6.49\ sec/unit$$

Producing wrenches at this volume months in advance of the high selling period at the end of the year requires large inventory storage capabilities. Assuming these capabilities are in place, the remaining production of 400,000 wrenches can be evenly distributed over the other nine months and distributed as needed. This allows us to design for a high production and low production level, so the workforce and factory operation can be constant for the whole year aside from the summer work force in June to August. Following a similar process to the high production with two shifts and only a five day work weeks yields a low production takt time of

$$\frac{1\ min}{2.47\ units} * \frac{60\ sec}{1\ min} = 24.29\ sec/unit$$

To account for variability in production, it is good practice to plan to produce goods at 85% of takt time. Therefore our target takt times for high and low volume production months are

High Production: 5.52 sec/unit
Low Production: 20.65 sec/unit

To reach these goals, we must design a line that can output a wrench every time takt passes. Since the output from the line is controlled by the bottleneck's cycle time, we must plan our line size and layout around this bottleneck.

First, we must design a work cell that can produce wrenches. Following initial setup steps, the minimum work elements and their cycle times for the production line are shown below in Table 3.

Table 3: Work Element Times

Element Label	Work Element	Cycle Time (sec)
A	Fixturing an inner assembly	14.9
B	Riveting an inner assembly	7.4
C	Fixturing an outer assembly	38.9
D	Riveting an outer assembly	18.6

E	Removing outer assembly from fixture and staging for jaws	5.5
F	Fixturing jaws in outer assembly	47.8
G	Riveting jaws and staging wrench for springs	22.7
H	Inserting a spring into a wrench	8.6
I	Staging batch of wrenches for packaging*	2.4
J	Packaging wrench and putting on grips	29.2
	TOTAL CYCLE TIME	196

**It is assumed that a worker will move batches of five wrenches to the next station, so the time of 12 seconds is divided by 5 wrenches to get the unit cycle time*

These work elements are largely dependent on the previous tasks for completion. In order to eliminate large buffer stocks and minimize batch size at any stage, the steps should be done either in series by a single worker or in parallel at the same rate by multiple workers. In our trial, we did the first, in which a single worker completed every task. Implementing this in a factory setting would require thirty copies of each fixture, thirty riveters and excessive amounts of training during high production months. Additionally, larger work elements are more susceptible to large variability in production times. Since the majority of the workforce would be seasonal, this additional investment in fixtures, machinery, and training is not justifiable. To avoid these wastes, the following analysis divides the work elements between multiple workers while maintaining the intended use of our fixtures. Table 4 below breaks down the work elements into three roles.

Table 4: Worker Roles

Role Number	Role Responsibilities	Cycle Time (sec)
1	Fixturing and riveting inner and outer assemblies	85.3
2	Fixturing and riveting jaws, adding springs to wrenches	81.5
3	Packaging wrenches and adding grips	29.2

The first two roles above have cycle times within 5% of one another, and with the measured variability for the tasks, they can be considered equivalent. Role 3, however, has a substantially lower cycle time than the other two. Based on our fixtures, it is difficult and illogical to subdivide Role 1 into smaller chunks. Moving responsibilities from Role 2 to Role 3, such as inserting springs, would therefore not fix the time disparity. In order to account for this, we can scale up the number of workers with the first two roles to balance the cycle times.

The cycle time of Role 3 is roughly one third of the other two

$$29.2\ sec * 3 = 87.6\ sec$$

Therefore, by having three times as many Role 1 and 2 workers as Role 3 workers, the line is much closer to balanced. With this in mind, Table 5 below provides a cycle time estimate for the minimum number of workers that create a balanced line.

Table 5: Adjusted Cycle Time

Role Number	Cycle Time (sec)	Number of Workers	Adjusted Cycle Time (sec)
1	85.3	3	28.4
2	81.5	3	27.2
3	29.2	1	29.2

Based on this adjustment, the bottleneck process is Role 3, which means that the line could produce one wrench every 29.2 seconds. This number is significantly higher than our target takt time, so we will need to scale up our number of workers further to reach our production goals. Table 6 below outlines the number of workers needed to reach our high and low takt time targets. In each case, the number of Role 2 workers is one higher than the minimum. This choice was beneficial for two reasons. First, it keeps the number of Role 1 and Role 2 workers the same, simplifying physical line layout for various production levels. Second, it makes the adjusted cycle times for the three roles closer together, meaning the resulting line will be better balanced.

Table 6: High and Low Production Rates

		Low Production, takt = 20.65 sec		High Production, takt = 6.49 sec	
Role Number	Cycle Time (sec)	Number of Workers	Adjusted Cycle Time (sec)	Number of Workers	Adjusted Cycle Time (sec)
1	85.3	5	17.06	14	6.09
2	81.5	5	16.3	14	5.82
3	29.2	2	14.6	5	5.84

Physical Line Design

With the above responsibilities, the Role 1 worker delivers finished assemblies directly to the Role 2 workers as his or her input stock. Given the one to one ratio of created parts, Roles 1 and 2 can always be setup at a work cell together, containing the necessary fixtures and riveters. A work cell containing both Role 1 and 2 workers is additionally beneficial in that the workers will have a companion with whom to talk. This can improve communication on the line and the morale of workers. Additionally, this proximity allows for the potential for cross training the Role 1 and 2 workers to help the other if they fall behind.

