

Interim Report

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BSc in Electrical & Electronic

Engineering



PSDE 6019: Major Project

Interim Report

Airway Height Control System

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1 INTRODUCTION

The purpose of this project is to reduce rejects, scrap and downtime caused by a not capable airway production process. In order to achieve the aim of the project an automated control system for airway height will be implemented. This system will allow obtaining a stable airway production process. *what does 'not capable' mean?*

This project could have a significant impact on the business since it would not only allow reducing production downtime by eliminating the need for operators to periodically measure the airway height and manually adjust the strip tension, but it would also significantly reduce the number of rejects and scrap, which is one of the major downfalls of the business.

As a company standard, airway height is manually measured at the start of every shift and after every change of coil. Despite these periodic checks, there is no guarantee that the airways produced are always within the specified tolerance.

Figure 1.1 shows the process capability report for airway height. As it can be seen below, the process is not capable. *This diagram / graph needs further explanation*

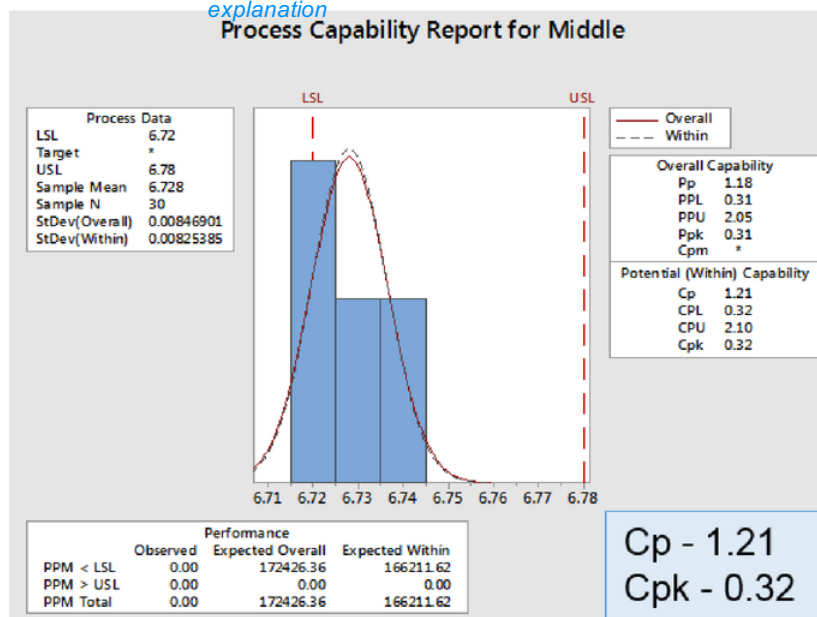


Figure 1.1 - Airway height capability report

Figure 1.2 shows the variation in airway height measurement due to operator interaction. Ten samples were measured by three different operators and as it can be seen below, the results obtained were different from one operator to the other. This shows that although the process is not capable there is a variation caused by the operator interaction with the measurement of airway height.

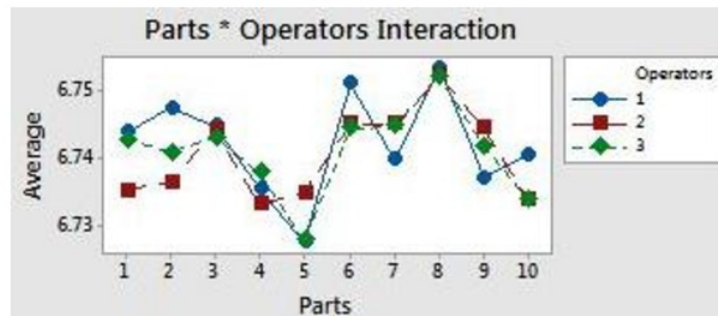


Figure 1.2 - Operator interaction

Although experienced operators usually detect products with airways that are not to specification by handling the product and visually inspecting it, these unwanted changes are usually undetected and cause rejects and scrap.

When airways are deemed to be outside specifications, the operator adjusts the pressure regulator, which then changes the tension of the aluminium strip and therefore changes the height of the airway.

After the adjustment, the operator measures the height of one airway by using the DTI. If the height is still not in specification, the pressure is adjusted again. This process is repeated until the height measured with the DTI is within the provided specification. This adjustment method can often last several minutes causing significant production downtime.

*Very good detailed introduction which states clearly,
what the problem is?*

2 BACKGROUND RESEARCH

2.1 Airway / Fin

This project will focus upon the measurement of a fin or airway. Figure 2.1 shows an airway. Every airway has three important parameters, which are the height, the length and the fin pitch. In order for an airway to be deemed as acceptable all these parameters must be within a defined tolerance.

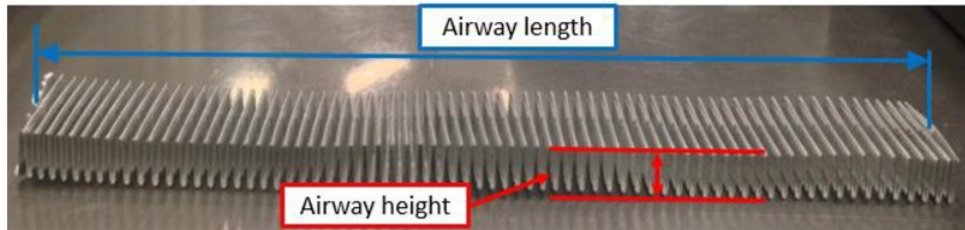


Figure 2.1 – Airway / Fin

Figure 2.2 shows the drawing of an airway. Highlighted below is the height and pitch of the airway. The fin pitch is the distance between a top peak and the next bottom peak, while the height is the distance between the highest and lowest point.

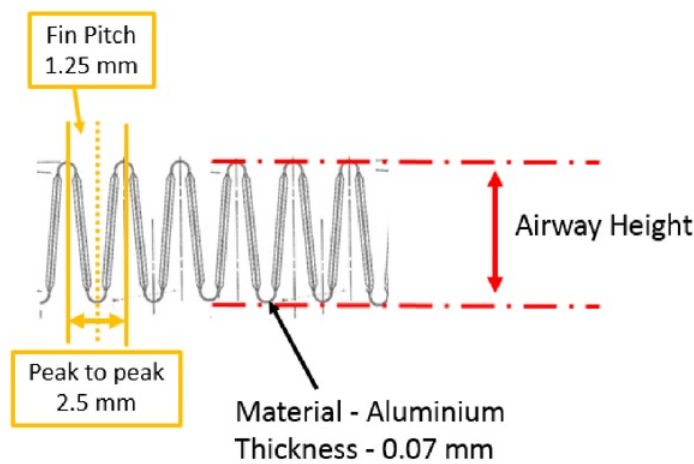
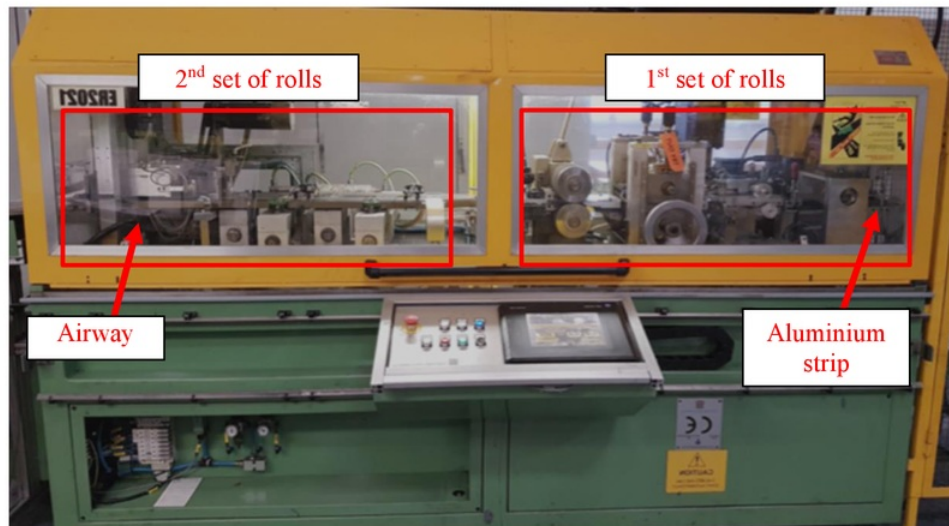


Figure 2.2 - Airway height and pitch
Very good detail

2.2 Airway machine operation

Airways are produced from a machine known as fin mill or airway machine.

Figure 2.3 shows an airway machine. This machine allows producing airways from an aluminium strip that passes through the sets of rolls shown below.



