Engineering 2019 v1.1

IA3 high-level annotated sample response

June 2018

Project — folio (25%)

This sample has been compiled by the QCAA to assist and support teachers to match evidence in student responses to the characteristics described in the instrument-specific marking guide (ISMG).

Assessment objectives

This assessment instrument is used to determine student achievement in the following objectives:

1. recognise and describe the machine and/or mechanism problem, engineering technology knowledge, and mechanics, materials science and control technologies concepts and principles in relation to machines and/or mechanisms
2. symbolise and explain ideas and a solution in relation to machines and or/mechanisms
3. analyse the machine and/or mechanism problem and information in relation to machines and/or mechanisms
4. determine solution success criteria for the machine and/or mechanism problem
5. synthesise information and ideas to predict a possible machine and/or mechanism solution
6. generate a machine and/or mechanism prototype solution to provide data to assess the accuracy of predictions
7. evaluate and refine ideas and a solution to make justified recommendations
8. make decisions about and use mode-appropriate features, language and conventions to communicate development of the prototype solution.

Instrument-specific marking guide (ISMG)

Criterion: Retrieving and comprehending

Assessment objectives

1. recognise and describe the machine and/or mechanism problem, engineering technology knowledge, and mechanics, materials science and control technologies concepts and principles in relation to machines and/or mechanisms
2. symbolise and explain ideas and a solution in relation to machines and/or mechanisms

The student work has the following characteristics:	Marks
• accurate and discriminating recognition and discerning description of the machine and/or mechanism problem, engineering technology knowledge, and mechanics, materials science and control technologies concepts and principles in relation to machines and/or mechanisms • adept symbolisation and discerning explanation of ideas and a solution in relation to machines and/or mechanisms with sketches, drawings, diagrams, graphs, tables and/or schemas.	4–5
• accurate recognition and appropriate description of the machine and/or mechanism problem, engineering technology knowledge, and some mechanics, materials science and control technologies concepts and principles in relation to machines and/or mechanisms • competent symbolisation and appropriate explanation of some ideas and a solution in relation to machines and/or mechanisms with sketches, drawings, diagrams, graphs, tables and/or schemas.	2–3
• variable recognition and superficial description of aspects of the machine and/or mechanism problem, concepts or principles in relation to machines and mechanisms • variable symbolisation or superficial explanation of aspects of ideas or a solution in relation to machines and/or mechanisms.	1
• does not satisfy any of the descriptors above.	0

Criterion: Analysing

Assessment objectives

3. analyse the machine and/or mechanism problem and information in relation to machines and/or mechanisms
4. determine solution success criteria for the machine and/or mechanism problem

The student work has the following characteristics:	Marks
• insightful analysis of the machine and/or mechanism problem, and relevant engineering mechanics, materials science, control technologies, technology, and research information in relation to machines and/or mechanisms, to identify the relevant elements, components and features, and their relationship to the structure of the problem • astute determination of essential solution success criteria for the machine and/or mechanism problem.	6–7
• considered analysis of the machine and/or mechanism problem, and relevant engineering mechanics, materials science, control technologies, technology, and research information in relation to machines and/or mechanisms, to identify the relevant elements, components and features, and their relationship to the structure of the problem • logical determination of effective solution success criteria for the machine and/or mechanism problem.	4–5
• appropriate analysis of the machine and/or mechanism problem, and engineering mechanics, materials science, control technologies, technology, and research information in relation to machines and/or mechanisms, to identify some of the elements, components or features of the problem • reasonable determination of some solution success criteria for the machine and/or mechanism problem.	2–3
• statements about the machine and/or mechanism problem, or information in relation to machines and/or mechanisms • vague determination of some solution success criteria for the machine and/or mechanism problem.	1
• does not satisfy any of the descriptors above.	0

Criterion: Synthesising and evaluating

Assessment objectives

5. synthesise information and ideas to predict a possible machine and/or mechanism solution
6. generate a machine and/or mechanism prototype solution to provide data to assess the accuracy of predictions
7. evaluate and refine ideas and a solution to make justified recommendations

