Group 19 Final Report

Word limit: 2000. Use bullet points and be concise. Cite reference

1. Documentation: final documentation of your group outputs in each step (1-5), such as Problem Definition, Concept Designs, Decision matrix, DfMA/DfAM, two CAD drawing in separated PDF files (A3 size with UC template, 1\* solid model in colours, 1\* exploded view of assembly with BoM), material selection, manufacturing process selection, etc. All SolidWorks CAD files should be submitted as a zip file including a readme.txt for brief explanation. (3 points)

**Methodology**

**Step 1: Defining the problem & Administration**

Based on the constraints and success criteria established in week 1, the problem was defined as shown in the problem statement.

**Problem statement:** Design a CNC soldering machine that is accurate, smooth, easy for the operator to assemble and disassemble, easy to transport, and fits on a desk. The machine must also be constructed from the materials provided and bought from a small budget.

Team roles were also decided along with meeting times, frequency, and locations.

**Step 2: Generating concept designs**

Table 1. Concept designs

|  |  |
| --- | --- |
| Concept design # | Concept drawing/ model |
| 1 Rotary motion / cylindrical coordinate system.  Side supports are aluminium rails.  Radial axis   * Lead screw   Phi axis   * Two gears | A blueprint of a machine  Description automatically generated |
| 2 Dual axis PCB motion, single axis soldering iron motion (cartesian)  X axis   * Belt drive   Y axis   * undetermined | A drawing of a computer screen  Description automatically generated |
| 3 Tri axis soldering iron motion (cartesian)  X axis   * Lead screw   Y axis   * Belt drive |  |
| 4 Dual axis soldering iron motion, single axis PCB motion (cartesian)  X axis   * Lead screw   Y axis   * Lead screw | A computer software design of a machine  Description automatically generated |

**Step 3: Choosing and Developing the final design models**

In general the weighting for the decision matrix was based on our constraints and end user considerations defined in week 1. For example, ease of assembly/disassembly, and accuracy.

As an example of how we weighted the constraints: Smooth movement was rated a seven because while this improves stability and aesthetic function, if the outcome is still accurate and precise, jagged movement does not matter.

Table 2. Weighted decision matrix

A screenshot of a computer

Description automatically generated

Concept design one was the chosen design because it seemed easier to assemble, with smoother movement and a lower number of parts.

Design advantages:

* Minimal use of parts.
* High accuracy near the centre.
* The soldering iron can reach it’s intended target from 2 different angles but can also continue in the same direction to ignore backlash.
* Easy to assemble the frame and turntable.

Design disadvantages:

* Requires complex G-code set up and execution.
* Requires precise alignment.
* Variable accuracy
* Vibration caused by the high torque required to move the Z axis

**Step 4 & 5: Prototyping, testing, and evaluation**

During steps 4 and 5, all custom-made parts were prototyped and evaluated based on DfAM, DfM, DfA, structural integrity, and quality (dimensioning, tolerances and surfaces). Many parts needed multiple revisions due to improper dimensioning or finishes. Other parts needed a material change because of weakness, weight, manufacturing time, or assembly oversights.