The most efficient cell would contain a rivieter for each of the workers, so there would never be any unavailability of the tools. This layout is more expensive than sharing a riveter, but easier to monitor and improve, as the responsibilities of each worker will not be hindered by the progress of the other. This means any improvement to the process of one role will not hurt the productivity of the other. Additionally, this setup prevents the Role 1 worker from having to repeatedly lift the heavy main fixture. This being said, having two riveters would radically underutilize the equipment. The time spent riveting for the combination of the two roles is only 29.2% of the combined cycle times. Therefore, it is definitely possible for each work cell to only have one riveter and still function efficiently. The workflow would need to be adjusted such that the two workers would never need the riveter at the same time. As the workers both have multiple responsibilities, this change could be accomplished, but may require additional fixtures or buffer stocks, such that each worker would always have work that they could perform if the riveter is busy. Assuming this is possible, the total line would need a maximum of fourteen riveters at a time to reach high production levels.

There are fewer Role 3 workers required, and the difference in number between low and high production is small. They will need to receive inputs from several of the Role 1 and 2 stations, so it is easiest to have the Role 3 stations centrally located within a small group of Role 1 and 2 stations.

Figure 2 below is a schematic of one work cell in the production line. It includes three workstations for Roles 1 and 2 and one workstation for Role 3. The diagram includes one riveter at each workstation, but this could easily be expanded to two. Raw materials are fed on a U-shaped conveyor belt around all of the work stations to deliver inputs to each station. Following packaging, the Role 3 worker would put finished products back onto the same belt to take them away for shipping or storage.

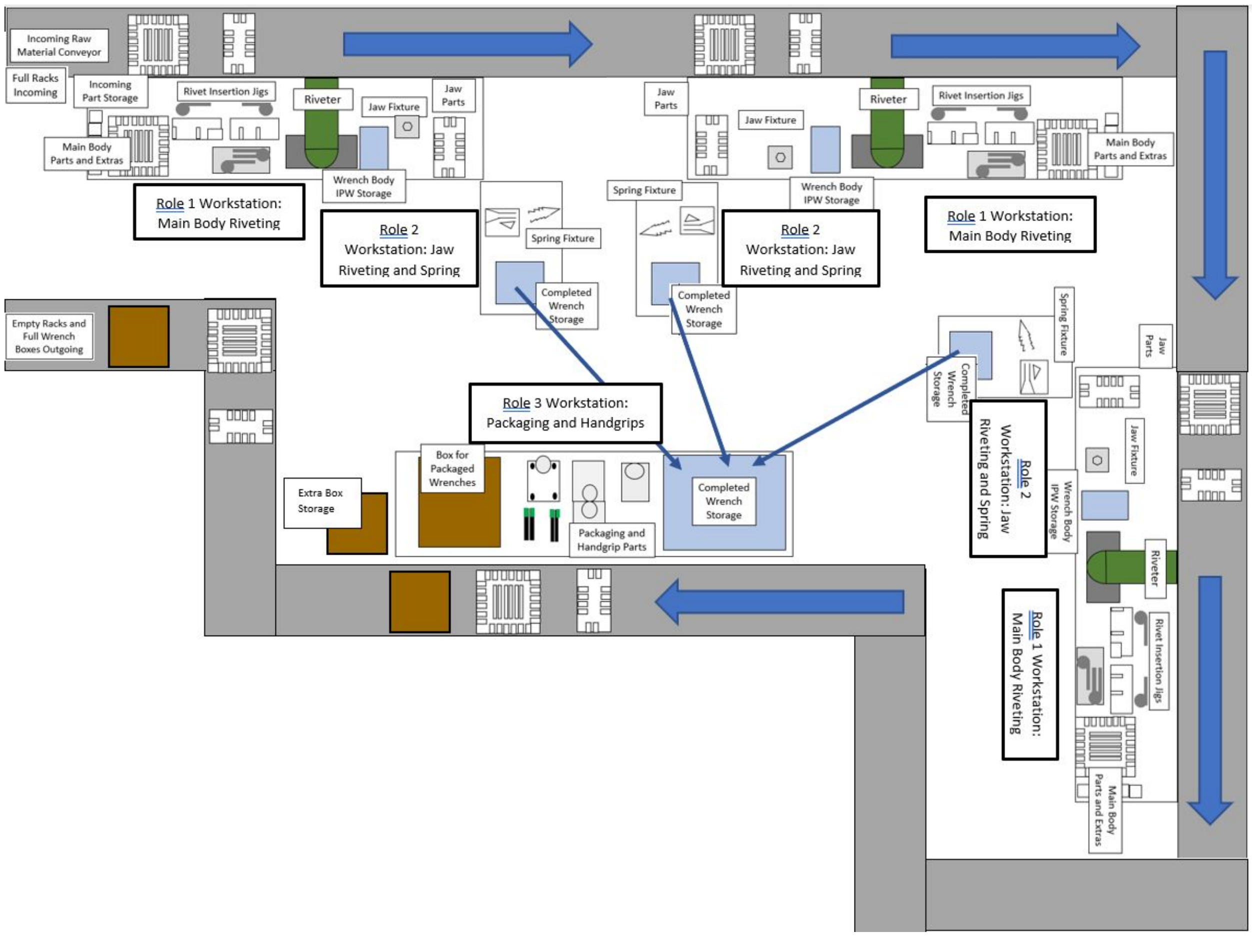


Figure 2: One Production Cell Layout

A series of these work cells could make up the whole production line as shown below in Figure 3. For low production, two work cells would be needed. For high production, five cells would be used. In each instance, one Role 1 and 2 workstation would lie vacant, so one Role 3 worker would be underutilized. During low production, the Role 3 worker could be cross-trained to complete Role 1 and 2 tasks as needed in the downtime. In high production months, the vacant workstation would allow for maintenance to be performed on one machine at a time without sacrificing production speed necessary to meet demand.