A block diagram showing each part would be beneficial. Figure 2.3 - Airway machine

Figure 2.4 shows the aluminium coil/strip, which is loaded on the fin machine in order to produce the airways. The coils are purchased from outside suppliers and are made of thin aluminium, typically of 70um thickness.



Figure 2.4 - Aluminium coil

Although there are several parameters that allow maintaining the airway height with the specified tolerance the tension of the aluminium strip fed into the machine is the most critical. Figure 2.5 shows the pneumatic actuated pressure pad, which allows achieving the required tension by applying pressure on the aluminium strip.

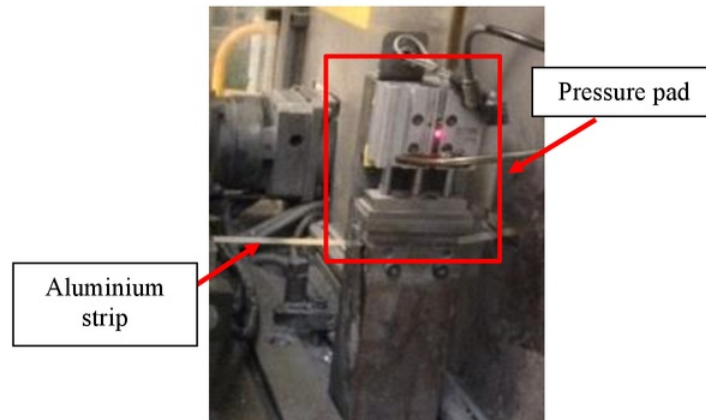


Figure 2.5 - Pressure pad

Some mathematical relationships could have

The pressure applied by the pad is proportional to the tension. Increasing the pressure will increase the tension and decreasing the pressure will decrease the tension.

The pressure, and therefore the tension, can be adjusted manually via a pressure regulator. Figure 2.6 shows the manual pressure regulator used for adjusting the tension applied on the aluminium strip.

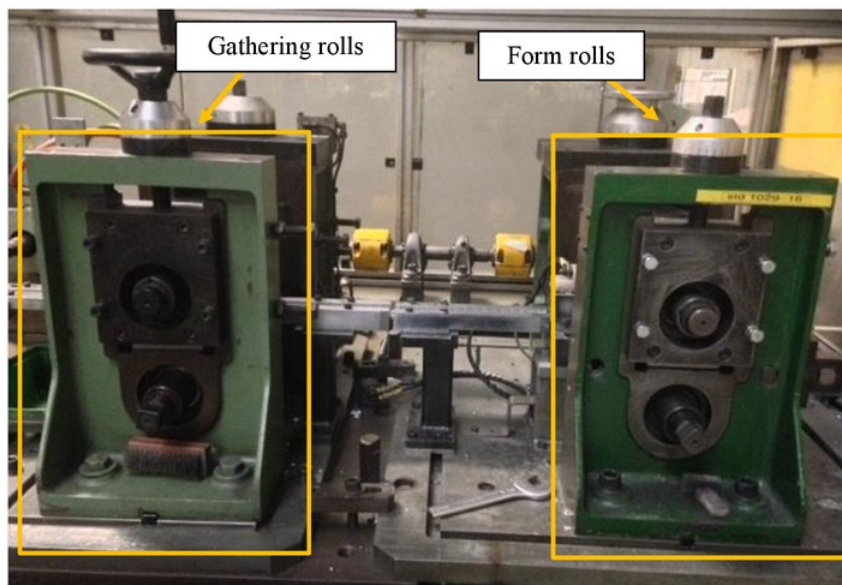


Figure 2.6 - Pressure regulator

Airway height is inversely proportional to the tension. Increasing the tension decreases airway height, while decreasing tension increases airway height.

Very clear detail given as to how the airway height can be adjusted

Figure 2.7 shows the first set of rolls, which are the two of the most important parts of the machine as they allow forming the airway.



Define terms 'gathering' & 'forming'.

Figure 2.7 – Forming rolls

Figure 2.8 shows the form rolls. They consist of a top and a bottom roll that, while rotating, bend the aluminium strip in order to form the airway.

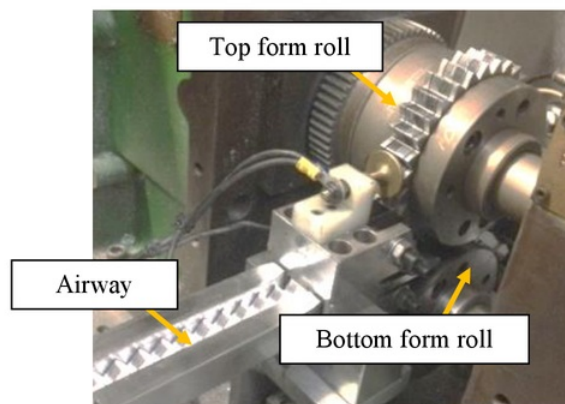


Figure 2.8 - Form rolls

Figure 2.9 shows the gathering rolls. They allow changing the profile of the airway by reducing the distance between the peaks in order to facilitate the next stage of the process.

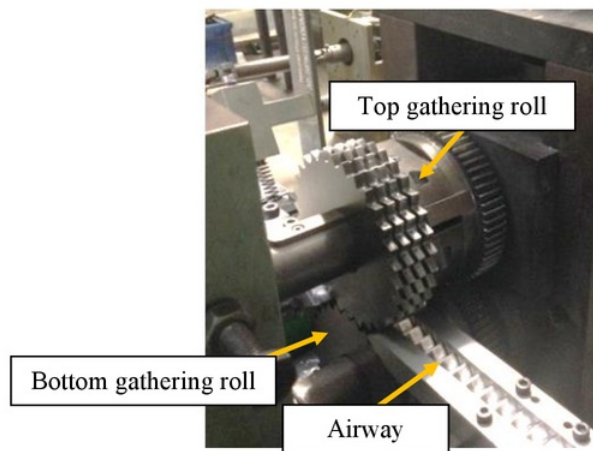


Figure 2.9 - Gathering rolls

Figure 2.10 shows the second set of rolls, known as scroll rolls. The scroll rolls are plastic coated rollers coupled to AC servomotors that give full control over their speed. They allow controlling the fin pitch and airway length.

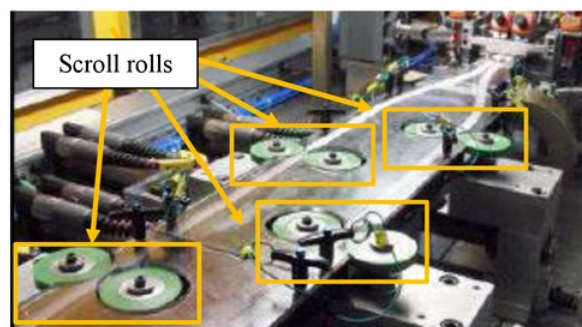


Figure 2.10 - Scroll rolls

Excellent detail on how the airway is formed

2.3 Airway Height Manual Measurement Method

Airway height is currently measured using a DTI (Dial Test Indicator). The first step for the measurement involves setting the DTI to zero on a steel bar. The airway is then placed under the steel bar in order to obtain the airway height measurement on the digital display, which is then recorded on a tracking document.

Figure 2.11 shows an example of airway height measurement performed using the DTI.



Figure 2.11 - (DTI) Dial test indicator
Good detail

3 SPECIFICATION

The project must deliver the following four outcomes:

1. Strip tension measurement
2. Strip tension control *Accuracy, response time, resolution, range and tolerance could have been specified.*
3. Measurement of airway height
4. Display airway height measurement

Figure 3.1 shows the diagram of the airway production process including the above-mentioned systems that will be developed within this project.

You could have drawn a standard control loop diagram that would have shown how one loop affects the other

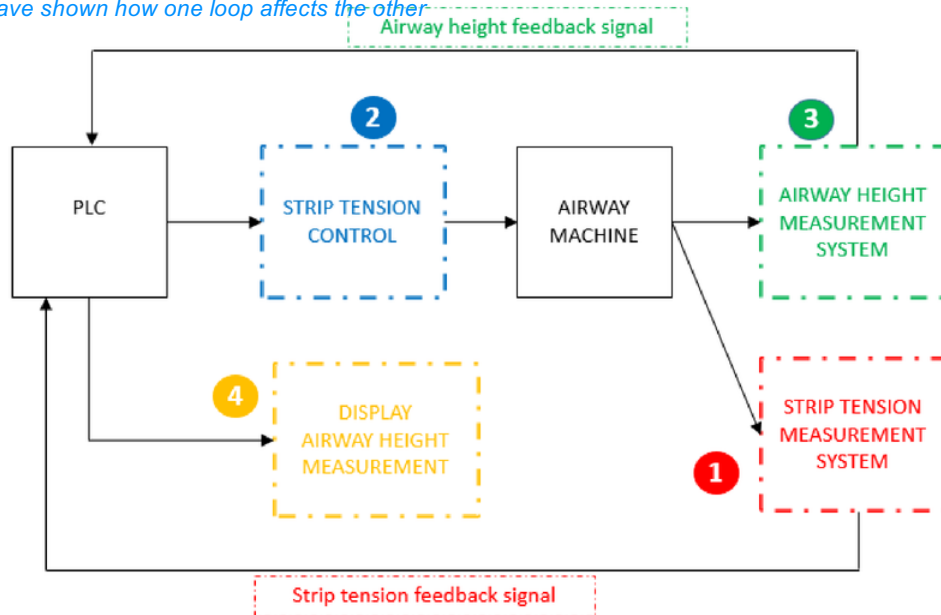


Figure 3.1 - Final system diagram

3.1 Tension measurement

Tension must be measured and clearly displayed. This will allow anomalies or unexpected changes in the process to be detected by monitoring the tension value.

could
Tension must be measured using either a load cell or a tension sensor.