Table 3. Material selection and manufacturing process for custom made components

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Component | Material  Final (initial/concept) | Manufacturing process | Justification / evaluation | #revisions |
| Driving gear | PLA (Steel) | 3D printing | * PLA – light loading, lower inertia * 3D printing – complex part. | 3 |
| Turntable | PLA (Steel) | 3D printing | * PLA – light loading, lower inertia * 3D printing – complex part | 3 |
| Motor mounting bracket | Sheet metal (PLA) | Water jet cutting | * Sheet metal - strength * Water jet cutting - accuracy | 2 |
| Lead screw mounting bracket | PLA (PLA) | 3D printing | * PLA because – light loading * 3D printing - easier for Additive manufacturing | 1 |
| Base motor slot | PLA (PLA) | 3D printing | * PLA – light loading * 3D printing – easier for AM | 3 |
| Turntable slot | PLA (PLA) | 3D printing | * PLA – light loading * 3D printing – easier for AM | 4 |
| Side plates | Sheet metal (Sheet metal) | Band saw cutting / drill press | * Sheet metal – rigidity, strength * Band saw/ drill press – manufacturing time | 1 |
| Structural bracket | PLA (Sheet metal) | Band saw cutting, drill press, and sheet metal bending | * Thicker PLA - medium loading * 3d Printing – easier for AM | 3 |
| Base plate | Acrylic (Sheet metal) | Laser cutting | * Acrylic – rigidity, reasonable strength * Laser cutting - accuracy | 1 |
| Solder feeder bracket | PLA (PLA) | 3D printing | * PLA – light loading * 3D printing – complex part | 3 |
| Solder feeder gear, shaft and connecting mechanism | PLA (PLA) | 3D printing | * PLA – light loading * 3D printing – small, complex parts | 3 |

1. Group reflection: How would your group evaluate your product? How did you apply engineering knowledge, such as DfMA, DfAM, etc.? What would your stakeholders like? What would not? How to improve? What lessons did you learn as a group? (1 point)

Evaluation of the CNC soldering machine at the end of week 5:

* Ease of assembly/disassembly:

Pros

* + The base of the machine, solder feeding mechanism, and gear mechanism are easy to assemble. The Side plates and aluminium rails require twelve 6mm screws, but they are easily accessible, which makes finger torquing easier.

Cons

* + The structural bracket is narrow and rigid, so there is little space for someone’s fingers when mounting the Z axis. There is also a particular assembly order.
* Cost: The design uses cheap sheet metal and 3D printed PLA filament.
* Reliability / precision: The gears have relatively high backlash due to 3D printing tolerances, and the Tera Term G code control box does not support polar coordinates. Consequently the angular resolution is lower compared with the theoretical; A different controller would fix this.
* Accuracy: with a gear ratio of 1:4, the turntable’s angular resolution is high. it has a maximum tolerance of about +- 0.3mm.
* Safety: This design lacks a ventilation system for solder fumes, and an emergency stop.
* DfM: Some of the 3D printed designs could be smaller. Overall most of the processes were simple, cheap, and quick.

knowledge of material properties and basic structural analysis helped during steps 4 and 5. Various constraints and principles (DfMA, DfAM) were considered while designing custom parts:

* Optimisation for additive manufacturing - self-supporting and complex.
* Optimisation for subtractive manufacturing – Simplicity and low quantities.
* Number of fasteners were minimised in favour of slots / press fit.
* Number of significant parts was minimised to reduce assembly complexity.
* The weight was minimised by changing material composition.

Our stakeholders would like the small number of significant parts required to assemble the machine. They would also like its relatively low cost.

Our stakeholders would not like the long assembly process. Screw assembly takes longer due to size variation. The lack of ventilation is another design fault, along with the fragility of the base and PCB mounting pins; these components are prone to breaking.

One of the problems was that the weighting of the decision matrix was not iterated upon. Initially, ease of manufacturing was a five because the machine would only be manufactured once. However, this does not account for prototyping and mis dimensioned parts, equipment limitations, available machining processes, nor the group members skill levels. Consequently, many prototypes were sub optimally designed and required complex subtractive manufacturing processes or long 3D prints.

As a group we learnt to start large projects early, and to organize more meetings. Another important aspect of the project that our group struggled with was manufacturing. We did not get inducted into the laser cutter or 3D printers until week 3 at the earliest. This significantly delayed the prototyping stage. There also could have been more communication outside of meetings.

1. Individual reflection in each step (4-5): what did you learn in step 4-5, and highlight those that you taught yourself in green colour? What did you like about the project and what would you like to be changed? What was your best contribution to the group’s success (give a specific example)? If you were to do this project again, what would you do differently? (1 point)

Lucas Kwan, ID: 44768081

Step 4 taught me how important prototyping is to identifying designs that do not work. Many parts in our prototypes didn’t have correct dimensions or did not function as intended. I learned how to use the 3D printer and the laser cutter to manufacture parts.