The student work has the following characteristics:	Marks
• coherent and logical synthesis of relevant engineering mechanics, materials science, control technologies, technology and research information, and ideas to predict a possible machine and/or mechanism solution • purposeful generation of a machine and/or mechanism prototype solution to provide valid performance data to critically assess the accuracy of predictions • critical evaluation and discerning refinement of ideas and a solution using success criteria to make astute recommendations justified by data and research evidence.	8–9
• logical synthesis of relevant engineering mechanics, materials science, control technologies, technology and research information, and ideas to predict a possible machine and/or mechanism solution • effective generation of a machine and/or mechanism prototype solution to provide valid performance data to effectively assess the accuracy of predictions • reasoned evaluation and effective refinement of ideas and a solution using success criteria to make considered recommendations justified by data and research evidence.	6–7
• simple synthesis of engineering mechanics, materials science, control technologies, technology and research information, and ideas to predict a possible machine and/or mechanism solution • adequate generation of a machine and/or mechanism prototype solution to provide relevant performance data to assess the accuracy of predictions • feasible evaluation and adequate refinement of ideas and a solution using some success criteria to make fundamental recommendations justified by data and research evidence.	4–5
• rudimentary synthesis of partial engineering mechanics, materials science, control technologies, technology or research information, or ideas to predict a machine and/or mechanism solution • partial generation of a machine and/or mechanism prototype solution to provide elements of performance data to partially assess the accuracy of predictions • superficial evaluation of ideas or a solution using some success criteria to make elementary recommendations.	2–3
• unclear combinations of information or ideas • generation of elements of a machine and/or mechanism prototype solution • identification of a change about an idea or the solution.	1
• does not satisfy any of the descriptors above.	0

Criterion: Communicating

Assessment objective

8. make decisions about and use mode-appropriate features, language and conventions to communicate development of the prototype solution

The student work has the following characteristics:	Marks
• discerning decision-making about, and fluent use of, - written and visual features to communicate about a solution - language for a technical audience - grammatically accurate language structures - folio and referencing conventions.	3–4
• variable decision-making about, and inconsistent use of, - written and visual features - suitable language - grammar and language structures - folio or referencing conventions.	1–2
• does not satisfy any of the descriptors above.	0

Task

Context
A food processing company currently uses one production line to deposit various food products into either round or hexagonal glass jars. The production line is capable of filling 30 glass jars per minute. The jar-feeder line can move glass jars to the production line at twice this rate. The company has decided to increase its output capacity by introducing an additional production line above the existing production line. Both production lines will be fed by the existing jar-feeder line and will each fill 30 glass jars with product per minute. The company requires a mechanism that will evenly distribute glass jars from the jar-feeder line to each production line. Each production run will only fill either round or hexagonal jars during that run. Requirements for the glass jar distribution system: • round glass jars have dimensions of 75 millimetres outside diameter and 150 millimetres overall height • hexagonal glass jars are the same height as the round glass jars and hold the same volume • shape and size of the screw lid area of the jar is irrelevant to the development of the glass jar distribution system • empty glass jars have a mass of 250 grams • glass jars have smooth exterior surfaces • glass jars need to be raised 1.5 metres to align with the new production line, which sits above the existing production line.
Task
There are two parts to this assessment. <u>Part A</u> Your task is to create a folio to document a solution to the glass jar distribution system problem, which meets the food processing company's requirements. In your folio, document the problem-solving process used to develop and predict a solution. Include pictures, sketches and/or CAD drawings of the virtual or actual prototype glass jar distribution mechanism to provide performance data concerning that part of the system that evenly distributes glass jars to each production line from the existing jar-feeder line. <u>Part B</u> Your task is to provide the Production Manager at the food processing company with a summary report of the preferred solution to the glass jar distribution system problem.

Sample response

Criterion	Marks allocated	Result
Retrieving and comprehending Assessment objectives 1, 2	5	5
Analysing Assessment objectives 3, 4	7	7
Synthesising and evaluating Assessment objectives 5, 6 ,7	9	9
Communicating Assessment objective 8	4	4
Total	25	**25**

The annotations show the match to the instrument-specific marking guide (ISMG) performance-level descriptors.

Part A

Communicating [3–4]

discerning decision-making about, and fluent use of folio and referencing conventions

The response includes the folio convention of a contents page (not included in the page count). Headings display thoughtful and astute choices used to organise and communicate the student's thinking during the problem-solving process in Engineering.

Table of Contents

1

Retrieving and comprehending [4–5]

accurate and discriminating recognition and discerning description of the mechanism problem, engineering technology knowledge, and mechanics and materials science concepts and principles in relation to mechanisms

The response includes information accurately drawn from the context, not just simply restated.