3.2 Tension control

Strip tension control must be automated, meaning that operator interaction with the control system must be completely removed.

The strip tension must be adjusted in order to alter the airway height and maintain it within its process control limits.

The control system must be developed using the PLC of the fin mill and a suitable device that will enable adjusting the tension of the aluminium strip.

3.3 Airway height measurement *Give detail as to +/- tolerance.*

Airway height must be measured accurately, via an in-line automated measurement system.

The measurement system must have an output signal that will be fed back to the controller for adjusting the tension of the aluminium strip, in order to increase or decrease the airway height.

The feedback signal will be obtained via a signal-conditioning unit purposely built or by a dedicated amplifier/controller unit provided by the manufacturer of the sensing device.

Programming using the software provided by the manufacture may be required in order to obtain the airway height measurement.

3.4 Display airway height measurement

The measured airway height must be clearly displayed to the user using the Allen Bradley Panel Builder 32 HMI.

3.5 Time constraints

The system must be fully implemented and tested by April 2018.

Very good, general specification given

3.6 Budgetary constraints

The budget allocated for this project is £6,000. This was determined through an estimation of the benefits to the business of the automated control system.

The benefits include scrap and rejects reduction savings, and decreased downtime, which will mean increased productivity.

3.7 Maintenance

Attention must be paid to the maintenance aspect when introducing the new systems, as they must be relatively easy to maintain and modify if production performance goals change.

Troubleshooting procedures must be clear and suitable training of maintenance personnel must be carried out.

Ease of maintenance will be determined by the downtime caused by the airway height control system.

3.8 Reliability

Although maintenance personnel will be trained in order to enable them to tackle any issue that may arise, the system must be reliable.

Maintenance intervention for unplanned maintenance must be limited. This will allow maintaining high productivity and low downtime.

Reliability will be tested by carrying out extensive testing and monitoring the frequency of failures.

3.9 Success / failure criteria

The table in Figure 3.2 shows the criteria that will determine whether the project is successful or not. In order for the project to be successful, the answer to all criteria questions must be positive.

CRITERIA	YES	NO
Is the machine capable of measuring strip tension?		
Is the tension automatically adjusted to suit airway height?		
Is airway height accurately measured?		
Is airway height clearly displayed to the user?		
Has the project been completed on time?		
Has the project been completed within the budgetary constraints?		
Has the maintenance of the system been taken into consideration?		
Is the system reliable?		

Figure 3.2- Successful / failure criteria

The success/fail criteria shown will allow the success of the project to be shown clearly although quantifying criteria would be a help at this point.

4 LITERATURE REVIEW

4.1 Strip tension measurement

The measurement of the strip tension could be achieved by using a load cell, which is a very accurate device that allows measuring weight or force. It consists of four strain gauges that are connected electrically in a Wheatstone bridge configuration in order to obtain maximum sensitivity and temperature compensation. Each strain gauge is a length of wire subject to a force, or tension, within its elastic limit. The length of the wire increases when the tension increases causing its diameter to increase. The increase in diameter causes the resistance to increase (Omega, 2017).

Figure 4.1 shows the Wheatstone bridge configuration in a strain gauge load cell.

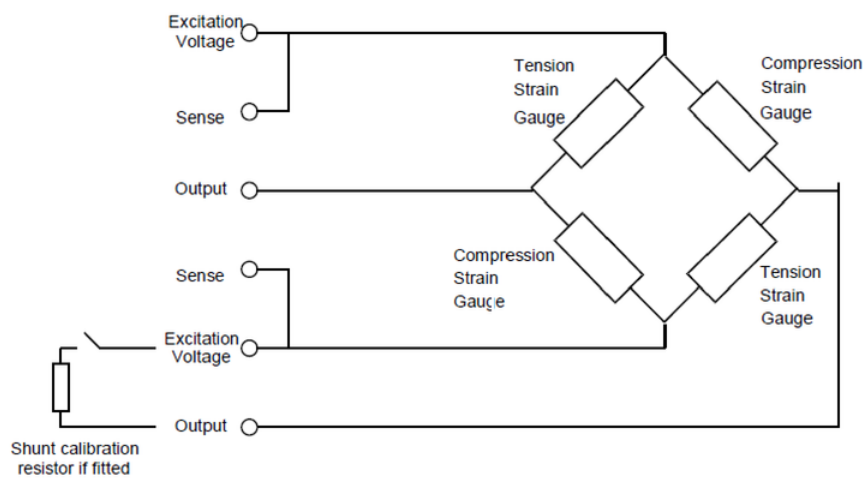


Figure 4.1 - Wheatstone bridge configuration (Hunt, et al., 1998)

Good detail

4.1.1 Load cell

A single point load cell could be used as it allows highly accurate force measurements even when loads are applied off centre (flintec, 2017). Figure 4.2 shows an example of single point load cell. As it can be seen below, the force can be applied anywhere on the top plate.

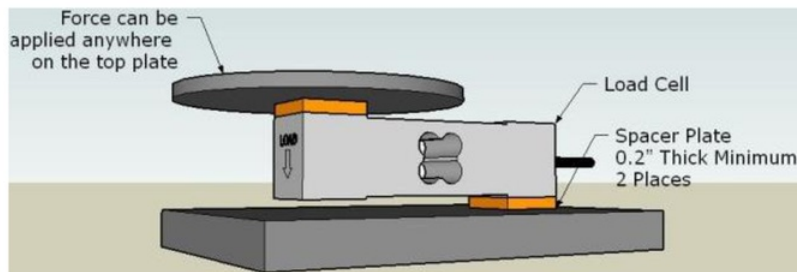


Figure 4.2 - Single point load cell (flintec, 2017)

Figure 4.3 shows how the tension of a strip can be measured using a roller. As it can be seen below, the strip passes over the roller 'C' in such a way that the strip tension produces a force on the roller.

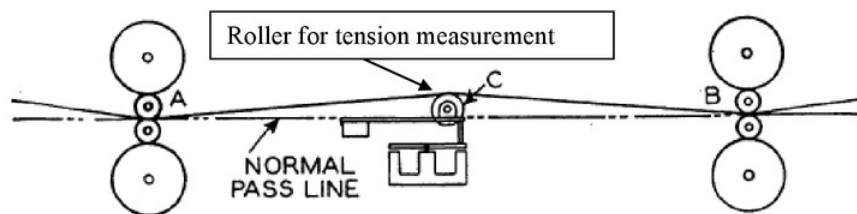


Figure 4.3 - Tension measurement (Hathaway & Mohler, n.d.)

The strip tension can be determined as a function of the force applied on the roller, which can be mounted on a load cell in order to obtain an accurate measurement (Hathaway & Mohler, n.d.).

4.1.2 Tension sensor

A tension sensor is a tension measurement device that uses an LVDT (linear variable differential transformer) in order to measure the displacement produced by the force of the web, which is proportional to the tension. The LVDT sensor converts the measured force into an electrical signal and it allows providing a very accurate tension measurement (Nexen, n.d.). Figure 4.4 shows the diagram of a tension sensor.