Figure 3: Full Factory Layout

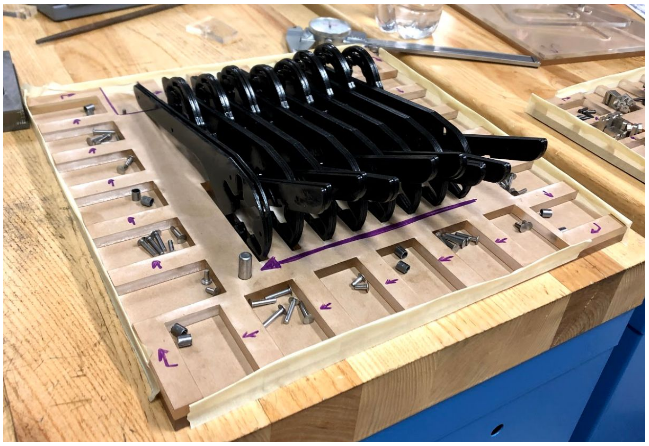
This layout is capable of producing seasonal demand in both low and high production times of the year. If demand increases in the future, more of the work cells could be utilized year-round instead of only during peak production.

Standard Operating Procedure: Bionic Wrench Assembly

Purpose: Assemble quality up to standard bionic wrenches ready for distribution

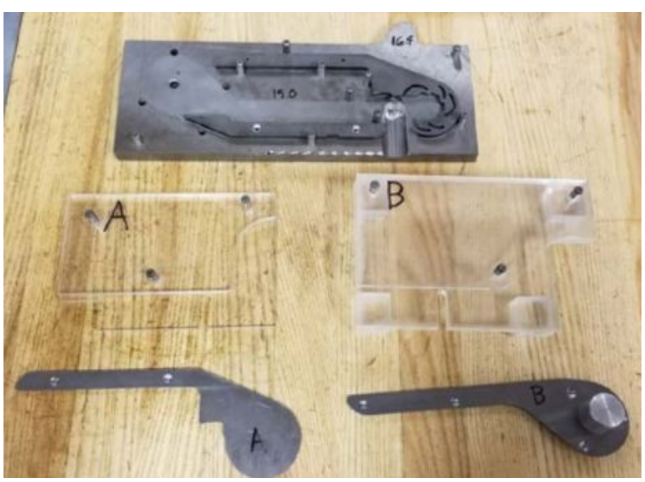
Definitions:
Part Storage Unit (A/B): Unit by which the specified number of quality selected assembly parts are stored prior to worker assembly operations
Main Body Jig: Main alignment and riveting fixture for body assembly
Jig A: Used to load rivets (S) into interior plates
Jig B: Used to load rivets (L) into exterior plate
Interior Flip Plate: used to flip interior plates into Main Body Jig
Exterior Flip Plate: used to flip exterior plate into Main Body Jig
Rivet S: Small rivets for use with interior plate subassembly
Rivet L: Large rivets for use with Main Body assembly
Rivet J: Rivets for use with Jaw Assembly
Center Alignment Boss: Aligns first exterior plate on Main Body Jig
Track Position #: Position number associated with riveting section of interior sub assembly as well as Main Body Jig

Pre-Assembly Notes



Part Storage Unit A
Inventory Worker
Before beginning the assembly process the required inventory of parts for the target number of wrenches will be added to Unit A by the Inventory Worker. The processes ensures a quality check to ensure all assembly components are non-defective. All Materials for the Main Body Assembly Process are included in Unit A.

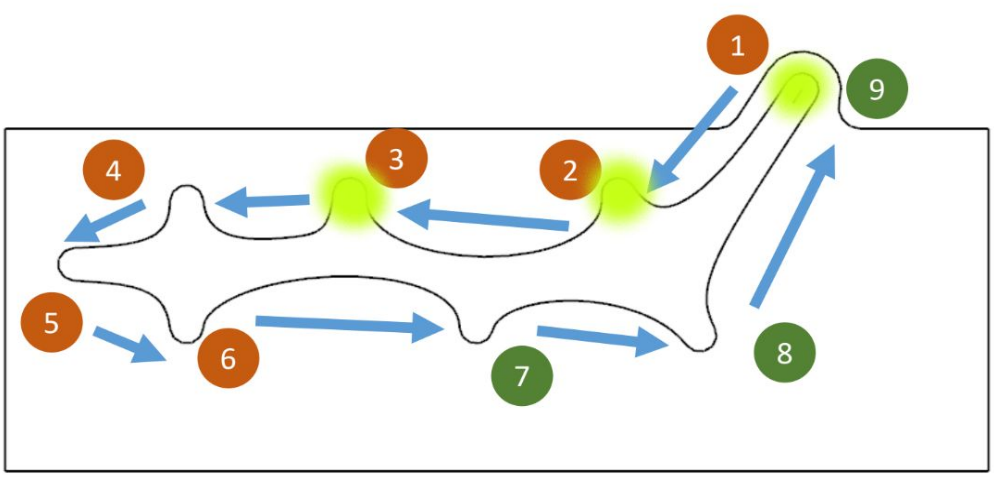
Part Storage Unit B
Inventory Worker
Before beginning the assembly process the required inventory of parts for the target number of wrenches will be added to Unit B by the Inventory Worker. The processes ensures a quality check to ensure all assembly components are non-defective. All Materials for the Jaw Assembly Process are included in Unit B.