Step 5 taught me about how iterative steps 4 and 5 really are. After evaluating prototypes, we would make changes to parts many times. I learned how to use the Tera term controller when testing the machine to control the motors using G code.

I liked the freedom we had to develop the CNC machine as if it were a real project for a company. I did not like the lack of information given at the start; I would have preferred an induction on every machine we need as well as an overall roadmap of the project.

My best contribution was designing the parts for the soldering iron mount as well as sourcing materials for various parts.

Next time I would have started on steps 4 and 5 earlier in the project as well as start manufacturing parts in the first weeks.

John-Luke Fenn, ID: 46554924

Step 4 was all about modelling and prototyping. Throughout this step I learnt that DFM was important. Every time a prototype failed it meant another part had to be redesigned. This happened when we tried to make a bracket out of sheet metal, it was not bent in the right places. 3D printing solved this as we could easily print complex objects overnight. I also learnt how to test our design using the Tera term controller.

Step 5 I learnt about the efficacy of laser cutting. This was because it is accurate, quick, and easy. Also, in step 5 I taught myself the importance of sticking to the engineering process instead of going my own way. Doing this throughout all the steps meant that we have a mostly successful design.

In this project I liked having a team that was always willing to do their best and put the group first. However, I did not like the final report being due before the presentation.

My biggest contributions were general help or ideas. Solving problems or machining most of the non-CNC made parts like our metal sides and the test bracket.

Jack Edwards, ID: 51427661

Step 4 taught me that 3d printing is an effective prototyping method, and some parts can be carried through to the final design. This step also taught me about how different manufacturing processes can take vastly different times - some of our 3d prints took over 12 hours to complete.

Step 5 taught me about the use of different materials. For example, our radial motor mount was 3d printed, but wasn’t strong enough to hold up the motor and was replaced with a sheet metal version.

I liked having well defined weekly milestones. I did not like how the final report was due at the same time and day as the week 5 submission.

My biggest contributions were helping depict the machines motion in the prototyping video, and sourcing the sheet metal motor mount.

Reuben Smitheram, ID: 33115524

In step 4 I learnt how to use the 3D printers and the laser cutter. I also learnt that changing the thickness and infill of prototyped parts would reduce the print time, and that you have to be assertive when 3D printing due to the scarcity of 3D printers.

In step 5 I learnt how to operate the Tera Term control box and use G code to control the CNC machine.

In this project I liked the challenge of developing and modelling solutions to an open ended mechanical problem – which was new for me. I did not like the administration (deadlines, lab session time slots etc.).

My best contribution to the groups success in step 4 would be designing and 3D printing various components. In step 5 it would be finalising the development of different 3D printed parts (driving gear, turntable and more).

If I were to do this project again I would start earlier, ensure I knew of the available subtractive and additive manufacturing processes, and begin prototyping earlier.

# Final Report Individual Contributions

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Contributions | Mark | Signature |
| Reuben Smitheram | Finalised SolidWorks assembly, part files, and exploded view with BoM. Wrote methodology and parts of group reflection.  Proofread and edited the report.  Tested the CNC machine with G code. | 2 | Reuben |
| John-Luke Fenn | Individual reflection, worked on CNC machine. Tested machine with G code | 2 | John-Luke Fenn |
| Jack Edwards | Wrote individual reflection, proofread the documentation and group reflection | 2 | Jack |
| Lucas Kwan | Wrote evaluation and concept design reasoning. Helped evaluate prototype and designed parts. Wrote individual reflection. Tested machine with G code. | 2 | Lucas |
|  |  | Sum=2\*N |  |

N: number of group members. Every group member is expected to take part in the whole process, not just work on one part, for example, report writing only.

# References

ENMT 221 Lecture 2

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