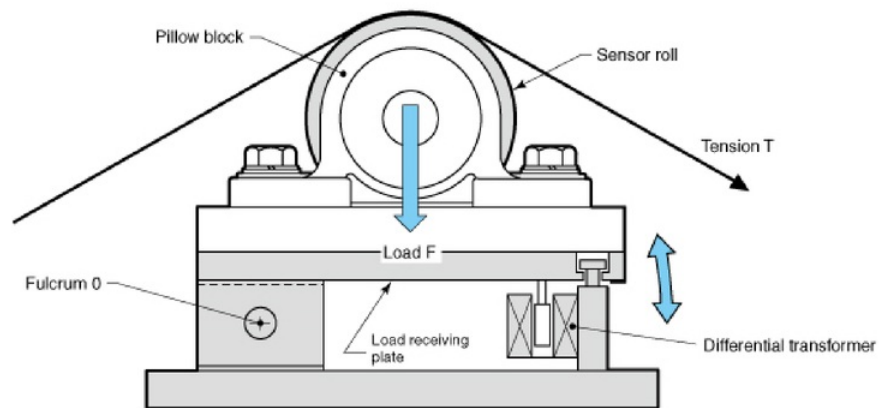


Figure 4.4 - LVDT tension sensor (Nireco, 2016)

Excellent detail on strip tension measurement

4.1.3 Decision

Figure 4.5 shows the multiple criteria decision analysis matrix used in order to establish the appropriate solutions for the tension measurement.

CRITERIA	Weighting (1 to 5)	Cantilever load cell				Tension sensor			
		Value	Score	Total	Comment	Value	Score	Total	Comment
Load range	5	68 Kg / 150 LB	5	25	High load range	10 Kg / 22 LB	3	15	Lower load range.
Repeatability/ Accuracy	4	0.2% (136g) <i>Accuracy should be split.</i>	4	16	Very good repeatability	± 1% (100g)	4	16	Very good accuracy
Amplifier input	1	240 VAC 115 VAC	3	3	Only AC input power can be used.	240 VAC 100 VAC 24 VDC	5	5	Both AC and DC power can be used. DC power supply can be used if available
Amplifier output	4	0-10 V 4-20 mA	4	16	Both voltage and current output is available	0-10 V 0-5 V 4-20 mA	4	16	Both voltage and current output is available
Ease of installation	3	N/A	4	12	Mounting frame and a shaft roll assembly required	N/A	3	9	Can be installed at any angle
Ease of calibration	3	N/A	3	9	Requires calibration	N/A	5	15	Calibration is not required
Cost	3	£1,189	4	12	Very cost effective	£2,010	3	9	Nearly twice as expensive
Availability	3	N/A	5	15	Device currently available and therefore does not require to be purchased	N/A	3	9	Device currently not available and therefore require to be purchased
Items required	2	Yes	3	6	Shaft/roll assembly	Yes	4	8	Pillow block
IP Protection Classification	4	IP67	4	16	Total protection against dust and liquids	IP30	3	12	Protection against tools and wires. No protection against liquids
				130					114

Figure 4.5 - Criteria decision analysis for strip tension measurement

The cantilever load cell was chosen due to the higher score obtained via the multiple criteria analysis matrix shown in the above table.

Excellent,
reasonable choice
made

4.2 Strip tension control

In order to achieve strip tension control will be required a controller and an actuation device for adjusting the strip tension (Becker, n.d.).

The controller will be the PLC used for controlling the operation of the airway machine, while the type of control will be either the common proportional–integral–derivative (PID) controller or a predictive control, which allows combining time-delay capabilities and disturbance rejection to the PID control system (Giovannini, 2009).

The actuation device for adjustment of the strip tension could be one of the following:

- Speed regulation of a motor (Whiteside, 2007) *Very good*
- Torque regulation of a motor (Whiteside, 2007)
- Electronic pressure regulator

4.2.1 Speed control

One of the methods used for the adjustment of strip tension is that mentioned in “A survey of the looper-tension control technology in hot rolling mills” where it is stated that the rotating speed of a mill motor is used for tension control (Choi, et al., n.d.).

Figure 4.6 shows how a clutch can be used to adjust the speed and therefore control the tension in the strip. As it can be seen below, the tension is the ratio between the torque and the radius of the nip roll.

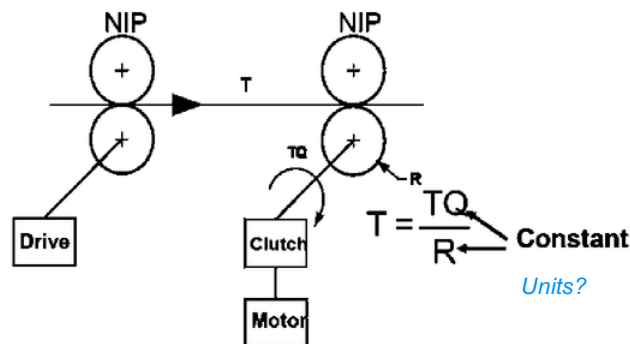


Figure 4.6 - Tension control via speed adjustment (Whiteside, 2007)

Excellent detail

4.2.2 Torque control

Tension adjustment through torque control can be achieved by using a brake.

Figure 4.7 shows how a brake can be used to adjust the torque and therefore the tension on the strip. As in the previous case, the tension is a result of the ratio between the torque and the radius of the nip roll.

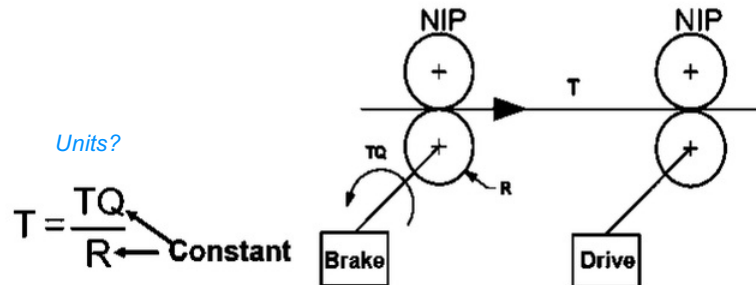


Figure 4.7 - Tension control via torque adjustment (Whiteside, 2007)

4.2.3 Electronic pressure regulator with pressure pad

The third alternative would be to use an electronic pressure regulator connected to the pneumatic cylinder. This would allow controlling the pneumatic pressure, and therefore the strip tension, via a voltage or current signal.

Figure 4.8 shows the pneumatic cylinder and the pressure pad currently used for adjusting the strip tension.

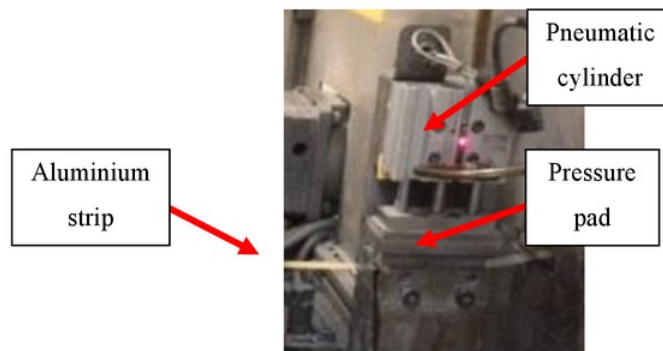


Figure 4.8 - Tension control via pressure pad

The addition of an electronic pressure regulator would allow automating the adjustment process by removing any operator interaction.

Electronic pressure regulators provide a regulated output pressure that is proportional to its electrical input signal. Figure 26.1 shows a diagram of an electronic pressure regulator. As it can be seen below, it uses a push valve, shown as air supply, and a vent valve to maintain the outlet pressure at the required set point (Equilibar, n.d.).

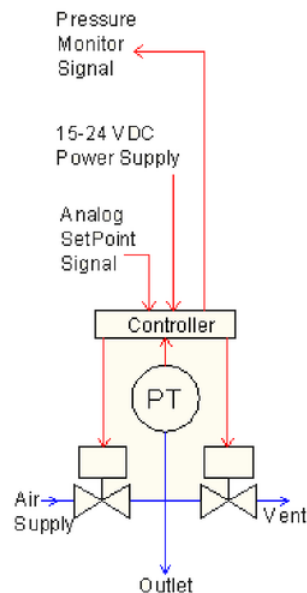


Figure 26.1 - Electronic pressure regulator diagram (Equilibar, n.d.)

Good clear understanding
shown

4.2.4 Decision

Figure 4.9 shows the multiple criteria decision analysis matrix used in order to establish the appropriate solutions for the strip tension control system.

CRITERIA	Weighting (1 to 5)	Motor torque control			Motor speed control			Electronic pressure regulator		
		Score	Total	Comment	Score	Total	Comment	Score	Total	Comment
Reliability	4	4	16	Motor is reliable	4	16	Motor is reliable	3	12	Pressure required depends upon quality of pressure pad
Availability	3	3	9	Motor available on site. AC/DC drive must be purchased	3	9	Motor available on site. AC/DC drive must be purchased	5	15	Electronic pressure regulator is available on site
Ease of installation	3	2	6	Looper angle (contact land on shaft) is critical	2	6	Looper angle (contact land on shaft) is critical	5	15	Easy to install (replace manual pressure regulator)
Cost	4	2	8	Exact cost to be confirmed	2	8	Exact cost to be confirmed	4	16	Relatively cheap £219,49
Maintenance	3	5	15	Does not require maintenance	5	15	Does not require maintenance	3	9	Pressure pad requires periodic maintenance / replacement
Additional items required	3	3	9	AC / DC drive	3	9	AC / DC drive	5	15	None
Energy consumption	3	3	9	Higher energy consumption although energy efficient	3	9	Higher energy consumption although energy efficient	5	15	Lower energy consumption
		72			72			97		

Figure 4.9 - Criteria decision analysis matrix for strip tension control

The electronic pressure regulator was chosen for controlling the strip tension mainly due its ease of implementation and its relatively cheap cost.