The response shows accurate and discriminating recognition and discerning description through what the student knows about the context of the problem, including the mechanics fundamentals involved in comprehending the related mechanical concepts and principles.

Assumptions are stated which clarify the problem with reference to unknowns. Evidence is provided of accurate and discriminating recognition and description of engineering technology knowledge in relation to the mechanical problem.

Exploring the problem

Characteristics of the required glass-jar distribution system

What is known about the problem

- The jar-feeder line delivers 60 jars per minute.
- The two production lines require even distribution of 30 jars per minute from the feeder line.
- Every second Jar needs to be raised 1.5 m to align with the new production line directly above the existing production line.
- Two different shaped jars need to be distributed by the system (round and hexagonal).
- A production run includes either round or hexagonal jars and not both.
- Empty jars have a mass of 250 grams regardless of shape.
- Jars have smooth exterior surfaces.
- Jars have an impact strength that can resist some externally applied forces when transferring from the feeder-line to the two production lines.

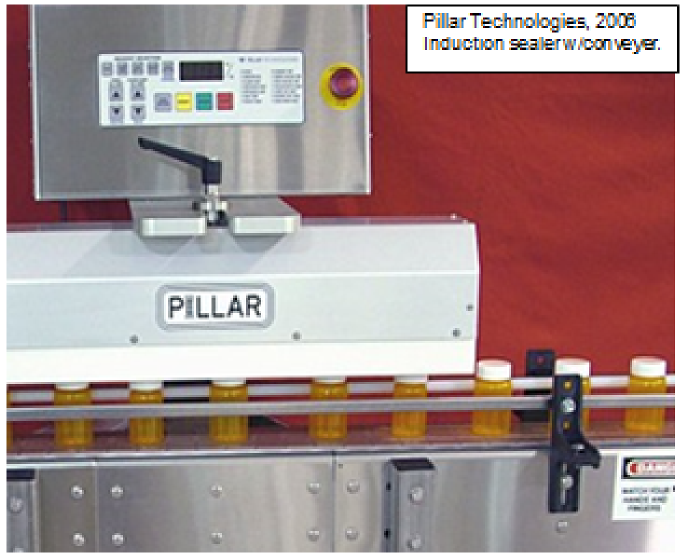
Assumptions

- The existing jar-feeder line includes a surface material that is non-slip against the base of the jars.
- Jars are currently kept apart (100 mm centres) to allow jars to be filled with product at regulated intervals and the new production line will require the same interval spacing between jars.
- The jar-feeder line is separate from the existing production line and so can be adjusted or modified without effecting the production line mechanism which fills jars with product at a rate of 30 per minute.
- The jar-feeder and production lines have some form of positioning rail (see figure 1) that holds the jars in position on the conveyer.
- The rail is positioned at a width dimension that allows both round and hexagonal jars to travel freely on the conveyer.
- That factory floor space is limited, and the new production line will be positioned above the existing production line.

Materials

- The jar-feeder line surface material will need to be investigated as this may impact on the development of the jar distribution system mechanism.
- Materials used should be recyclable, prevent damage to jars, be easily maintained or replaceable with wear.
- Material surfaces in contact with each other should be compatible, wear resistant and capable of lubrication as required.
- Materials used should be food safe and easily cleaned.
- Materials must be non-corrosive if contacted by food products and liquids as required to maintain cleanliness and hygiene standards.

Figure 1



Pillar Technologies, 2006 Induction sealer w/conveyer.

Mechanics fundamentals

Glass jar dimensions (round) = 75 mm dia × 150 mm high

Area of the round jar base = $\pi R^2 = 4417.86 \approx 4418\ \text{mm}^2$

$$\text{area of a hexagon} = 3\frac{\sqrt{3}}{2} \times \text{side of hexagon}^2$$

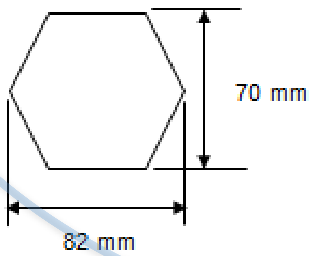
$$4418 = 2.6 \times \text{side of hexagon}^2$$

$$\text{side of hexagon} = \sqrt{\frac{4418}{2.6}} \approx 41\ \text{mm} \therefore \text{dia} = 82\ \text{mm}$$