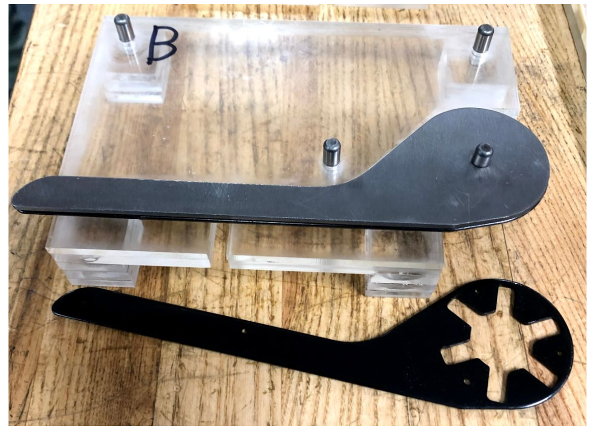


Required Fixtures for Main Body Assembly Processes
Assembly Worker
Once the inventory is satisfied ensure all fixtures for assembly are present at the workstation. Main Body Jig, Jig A, Jig B, Interior Flip Plate and Exterior Flip Plate with Center Alignment Cylinder should be present.

Main Body Assembly Process

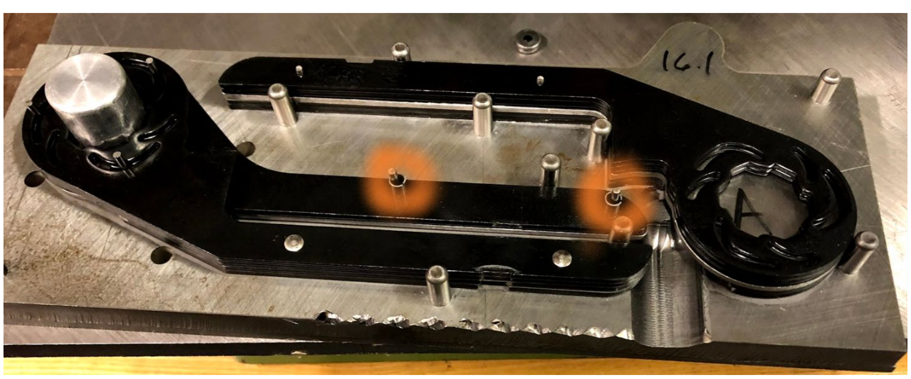
1. Place TWO INTERIOR PLATES on to Jig A
2. Place TWO S RIVETS into the plates
3. Place the INTERIOR FLIP PLATE onto the subassembly, totaling 3 plates on the Jig
4. Holding all plates together, FLIP subassembly on MAIN BODY JIG
5. For the FIRST SUBASSEMBLY A continue to step 5a, otherwise move to step 6
    a. RIVET according to rivet track Position number 1 through 3, set the subassembly aside





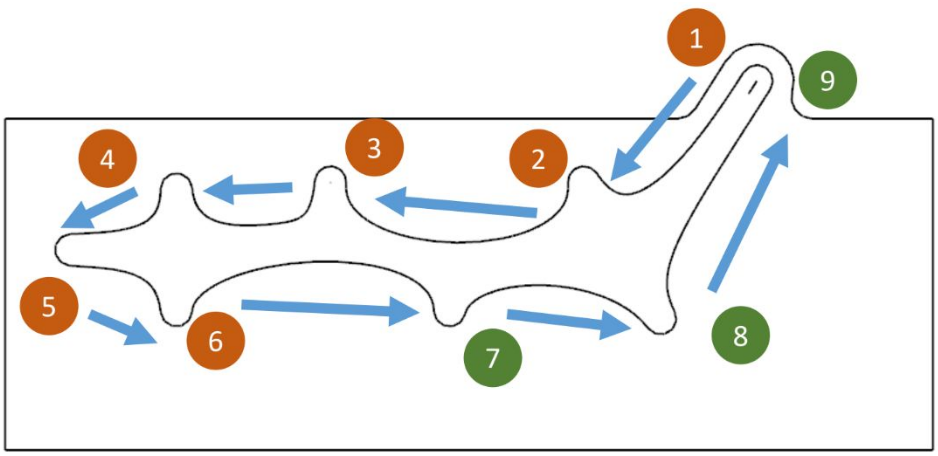
6. Repeat steps 1-4
7. Place ONE EXTERIOR PLATE on JIG B
8. Place 5 L RIVETS into plate
9. Place the EXTERIOR FLIP PLATE onto the subassembly
10. Flip EXTERIOR PLATE on to MAIN BODY JIG