The control system will be developed within the Allen Bradley PLC used for controlling the airway machine. The signal from the cantilever load cell, used for strip tension measurement, will be used for controlling the strip tension.

Programming will be carried out using the RSLogix500 software in order to allow the Allen Bradley PLC to send an output signal to the electronic pressure regulator that will be used for the adjustment of the strip tension.

The electronic pressure regulator will then increase or decrease the air pressure in order to enable the pressure pad to increase or decrease the tension on the aluminium strip.

Again, excellent detail shown in coming to a decision as to which method of strip tension control to be taken forward

4.3 Airway height measurement

As previously mentioned this project will require the introduction of an airway height measurement system, which will use one of the following devices:

- Laser displacement sensor
- Image sensor *Broken down well but should contain values for accuracy, repeatability, resolution etc.*
- Laser micrometre
- Linear Variable Differential Transformer (LVDT)

4.3.1 Laser displacement sensor

Laser

There are two types of laser displacement sensors. One operates upon the basic principle of triangulation. Figure 4.10 shows the triangulation principle used in laser displacement sensors. As it can be seen below, the semiconductor laser emits a laser beam, which is reflected from the surface of the target. The reflected light is then collected by the light-receiving element. Due to the known position of the semiconductor laser and the light-receiving element the position of the target can be calculated by determining the position of the reflected light spot produced on the receiving element.

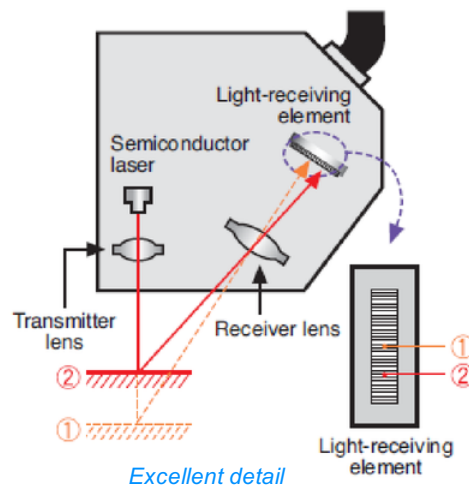


Figure 4.10 - Triangulation principle (Keyence Corporation, 2008)

The second type of laser displacement sensor is based upon the confocal principle of operation, which uses white light instead of a laser beam.

Figure 4.11 shows the confocal measurement principle.

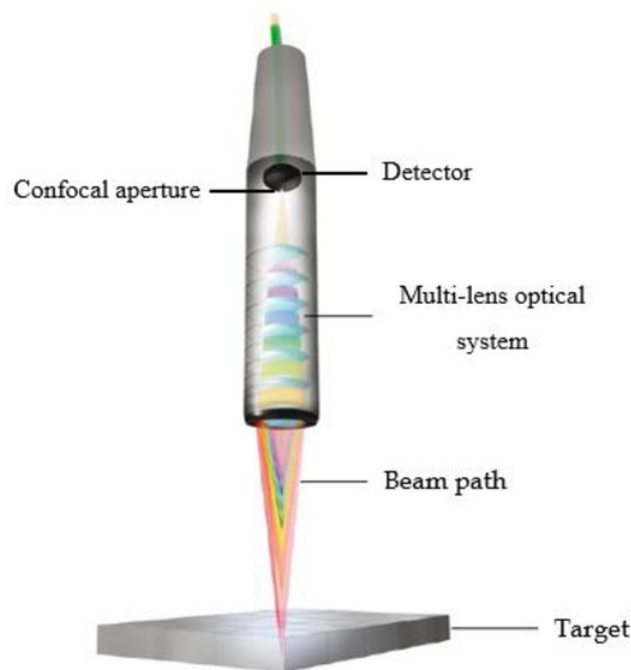


Figure 4.11 - Confocal principle (Micro-epsilon, 2017)

As it can be seen above, a confocal displacement sensor consists of a multi-lens optical system that allow focusing polychromatic white light onto the target surface.

The lenses allow dispersing the light into monochromatic stages along the measurement axis in order to create different wavelengths. Each wavelength corresponds to a specific distance to the target, which is determined by the deviation assigned in the factory calibration.

The reflected light from the target surface is passed via the confocal aperture to the detector. The optical system oscillates over the whole measurement range changing the intensity of the white light reaching the detector. At the true focal point, which is the instant where all of the reflected light reaches the detector via the pinhole, the profile value is calculated in order to obtain the displacement.

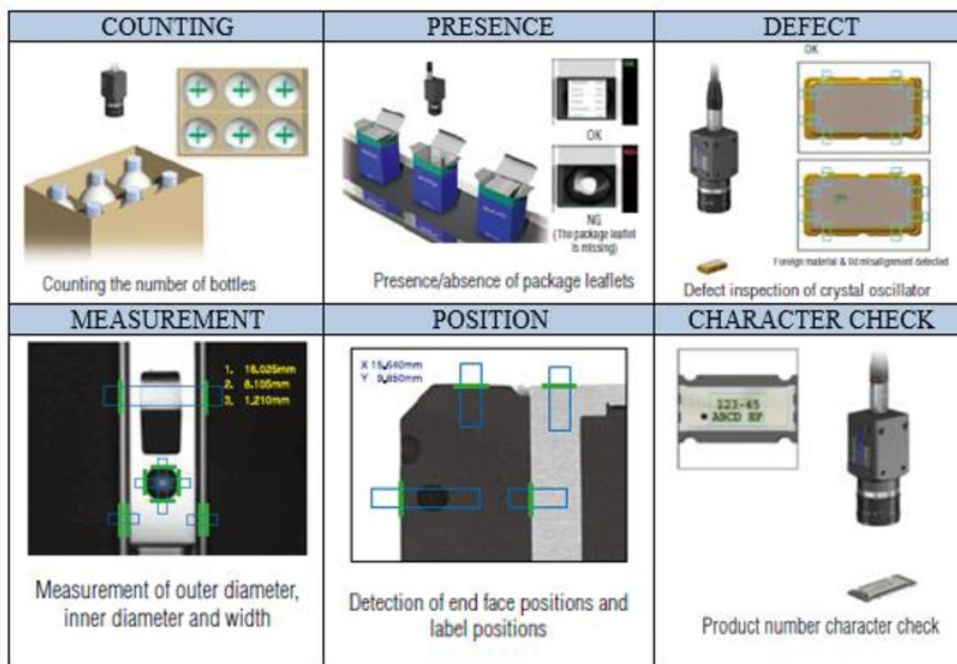
Very good detail given which has been well researched

4.3.2 Image sensor

Image sensors, also known as vision systems, consists of one or more sensors that capture pictures, an inspection software and a processing element that executes the user-defined program created using the inspection software.

The result of the inspection is then sent to an equipment or device for controlling or acting upon the inspection result (Teledyne DALSA , 2017).

They can be used for several types of inspections such as counting the number of objects, checking presence, detecting flaws/defects, measurements, positioning and character checks. Figure 4.12 shows some practical examples of the mentioned applications (Keyence Corporation, 2017).



Good detail

Figure 4.12 - Image sensor applications (Keyence Corporation, 2017)

4.3.3 Laser Micrometer

Laser micrometers, also known as optical micrometers, operate based on the thru-beam principle.

Figure 4.13 shows the measurement principle of a laser micrometer. As it can be seen below, a transmitter, shown as a rotating mirror, produces a parallel light curtain that is transmitted via a lens arrangement into a receiving unit. When an object is in the light path, the beam is interrupted. The shadow generated by the object is then detected by the receiving element, which is a photocell that analyses the time at which each laser crosses each part of the photocell. Software is then used to convert the timing data into a meaningful distance measurement.