Jar weight force = $0.25\ \text{kg} \times 9.8 = 2.45\ \text{N}$

$s = 0.1\ \text{m}$

$t = 1$ second



jar delivery:feeder line = 60 per minute or 1 per second

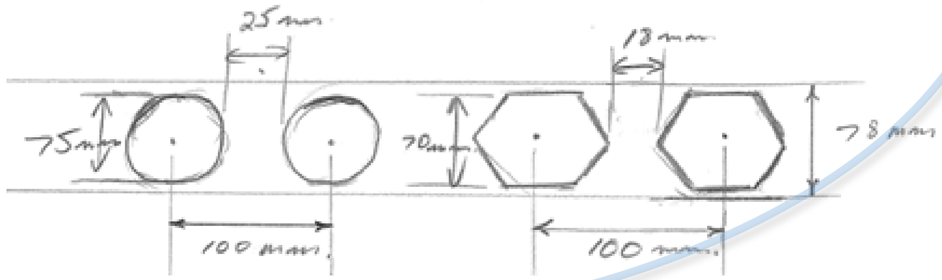
jar delivery:production lines = 30 per minute or 1 per 2 seconds

Given that the positioning rail provides a space for jars and that the distance between rails is constant the minimum clearance between the rails is 78 mm. This allows for 3 mm clearance for round jars and 8 mm clearance for hexagonal jars (small dimension) separation of jars is 100 mm centre to centre

Jar-feeder line

$\therefore v_{av}$ round jars = 0.1 m/s in the direction of the feed

$\therefore v_{av}$ hexagonal jars = 0.1 m/s in the direction of the feed



2

Analysing [6–7]

insightful analysis of the machine and/or mechanism problem, and relevant engineering mechanics, materials science, control technologies, technology, and research information in relation to mechanisms, to identify the relevant elements, components and features, and their relationship to the structure of the problem

The response analyses research information that has a direct bearing on understanding the mechanical problem.

The response identifies the relevant elements, components and features, and their relationship to the structure of the mechanical problem.

The environmental impact assessment analyses the material properties of stainless steel and food grade plastics to determine the sustainability of the materials from a life cycle perspective, in the context of the mechanical problem.

Research about the problem

Materials

In the food preparation industry, there are two processes which are generally used to sanitise surfaces; thermal and chemical sanitisation (Schmidt, 2015). The industry uses various methods to clean food processing equipment with either process, which can involve either disassembly, partial disassembly or no disassembly of the equipment to be sanitised (Schmidt, 2015). This is an important consideration for the modifications required to be made to accommodate the assembly that distributes glass jars to the two production lines.

Water is used to carry cleaning agents that may contain either acid or alkaline substances or oxidising agents such as chlorinated detergents depending on the type of food materials used and substances to be removed (Schmidt, 2015). Therefore, materials used in the development of the distribution system must be resistant to attack by the various cleaning agents used to sanitise equipment.

Stainless steel and food contact grade polymers can be used for a variety of specific purposes including manufacturing conveyers using lightweight polymer chains that outlast and outperform heavier metal chains that require more regular maintenance and lubrication (Dupont, 2018). Nylon is a plastic that is food contact compliant, has good stiffness, tensile and wear and heat resistance properties and therefore a useful plastic for consideration in food machinery applications (Curbell Plastics, 2016). Nylon is a very tough, durable material that can be used in high temperature environments up to 185°C (D&M Plastics, 2018) as required during food machinery steam cleaning operations.

304L grade stainless has the properties to reduce sensitisation corrosion in welded components brought about by cleaning operations in the food industry (See Figures 2 and 3). 304L grade stainless steel has excellent toughness and heat resistance making it an ideal material for applications in food processing machinery (Australian Stainless Steel Development Association, 2017). 304L stainless steel has a yield strength of 172 Mpa, tensile strength of 483 Mpa and percentage elongation of 40%. 304L stainless steel is a low carbon iron alloy that has an austenitic structure containing up to 20% chromium and 12% nickel, which improves the materials corrosion resistance and workability properties (covert & Tuthill, 2000).