11. Place the interior subassembly made in step 5a onto the Main Body Jig Silhouette
12. Add SPACERS to handle rivets



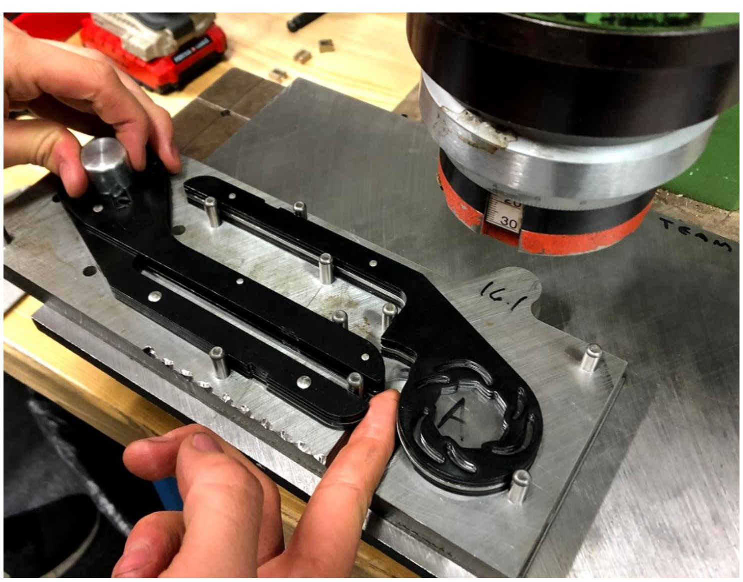
13. Place ONE EXTERIOR PLATE onto the stack, ensuring rivets pass through proper holes

14. Rivet both the SUBASSEMBLY and OUTER ASSEMBLY of the MAIN BODY JIG according to the indicated heights and based on the track position # order shown below.



16.4 for the SUBASSEMBLY and HEAD RIVETS

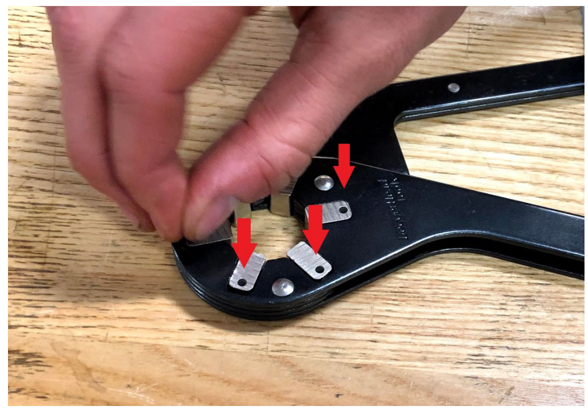
15.0 for the HANDLE RIVETS



15. Remove the assembly from the fixture using the CENTER ALIGNMENT BOSS and FINGER GROOVE, set the assembly aside for JAW ASSEMBLY PROCESS

Jaw Assembly Process

1. Place 6 JAWS into wrench head
2. Place 6 J RIVETS into JAWS
3. Squeeze wrench to ensure all rivets seat flush to the jaws



4. Place Jaw Fixture onto wrench
5. Rivet 6 JAW RIVETS

Auxiliary Assembly Processes

Spring

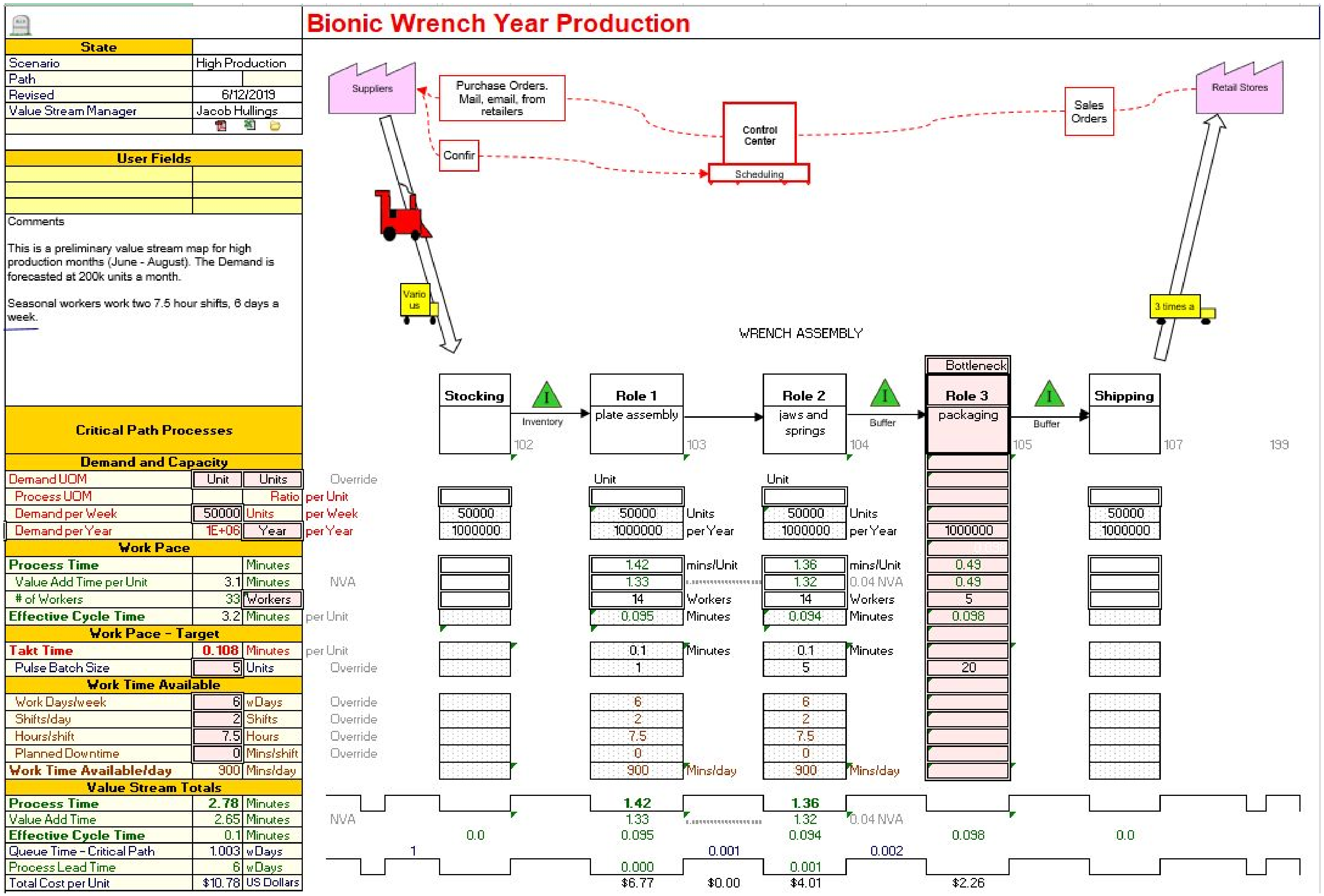
1. Insert the wrench from the end
2. Place spring on fixture behind wrench
3. Using the hand tool, pull the spring towards the wrench in order to insert the spring
4. Remove the Wrench by lifting the interior plates and sliding out from the side of t