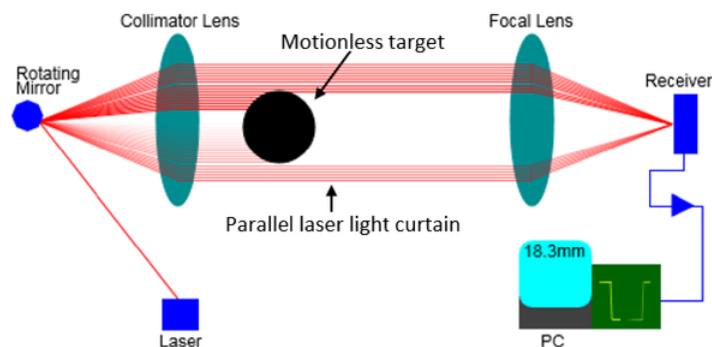


Figure 4.13 - Laser micrometer principle (LaserLinc, 2015)

They are typically used for dimensional measurements such as diameter gap, height and position (Micro-epsilpon, 2017).

Figure 4.14 shows three different measurement modes that can be achieved using an optical micrometer.

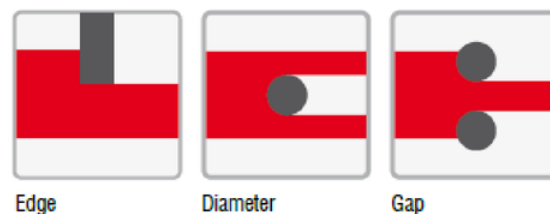


Figure 4.14 - Optical micrometer measurement modes (Micro-epsilpon, 2017)

Again, very good detail

4.3.4 Linear variable differential transformer (LVDT)

Figure 4.15 shows the basic components that constitute an LVDT. As it can be seen below, it is made of:

- A coil winding assembly, which consists of a primary and two secondary coils spaced from the centre.
- A cylindrical case that encloses and protects the coil windings.
- A magnetic core that moves freely axially within the coil winding assembly,
- A shield used for electromagnetic shielding.

(Collins Technologies, 2003).

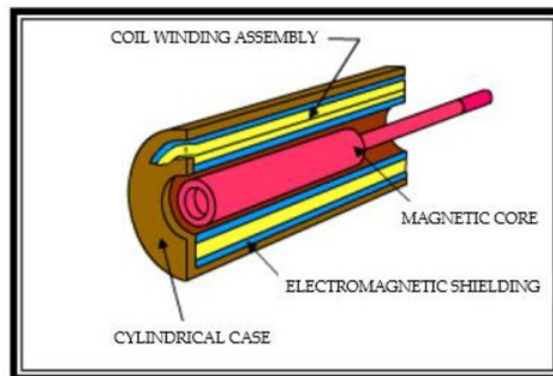


Figure 4.15 - LVDT basic components (Collins Technologies, 2003)

As suggested by their name, LVDTs operate on the principle of a transformer. Figure 4.16 shows an electrical diagram of an LVDT. As it can be seen below, the movable core can move freely in the cylindrical form, while the primary winding is excited by an AC source. The movement of the core causes the electrical voltage induced in the two secondary coils to change. This electrical voltage is proportional to displacement of the core. (National Instruments, 2016)

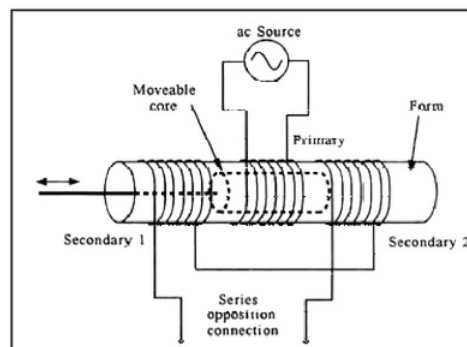


Figure 4.16 - LVDT electrical diagram (National Instruments, 2016)

Excellent research carried out

4.3.5 Decision

Figure 4.17 shows the multiple criteria decision analysis matrix used in order to establish the appropriate solutions for the strip tension control system.

CRITERIA	Weighting (1 to 5)	Laser sensor		Image sensor		Laser micrometer		LVDT	
		Score	Total	Score	Total	Score	Total	Score	Total
Accuracy (must be < 6um) <i>Good!</i>	4	5	20	4	16	4	16	5	20
Suitable for the environment	3	3	9	4	12	4	12	5	15
Suitable for the application	4	4	16	5	20	2	8	3	12
Cost	3	3	9	1	3	4	12	5	15
Distance from the product	4	4	16	3	12	5	20	4	16
Reliability	4	4	16	3	12	3	12	4	16
Effect on component being measured	4	5	20	5	20	5	20	3	12
			106		95		100		106

Figure 4.17 - Decision for airway height measurement

The LVDT measurement device was chosen ahead of the laser sensor due its lower cost and ease of set-up.

Very clear indication as to which sensor should be taken forward

4.4 Display airway height measurement

The result of the airway height measurement can be clearly displayed via an HMI (Human Machine Interface). HMIs are software applications that allow presenting information relating to the state of the equipment to the user of the machine.

In order to be able to display the result of the airway height measurement to the user as a meaningful parameter, the output signal of the measurement device must be scaled. This can be achieved through programming of the Allen Bradley PLC, using the software RSLogix500, or by implementing a signal-conditioning unit that will manipulate the output signal of the measurement system and display it to the user.

As well as displaying the measurement, the system will be programmed in such a way that the user of the machine will be notified when and if the airway height is outside the specified limits via a signal or alarm.

Summary of choices would have been nice at this point.

5 PLANNING AND PROCEDURES

Figure 5.1 shows the project plan. Highlighted in red are four main stages to this project.

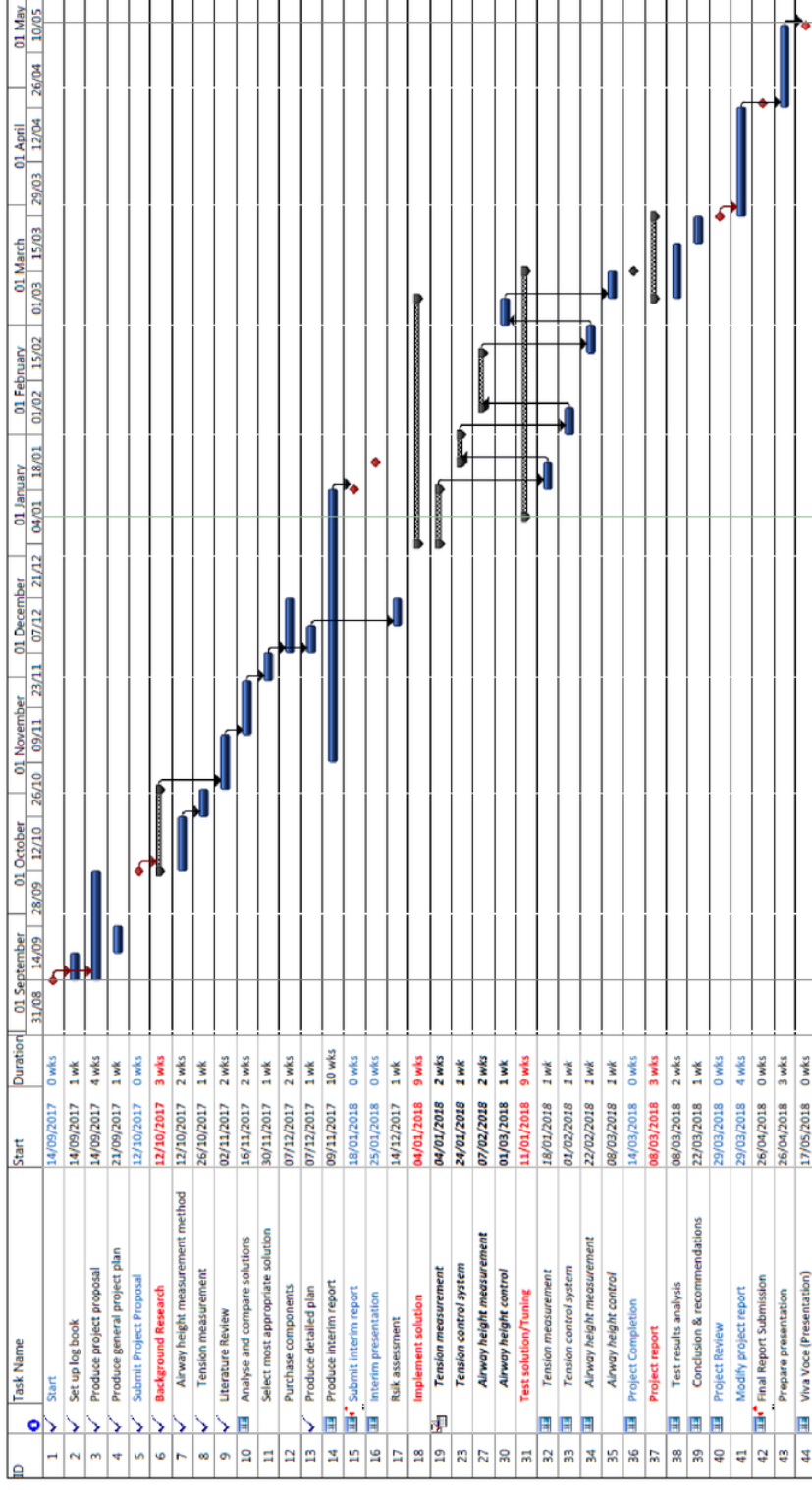


Figure 5.1 - Project plan

Work breakdown shown clearly through
Gantt Chart but no WBS shown

5.1 Detailed description

The implementation of the project solution can be broken down into three stages.