Environmental impact assessment

Stainless steel has an estimated end of life recycling ratio of 80 to 90% (International Stainless Steel Forum, 2007). Stainless steel contains iron and a number of valuable raw materials, including chromium, nickel and molybdenum. These materials are melted down in a process that includes the use of raw and recycled materials. Therefore, the production and life cycle of the material are interwoven because of the economic viability associated with the end of life recovery of stainless steels (International Stainless Steel Forum, 2018). It is estimated that products made from stainless steel include up to 60% recycled content (International Stainless Steel Forum, 2018). Additionally, Australia exports scrap stainless steel to a number of countries, including China, Japan and Taiwan (Australian Stainless Steel Development Association, 2017).

Plastics are made from non-renewable resources and as such have a finite availability. Therefore, it is important to recycle rather than discard these materials as landfill where they produce methane gas during decomposition (Clean up Australia, 2009). Plastic waste dumped into the world's oceans also has a devastating impact on sea birds and mammals with many dying because of contact with and ingestion of plastic waste materials. Recycling also reduces the energy required to manufacture plastics from raw materials (Clean up Australia, 2009). Nylon is recyclable at any stage of production using either chemical or mechanical methods (INVISTA, 2017). The tensile strength and wear resistance of nylon machine components means that they would be less likely to fail and wear during use in machine applications and as such require less service or replacement.

The use of heat resistant materials, such as 304L stainless steel, food grade plastic conveyer belts (Made in China.com, 2018) and Nylon increases the likelihood that steam cleaning methods may be used to sanitise the machine and jar-feeder distribution system components, rather than chemical cleaning agents that have potential negative environmental and worker health impacts. However, the use of steam to clean machine surfaces does require careful consideration of factory floor layout to exclude accidental worker exposure to the risk of scalding hazards during the cleaning process.

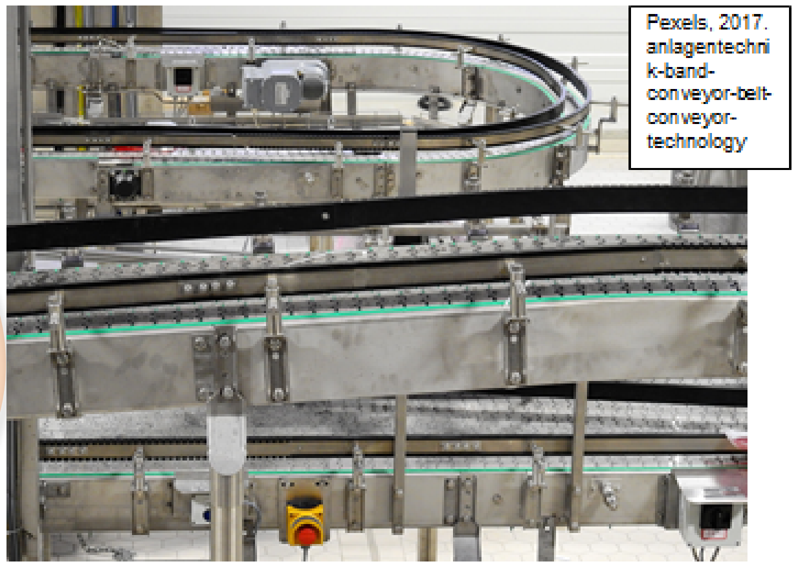
3

Figure 2

Bernt Rostad, taken on 20.09.2012, Schneider Weisse bottling line. CC. Attribution 2.0 Generic. Accessed https://www.flickr.com/photos/brostad/706397720 5/in/photostream/

This glass-bottle conveyer system raises or lowers bottles through use of a gradual incline. The gradient is small which may be because of the bottle height and velocity. This system takes up a lot of factory floor space. I will need to research the coefficient of static friction of glass on the plastic conveyer belt to calculate the required gradient.

Figure 3



Pexels, 2017. anlagentechnik-band-conveyor-belt-conveyor-technology

Food conveyer materials: stainless steel and plastics, including the rail and plastic conveyer belt and conveyer drive motor and safety switches.

Synthesising and evaluating [8–9]

coherent and logical synthesis of relevant engineering mechanics, materials science, control technologies, technology and research information, and ideas to predict a possible machine and/or mechanism solution

The response provides evidence of an ordered, logical and well-structured synthesis of research that has a direct relationship to the structure of the problem.