Packaging

1. Place plastic wrapping on PACKAGING JIG
2. Place Wrench handles through plastic packaging openings, laying the wrench head into packaging cavity
3. Place PAPER LABEL WHITE SIDE UP into the packaging, close the other side of the packaging onto the cavity side
4. Spray big handle for ~.5 sec duration with WD40
5. Load both handles onto wrench, remove packaged wrench from jig

Value Stream Map

Figure 4 on the following page is a preliminary value stream map for assembling the Bionic Wrench. Production numbers are based on estimates provided for a high demand summer month (see Appendix C). The map examines times and costs for the assembly of the wrench based on the above line analysis.



Bionic Wrench Year Production
State
Scenario
High Production
Path
Revised
6/12/2019
Value Stream Manager
Jacob Hullings
User Fields
Comments
This is a preliminary value stream map for high production months (June - August). The Demand is forecasted at 200k units a month.
Seasonal workers work two 7.5 hour shifts, 6 days a week.
Critical Path Processes
Demand and Capacity
Demand UOM | Unit | Units | Override
Process UOM | Ratio | per Unit
Demand per Week | 50000 | Units | per Week
Demand per Year | 1E+06 | Year | per Year
Work Pace
Process Time | Minutes
Value Add Time per Unit | 3.1 | Minutes | NVA
# of Workers | 33 | Workers
Effective Cycle Time | 3.2 | Minutes | per Unit
Work Pace - Target
Takt Time | 0.108 | Minutes | per Unit
Pulse Batch Size | 5 | Units | Override
Work Time Available
Work Days/week | 6 | wDays | Override
Shifts/day | 2 | Shifts | Override
Hours/shift | 7.5 | Hours | Override
Planned Downtime | 0 | Mins/shift | Override
Work Time Available/day | 900 | Mins/day
Value Stream Totals
Process Time | 2.78 | Minutes
Value Add Time | 2.65 | Minutes | NVA
Effective Cycle Time | 0.1 | Minutes
Queue Time - Critical Path | 1.003 | wDays
Process Lead Time | 6 | wDays
Total Cost per Unit | $10.78 | US Dollars
Suppliers
Purchase Orders. Mail, email, from retailers
Confir
Control Center
Scheduling
Sales Orders
Retail Stores
Vario us
3 times a
WRENCH ASSEMBLY
Stocking
102
50000
1000000
Inventory
Role 1
plate assembly
103
Unit
50000 | Units
1000000 | per Year
1.42 | mins/Unit
1.33
14 | Workers
0.095 | Minutes
0.1 | Minutes
1
6
2
7.5
0
900 | Mins/day
Role 2
jaws and springs
104
Unit
50000 | Units
1000000 | per Year
1.36 | mins/Unit
1.32 | 0.04 NVA
14 | Workers
0.094 | Minutes
0.1 | Minutes
5
6
2
7.5
0
900 | Mins/day
Buffer
Bottleneck
Role 3
packaging
105
1000000
0.49
0.49
5
0.098
20
Buffer
Shipping
107
50000
1000000
199
1
0.0
1.42
1.33
0.095
0.000
$6.77
0.001
$0.00
1.36
1.32
0.04 NVA
0.094
0.001
$4.01
0.002
0.098
$2.26
0.0

Cost Analysis of Fixtures and Capital Expenses

Riveter Costs

As established, the line request 15 riveters, with 1 out of operation at all times during peak season (based on the above calculations) to allow for preventative maintenance. Based on an estimated cost of 15-45K per riveter from the National Rivet and Manufacturing Company, it would cost between $225,000 and $675,000.

Space Costs

Based on rental costs from Loopnet.com, manufacturing space costs around $1 per square foot per month. Our space needs can be estimated at between 225 and 250 square feet per cell, and factoring in the 5 cells as well as additional space for material handling and shipping, our space needs will be around 2000 square feet. Therefore we would estimate this to cost around $24,000 annually.

Conveyor Costs

According to Bastian Solutions (https://www.bastiansolutions.com/project-planning-how-much-does-conveyor-cost/), it costs around $174 per foot. Estimating the length of conveyor that would be needed for this project (estimated at around 500 feet), it would likely cost around $87,000 for conveyor belts.