5.1.1 Stage 1 – Strip tension measurement

The first stage will involve:

- Implementing a tension measurement system
- Carry out testing in order to understand the correlation between strip tension and airway height

5.1.2 Stage 2 – Strip tension control

The second stage will involve:

- Testing of electro-pneumatic regulator to ensure correct functioning
- Installation of electro-pneumatic regulator
- Test strip tension adjustment using electro-pneumatic regulator
- Use strip tension measurement feedback to develop a strip tension control system

5.1.3 Stage 3 – Measurement and control of airway height

The third stage will involve:

- Installation of airway height measurement system
- Test measurement system (compare with current manual measurement method)
- Replace strip tension control feedback with that of the airway height measurement
- Test automated airway height control system

5.2 Health and safety

Following the implementation of any changes on the equipment an assessment of all risks associated with the system will be carried out. The user of the equipment will be informed of the identified risks and training on how to deal with those risks will be carried out. Where appropriate suitable arrangements aimed at managing and controlling the health and safety risks will be put in place (HSE, 2013).

Where is the risk assessment?

5.3 Contingency plans

A contingency plan was drawn up following an analysis of the risks and the possible consequences upon the delivery of the project. The purpose of this plan is to reduce the risks that could cause the objectives of the project not to be met.

As previously mentioned, in order for the project to be successful, a system capable of accurately measuring airway height must be implemented.

Due to the difficulties encountered during the search for a suitable measurement system, it is likely that airway height might not be able to be accurately measured.

In the event where the selected device was not able to measure airway height, the control system developed will aim to control the airway production process via the tension measurement feedback.

Trials will be carried out in order to identify a correlation between airway height and strip tension.

Nice to see contingencies noted.

6 PROJECT PROGRESS AND TESTING

6.1 Machine process characteristic

Testing will be carried out in order to understand the effect of the process variables on the airway height prior to the introduction of the tension measurement and control system.

This test will involve operating the machine at different speeds and strip tensions in order to understand the effect upon the airway height.

The table below shows an example of the series of tests that can be carried out in order to understand the effect of different machines speed and tension levels.

Machine (input) parameters	Airway height (Output parameter)
pneumatic pressure (1) @ machine speed (1)	To be measured
pneumatic pressure (2) @ machine speed (1)	To be measured
pneumatic pressure (1) @ machine speed (2)	To be measured
pneumatic pressure (2) @ machine speed (2)	To be measured

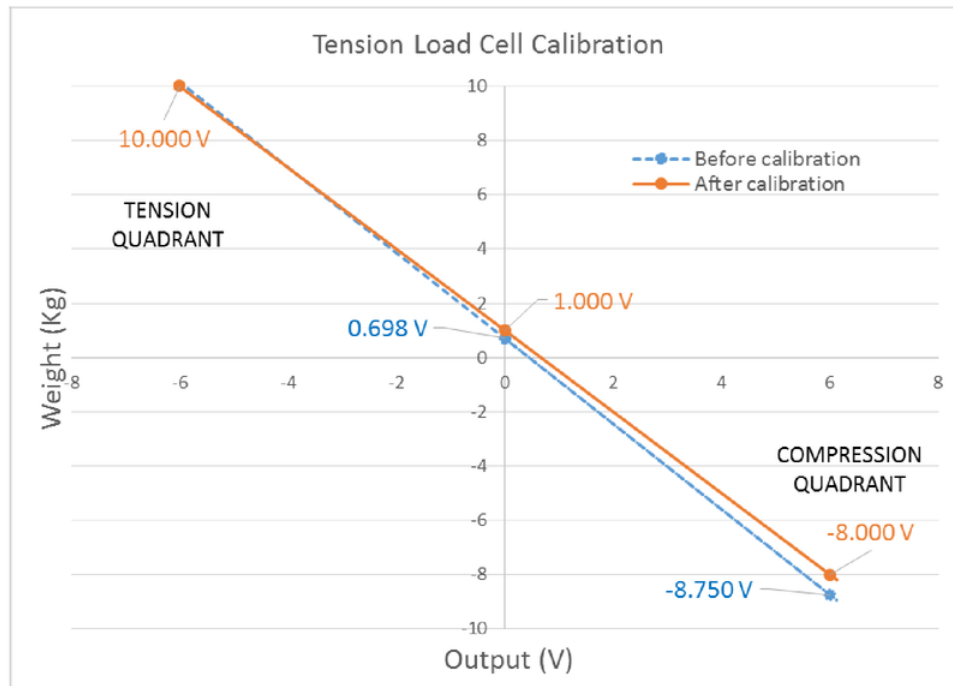
Figure 6.1 – Machine characteristic test plan

Since the strip tension is not being measured, the pneumatic pressure to the pressure pad will be used for correlating variation in tension to airway height.

Good but this is not work that has been completed!

6.2 Tension measurement system

Prior to the installation of the load cell, it was tested and calibrated. Figure 6.2 shows the behaviour of the load cell before and after calibration. As it can be seen below, the load cell was calibrated to output 1V at no load and -8V at know ^{a known} load of 6Kg.



Very good clear set of results

Figure 6.2 - Load cell calibration

Following the installation of the load cell on the fin mill machine, testing will be carried out in order to confirm that the calibrated output has not changed.

After ensuring its calibration, testing will be carried out in order to understand the variation of the tension during the operation of the machine.

Measuring the strip tension will help identifying the cause of airway height variation and will also allow understanding the effect of varying the pneumatic pressure.

Additional tests may be required in order to understand the effect of a large or smaller coil diameter on strip tension. This test will be necessary if there is a variation in strip tension when all other parameter, such as machine speed and pneumatic pressure, are constant.

6.3 Electro-pneumatic regulator

The electro-pneumatic regulator, to be used for adjusting the strip tension was tested in order to ensure that the voltage input parameters produce the required pneumatic output pressure, as stated in the product datasheet.

Figure 6.3 shows the linearity of the device obtained from the datasheet against that obtained from practical testing.

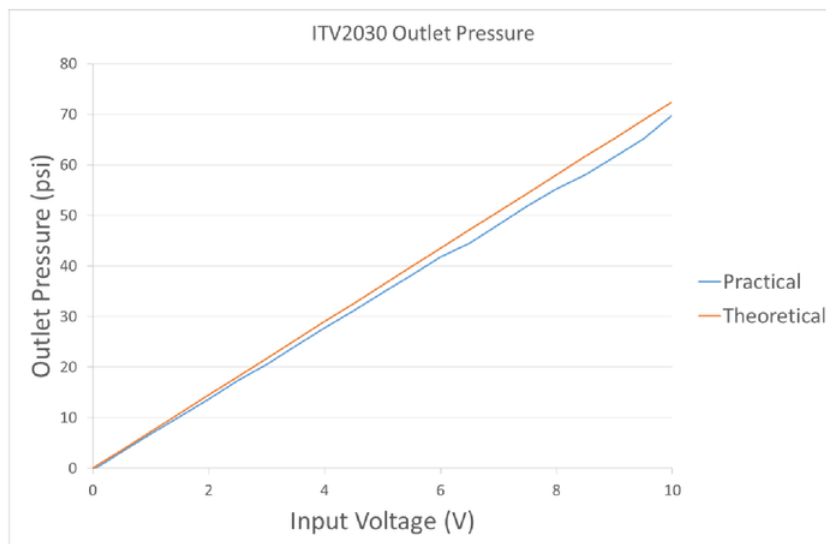


Figure 6.3 - Electro-pneumatic regulator testing results

Good test results noted

As it can be seen above, the output of the device measured during the practical experiment is not as linear as that stated in the product datasheet.

Just about linear but gradient

This could be due to the device *different* having been used for a long period, which could have caused a loss in sensitivity of the internal pressure sensor that offers feedback. Although this is not ideal, it does not cause any issues in terms of achieving the required control of strip tension. The feedback from the load cell will be used to adjust the pressure and therefore eliminate any error.

7 CONCLUSION AND RECOMMENDATIONS

7.1 What has been achieved

Research has been carried out in order to understand the operation of the machine and key characteristics to be taken into consideration.

been

A specification has devised identifying the aims and objectives of the project. Criteria that will define whether the project has been successful have also been stated.