Analysing [6–7]

astute determination of essential solution success criteria for the mechanism problem

The response provides an accurate assessment of the problem to identify success criteria that are of critical importance to the mechanical problem solution.

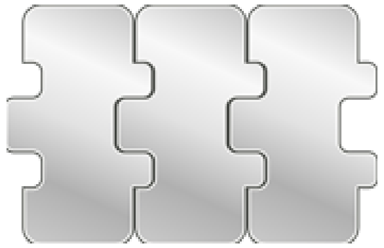
Figure 4

Movitec Wrapping Systems, 2011 CC. Attribution 3.0 Unported.

Automation and control technologies

Figure 4 displays an automated product wrapping machine used in the food processing industry. Automation and control technologies are important aspects of current and future food processing methods, although in certain sectors this uptake has been slow because of market forces and the associated lower volumes of product required (Davis, 2014). This often means that high levels of automation are not cost effective for smaller enterprises. However, many smaller food processing companies are recognising the need for automation that streamlines packaging operations, such as that depicted in Figure 4. Conversely, the introduction of pick and place robots and control technologies at the food processing level has been slower to progress due to the current low levels of technological expertise (Davis, 2014). It is expected that when a company moves to automation and process control that they do so with a full understanding of the implications within the various integrated systems that incorporate the food production process (Weisgerber, 2006). In the context of the glass-jar conveyer and distribution system problem, a highly automated system is a possible option. However, high levels of automation require a corresponding high level of service technician expertise that may, or may not be available to support the ongoing operation of the glass-jar distribution system. Therefore, it may be advisable to consider options that involve a minimum of moving parts and/or complex electronic components.

Figure 5



Pixabay, 2018. Conveyer belt silver

Conveyer belt material

Figure 5 displays the interlocking structure of one type of food grade plastic conveyer. These conveyer belts have high tensile strength and are resistant to oils, acids and alkalis, tearing, heat, cold and wear (Made in China.com, 2018). These types of belts have the capacity to move through a reasonably tight radius to allow conveyer systems to transfer various food products within restricted factory spaces, such as those identified in the distribution of glass jars to the two production lines from the one jar-feeder line in this conveyer system problem. When used in conjunction with the rails as seen in Figure 3, it would be expected that jars of the dimensions identified in this problem would be able to be held without risk of breakage and moved safely and efficiently at the required rate of 60 and 30 glass jars per minute.