Labor Costs

Additionally, we would require 12 workers year-round and 33 workers during the 3 month peak production. According to PayScale, the average manufacturing worker makes around $15 per hour in the US. Assuming that the year-round workers make slightly more, around $17 per hour, and that we are running two shifts year-round with 12 workers in each, our labor costs for the base labor force will be around $163,200. This also assumes two weeks per year of manufacturing shutdown. During peak production, there will be an additional 21 workers, working 6 days per week (in addition to our base workers working an additional two days), we find that the labor cost for peak production is $362,880 for the new labor and $78,336 extra to the year-round labor, leading to a total annual labor cost of $604,416. Therefore, it is clear that, while the riveter will have a high up-front cost, labor also represents a significant expense and will be incurred annually.

Fixture Costs

Based on the calculations above, it will cost around $411.67 for assembly fixtures per station, or around $5,700 for fixtures overall. Since this will be outsourced, we are estimating the total cost to be around $8,000.

Raw Material and Parts Cost

Estimating that rivets and spacers cost around a cent each, springs, jaws, and plates cost around $.75 each, and packaging and handles costs around $1.50, the cost of parts per wrench would equate to around $9.90 per wrench. Across all wrenches, this would come to around $9,900,000.

Therefore, our total up-front costs would be expected to be around $772,000. On top of that, we would incur annual labor costs of $604,416, annual space costs of $24,000, annual components cost of $9,900,000, as well as any additional costs for parts management, inventory, maintenance, repair, etc. Therefore, assuming that the up-front cost can be seen as spread over the first three years, the cost per wrench would come to around $10.79, which seems reasonable for a product that sells for $28.99.

Areas for Investment

The line described above is capable of reaching the current yearly demand for wrenches, but it is far from perfect. Several aspects of the line could be improved with the help of automation or higher quality equipment.

To actually implement the work cell designed above, a conveyor belt to automatically bring in raw materials and remove finished wrenches is essential. The setup is not very conducive to individually delivered boxes of materials due to its shape, so doing this would be a waste of time and motion. An automatic stream of parts would eliminate these wastes and reduce the amount of space needed for inventory at the workstations.

Along with automating the delivery of supplies, the trays on which parts arrive to the workstations could be improved. The current design uses tape to hold the parts in the tray as it is moved. The tape is peeled away to allow for easy scooping of the small parts from their compartments. Crafting a tray in which the compartments have sloped sides would eliminate the need for tape while still allowing for easy part removal. This would eliminate the waste generated by single use tape, as well as the time it takes to apply and remove the tape.

The elements during which most time was lost during the assembly process are fixturing the outer assembly jaws before riveting. Specifically, inserting rivets into the plates and jaws was a task that requires lots of time and dexterity. Because of the necessary dexterity, inserting rivets would be difficult to automate. However, a worker could fixture the assembly and then have an automated riveter form the heads of the rivets. While the machine did its part, the worker could fixture another assembly for riveting, allowing the human workers to focus on the dextrous tasks and allowing tasks to be done in parallel, improving efficiency. Automating this part of the process would also minimize the mistakes made during the riveting process, such as spacers being crushed or plates becoming misaligned, and maximize the number of perfect rivets. Based on information from National Rivet and Manufacturing Company, it would likely cost between $45,000 and $60,000 per riveter.

A final potential area for investment would be to improve the precision of the main fixtures. The processes used to manufacture the fixtures were not always very accurate, which led to poor tolerances and problems with wrench quality. The locations for the divots to hold rivet heads during riveting were located using a manual mill, and small inaccuracies caused bent rivets and improperly formed heads in the finished product. Additionally, the water jet cut track was not terribly precise, so additional filing and sanding was required to allow for its use. Even after these additional steps, the location of one of the points on the track was inaccurate, so the riveter tool was not centered on the rivet during assembly. Investing in higher precision processes would improve the final rivet quality, which is a critical part of creating wrenches that do not bind and look professional.

Final Assembly Fixture Design

The final assembly fixture design consists of two main fixtures: the main body fixture and the jaw fixture, as well as a number of smaller fixtures and jigs for inserting rivets, springs, and packaging, and storing parts. The riveting fixtures are made of machined steel and the auxiliary fixtures are made of laser-cut acrylic and aligned with steel dowel pins. These could be alternatively made with other materials or processes to be more durable over long periods of production time, such as water-jet cut or machined aluminum.

Main Body Fixture

The main body fixture is made up of an upper section with alignment pins for the plates, as well as offsets for riveting heights, made of 4140 Tool Steel, and a water-jet cut base with the alignment track for aligning to rivets. The track is designed to locate on a ⅜" pin set directly under the riveter head.

One key feature of the main body fixture is that only one riveting height is needed, eliminating the need to reset the height for different rivets. Additionally, it holds a subassembly and a full wrench body at the same time, allowing for the simultaneous production of subassemblies and full wrenches (without rivets) without needing a separate fixture to do both.

The fixture also limits the number of alignment pins necessary by utilizing the exterior flip plate as a central locating feature. The cylinder located in the center of this plate aligns the exterior and interior plates by the center to ensure that they are located at the most important area and avoid binding.

Additionally, the riveting locations are located via arcs on the track, meaning the fixture needs only slide to locate, not be lifted or lowered, allowing for rapid alignment and riveting once the parts are inserted with the flip plates. The fixture can be seen below in Figure 5.