Literature review of the possible solutions for strip tension measurement and control, and airway height measurement has been presented along with reasons for selecting the load cell for strip tension measurement and the electro-pneumatic regulator for strip tension control.

Good detail

7.2 What is left to do

The next step will involve carrying out trials in order to determine machine characteristics and the behaviour of the process under different conditions.

Following these trials, the tension measurement system will be used for determining the optimum strip tension for obtaining the required airway height.

This will be followed by the implementation of an electro-pneumatic regulator that will allow controlling the strip tension with the aim of maintaining airway height at the required value.

Following the implementation of a tension control system an airway height measurement system, the LVDT, will be installed for accurately measuring the airway height. Trials will be carried out using the LVDT and its output signal will be used as feedback for controlling the strip tension.

Very good overall conclusion given which shows, clearly, what has been done and what is left to do. Very little reflection.

8 CITATION LIST

Becker, B., n.d. *Selecting the right tensioning system for the application*, Illinois: Warner Electric.

Choi, I. S., Rossiter, A. & Fleming, P., n.d. *A SURVEY OF THE LOOPER-TENSION*, Sheffield: University of Sheffield.

Collins Technologies, 2003. *LVDT Principle of operation*, Long Beach (California, USA): Collins Technologies.

Equilibar, n.d. *EQUILIBAR*. [Online]

Available at: <<https://www.equiblar.com/electronic-pressure-regulators/how-eprs-work/>> [Accessed 2017 November 2017].

flintec, 2017. *Single Point Load Cells*, s.l.: s.n.

Giovannini, L., 2009. *Predictive feedback control: an alternative to proportional–integral–derivative control*, Santa Fe (Argentina): s.n.

Hathaway, C. M. & Mohler, M., n.d. *Tension Measurement and Control in Cold-Strip Mills*, New York: IEEE.

HSE, 2013. *Plan, Do, Check, Act - An introduction to managing for health and safety*, s.l.: Health and Safety Executive.

Hunt, A. et al., 1998. *Guide to the Measurement of Force*, London: Institute of Measurement and Control.

Keyence Corporation, 2008. TECHNOLOGY BOOK. In: K. Corporation, ed. *LASER DISPLACEMENT SENSOR*. Osaka (Japan): s.n.

Keyence Corporation, 2017. *The A to Z of Machine Vision*, s.l.: Keyence Corporation.

LaserLinc, 2015. *Scanning Laser Micrometer Operating Principle*. [Online]

Available at: <http://laserlinc.com/laser_micrometer_operating_principle.html> [Accessed 23 October 2017].

Micro-epsilon, 2017. *confocalDT // Confocal chromatic measurement system*, Ortenburg (Germany): s.n.

Micro-epsilon, 2017. *Measurement Product Guide*, Brownleigh: Micro-epsilon.

National Instruments, 2016. *Measuring Position and Displacement with LVDTs*. [Online]
Available at: <http://www.ni.com/white-paper/3638/en/#toc2>
[Accessed 24 October 2017].

Nexen, n.d. *MB SERIES TENSION SENSORS*, Calgary (Canada): s.n.

Nireco, 2016. *Web Control Systems*. [Online]
Available at: <http://nireco.com/en/product/web/mb.html>
[Accessed 16th November 2017].

Omega, 2017. *Load Cell*. [Online]
Available at: <https://www.omega.co.uk/prodinfo/load-cells.html>
[Accessed 1st November 2017].

Teledyne DALSA, 2017. *Vision Systems 101: An Introduction*. [Online]
Available at: <https://www.teledynedalsa.com/imaging/products/vision-systems/vs101/>
[Accessed 22 October 2017].

Whiteside, D., 2007. *Basic of Web Tension Control Summary*, Missouri: Maxcess International.

*Very varied and detailed research
cited*

Interim Report

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

67 / 100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

Text Comment. what does 'not capable' mean?

Text Comment. This diagram / graph needs further explanation

PAGE 7

Text Comment. Very good detailed introduction which states clearly, what the problem is.

Text Comment. What does DTI mean?

PAGE 8

Text Comment. Very good detail

PAGE 9

Text Comment. A block diagram showing each part would be beneficial.

PAGE 10

Text Comment. Some mathematical relationships could have been presented here.

Text Comment. Very clear detail given as to how the airway height can be adjusted

Text Comment. Define terms 'gathering' & 'forming'.

Text Comment. Excellent detail on how the airway is formed

Text Comment. Good detail

Text Comment. Accuracy, response time, resolution, range and tolerance could have been specified.

Text Comment. You could have drawn a standard control loop diagram that would have shown how one loop affects the other

Text Comment. could

Text Comment. Give detail as to +/- tolerance.

Text Comment. Very good, general specification given

Text Comment. The success/fail criteria shown will allow the success of the project to be shown clearly although quantifying criteria would be a help at this point.

Text Comment. Good detail

Text Comment. Excellent detail on strip tension measurement

Text Comment. Repeatability & Accuracy should be split.

Text Comment. Excellent, reasoned choice made

PAGE 22

Text Comment. Very good

Text Comment. Units?

Text Comment. Excellent detail

PAGE 23

Text Comment. Units?

PAGE 24

Text Comment. Good clear understanding shown

PAGE 25

PAGE 26

Text Comment. Again, excellent detail shown in coming to a decision as to which method of strip tension control to be taken forward

PAGE 27

Text Comment. Broken down well but should contain values for accuracy, repeatability, resolution etc.

Text Comment. Laser

Text Comment. Excellent detail

PAGE 28

Text Comment. Very good detail given which has been well researched

PAGE 29

Text Comment. Good detail

PAGE 30

Text Comment. Again, very good detail

PAGE 31

Text Comment. Excellent research carried out

PAGE 32

Text Comment. Good!

Text Comment. Very clear indication as to which sensor should be taken forward

PAGE 33

Text Comment. Summary of choices would have been nice at this point.

PAGE 34

Text Comment. Work breakdown shown clearly through Gantt Chart but no WBS shown

PAGE 35

Text Comment. Where is the risk assessment?

PAGE 36

Text Comment. Nice to see contingencies noted.

PAGE 37

Text Comment. Good but this is not work that has been completed!

PAGE 38

Text Comment. a known

Text Comment. Very good clear set of results

PAGE 39

Text Comment. Good test results noted

Text Comment. Just about linear but gradient different.

PAGE 40

Text Comment. been

Text Comment. Good detail

Text Comment. Very good overall conclusion given which shows, clearly, what has been

Text Comment. Very varied and detailed research cited

GRADING FORM: CSG-RUBIC

BRUNO FORKUOH

67

RESEARCH-INFORMED LITERATURE



Introduction (4/5): Good. would have been nice to define terms; this would have made it easier for the reader to understand the graphical information presented. Background Research (3/4): Background Research: Very good with numerous photos to support description. Further marks could have been achieved by adding block diagrams to help in the explanation of the operation of the existing machine together with some theory and by citing sources used to gain this information. It would also have helped if the company's commercial activities and products had been mentioned as a lead in. Harvard referencing (3/4): A good range of sources used which have been listed and cited correctly. Literature Review (5/7): Literature Review: Good evidence of research and helpful tables provided for comparison of solutions. A summary of the final solution would be helpful at the end of this section and more citations are required.

15

KNOWLEDGE AND UNDERSTANDING



WBS (4/10): Present but could have been in a flow chart form. Further marks were available for more information on health and safety and no risk assessment included. Specification 7(/10): Good descriptions listed but there is a lack of technical data expected of the components such as resolution, accuracy, range, repeatability, response time etc. Some of this information is included in the literature review but could be stated here. Since errors accumulate, there could also be an overall accuracy figure aimed at. Gantt Chart (7/10): Good and detailed. However, contingency planning should not be about adopting another solution but rather, it should be about what could be done in a different order if circumstance change in order to ensure final outcome is achieved on time.

18

ANALYSIS



Analysis of test results (6/10): Some results of calibration discussed. Conclusions (7/10): Very good overall conclusion given which shows, clearly, what has been done and what is left to do. Very little reflection shown.

13

PRACTICAL APPLICATION AND DEP.



Progress to date (3/5): Testing involved calibration check on existing devices. It would be helpful to ensure that the test equipment used is also calibrated. Presentation of test results (4/5): Well presented in graphical form.

7

SKILLS FOR PROFESSIONAL PRAC.



Recommendations (6/10): Good but concern is expressed that if the solution fails, another solution will be chosen. However, this could have part of the literature review to ensure that the chosen solution is the best one. Report Quality (8/10): Report has a good structure (though not exactly as stated in the brief), figures are well presented. However, spelling and grammar need to be improved.