Moving forward

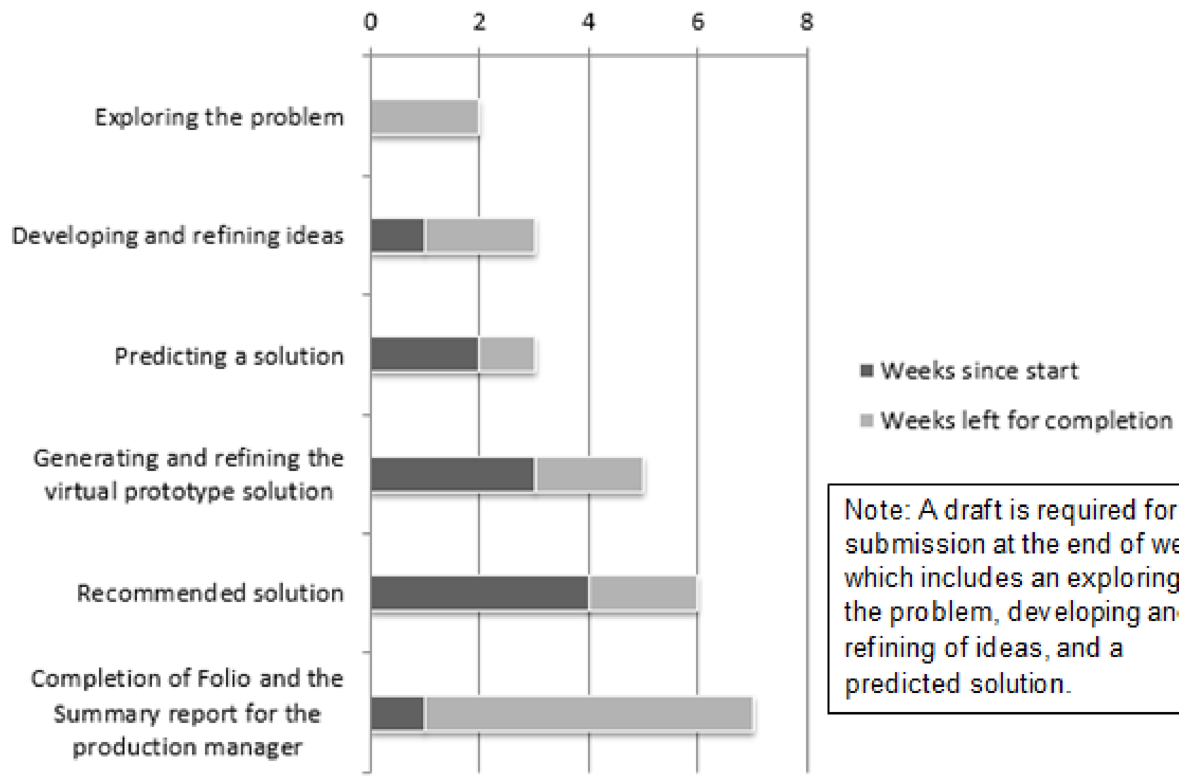
Determining solution success criteria

The glass-jar distribution system should:

- be energy efficient
- include minimal moving parts
- have repeatability and reliability
- maintain the separation distance between jars when distributed to the two production lines
- allow jars to be raised to the required 1.5 m to the new production line
- function effectively for both round and hexagonal jars
- be easily cleaned and sanitised
- be developed considering maintenance requirements
- distribute jars without risk of damage
- acknowledge the sustainability and environmental impacts associated with the manufacture, function, cleaning and maintenance of the system.

4

Project management (Gantt chart)



Note: A draft is required for submission at the end of week 3 which includes an exploring of the problem, developing and refining of ideas, and a predicted solution.

Retrieving and comprehending [4–5]

adept symbolisation and discerning explanation of ideas and a solution in relation to machines and/or mechanisms with sketches, drawings, diagrams, graphs, tables and/or schemas

The response demonstrates a very high level of skill and proficiency in sketching or drawing ideas and solutions.

Pictures, sketches and annotations are used to explain ideas and solutions in a way that demonstrates intellectual perception and good judgment.

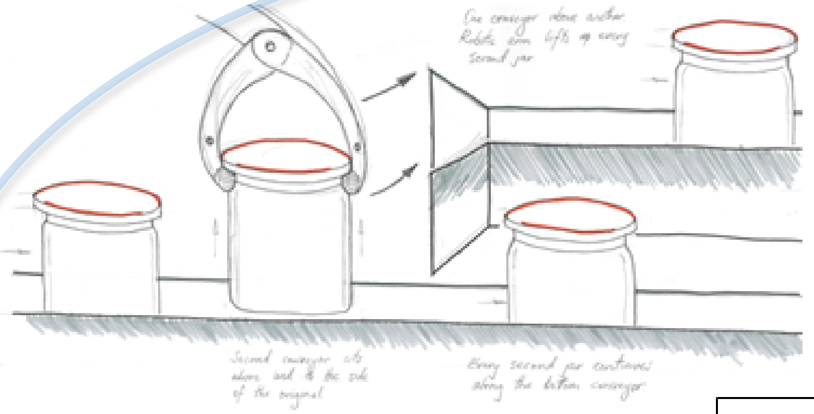
Synthesising and evaluating [8–9]

coherent and logical synthesis of relevant engineering mechanics, materials science, control technologies, technology and research information, and ideas to predict a possible machine and/or mechanism solution