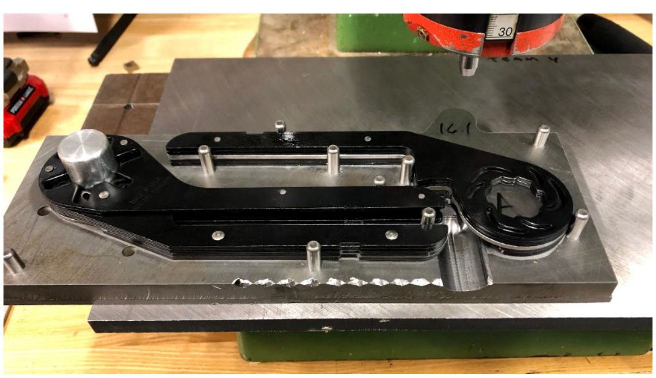


Figure 5a: Main Fixture Loaded

Figure 5b: Main Fixture Empty

Jaw Fixture

Similar to the main body fixture, the jaw fixture also features a central locator for the wrench head, ensuring that there will be no rotation while riveting. It also features an easy-aligning track with arcs to identify the locations for riveting jaws. While the current version includes divots for the jaw rivet locations, an updated version would remove these to improve wrench quality and remove witness marks from the jaws. This can be seen below in Figure 6.

Figure 6: Jaw Rivet Fixture

Spring Fixture

The spring fixture is made of a number of stacked acrylic sheets aligned with dowel pins. The wrench is slid into the slot in the base plate, and the upper handle spacer sits against the "shark fin" of the base plate. The spring is then placed on top of the base plate behind the handle of the wrench and, using the moving plate, the spring is guided along the path and then snapped into place.

Figure 7: Spring Insertion Fixture

Packaging Fixture
The packaging fixture consists of acrylic sheets and dowel pins to align the plastic packaging for wrench and grip insertion. It allows for easy closing of the packaging as the pins slot into the snaps on the packaging to allow packaging to be done quickly and repeatably.

Figure 8: Packaging Fixture

Rivet Insertion Jigs
Finally, rivet insertion jigs were created that align the plates for easy insertion of rivets and flip plates prior to insertion into the main riveting fixture. Images of these can be seen below.

Figure 9: Rivet Insertion Jigs with Flip Plates

Raw Material Delivery Racks

These racks hold raw materials for 8 wrenches parsed out by the amount needed in each step, allowing for efficient insertion of parts and rivets in the correct quantities. They can also be used in a factory setup as kanban racks that limit the amount of inventory in the system at any given time and save on work-in-process costs.

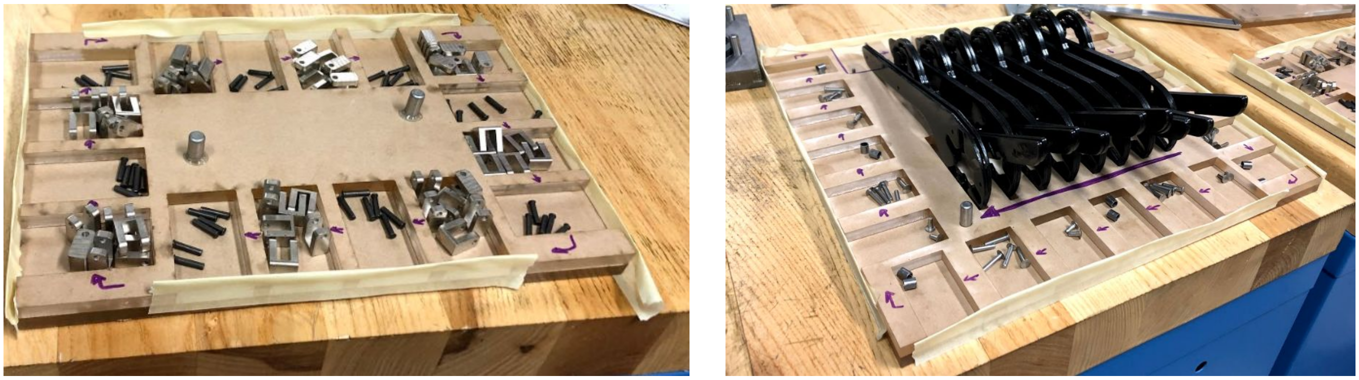


Figure 10: Material Storage Racks

Detailed drawings of all fixtures can be found in Appendix C.

Appendix A: Provided Demand Information

The following information was provided in the design brief by Professor Dan Brown.

DSGN 386 Manufacturing Engineering Design

1. Sales demand planning of 1 million units sold-shipped per year

    - 60% (600,000) units sold from Oct 1 - Dec 31 (in store Oct. 1st)
    - 20% (200,000) sold from May 1 - June 15 (in store May 1st)
    - 20% (200,000) distributed throughout the rest of the year
    - Assume 6 days per week during peak production
    - Assume access to a summer work force with 2 shifts June - August
    - Assume a third shift capacity in case it is needed but should design for a 2 shift operation.

2. For a high production month (e.g. June to August): 200,000 units / month

    - 2 shifts*24 work days / month (@ 6 days a week) = 48 shifts/month

    - 200,000 units / 48 shifts = 4,167 units/shift production rate

    - Assume 7.5 hours working time per shift 4,167 units-shift/7.5 hrs-shift = 555 units per hour or 9.25 units per minute for peak production

Appendix B: Parts and Assembly Drawings

This appendix contains detailed drawings of the Bionic Wrench components. Dimensions were found using calipers and an optical comparator. Tolerances were determined based on production methods and necessary interactions between components.

Appendix C: Fixture Drawings

This appendix contains detailed drawings of each fixture we propose to assemble the Bionic wrench using a manual riveter. The fixtures are designed such that one rivet height can be used for all rivets across the wrench. Riveting fixtures, auxiliary assembly fixtures, and part holding fixtures are included.