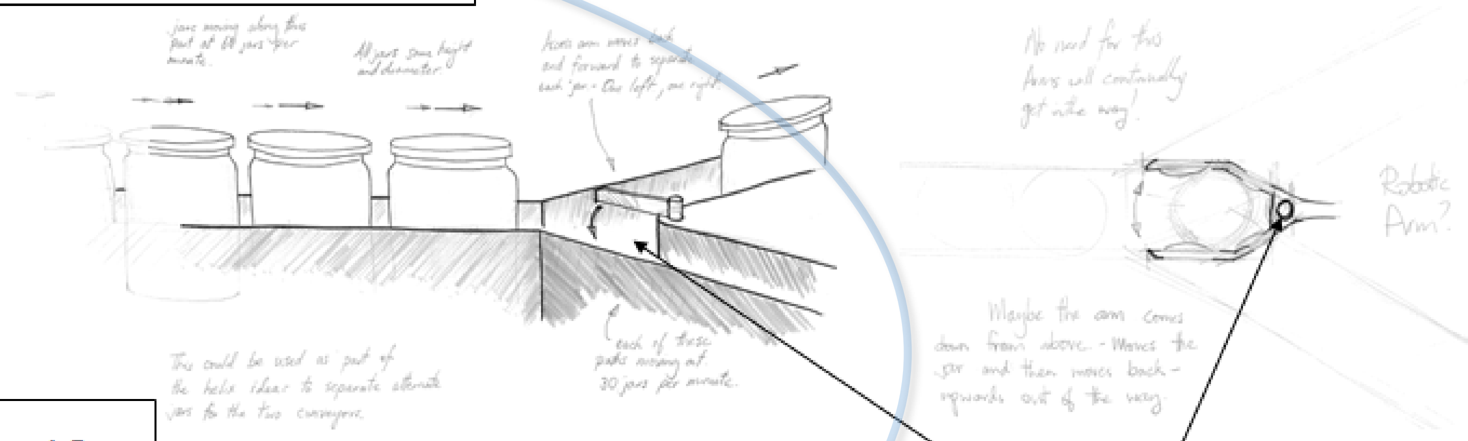
The response provides evidence of an ordered, logical and well-structured synthesis of ideas that incorporate research evidence and the use of mechanics and materials science information to move towards predicting a solution.

Idea and solution development considering success criteria

Initial thoughts

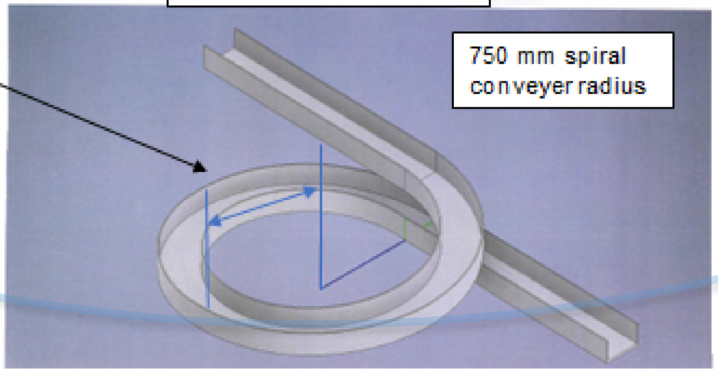


Glass-jar distribution system



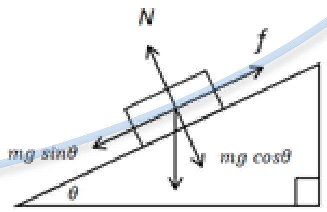
The spiral idea is in response to the assumption that the factory floor space is limited. The spiral conveyer allows for use of minimal floor space. The angle of repose will need to be found to determine the most efficient gradient.

Raising jars 1.5 m

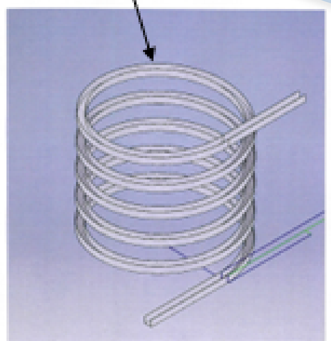


$\tan\theta = \mu_s$

$\therefore \mu_s = \tan 9 =$
0.16 for the glass jar on smooth hard plastic



A combination of these ideas may be useful to progress with refinement. Possibly could connect the pivot point to a linkage that transfers movement from the jar-feeder line to the distribution system arm. The timing of movement and the velocity ratio will need to be calculated and the range of movement of a specifically shaped distribution arm will need to be determined.



This is drawn to scale. When I looked at how steep the gradient was I could see the jars falling over. This example now has an internal diameter of 1.5m and five revolutions to achieve the 1.5m vertical height - Top and bottom conveyors are in line as required.

Allowing 1500 mm for the spiral conveyer diameter (centre line) and with the number of spiral rises at 4, the following formula can be written to calculate the appropriate angle for the conveyer gradient.

$$1500 = \text{Number of spirals} \times ((\text{centre line circumference} \div 100) \times \text{rise per } 100 \text{ mm}(x))$$

$$1500 = 4 \times (47.12 \times x)$$

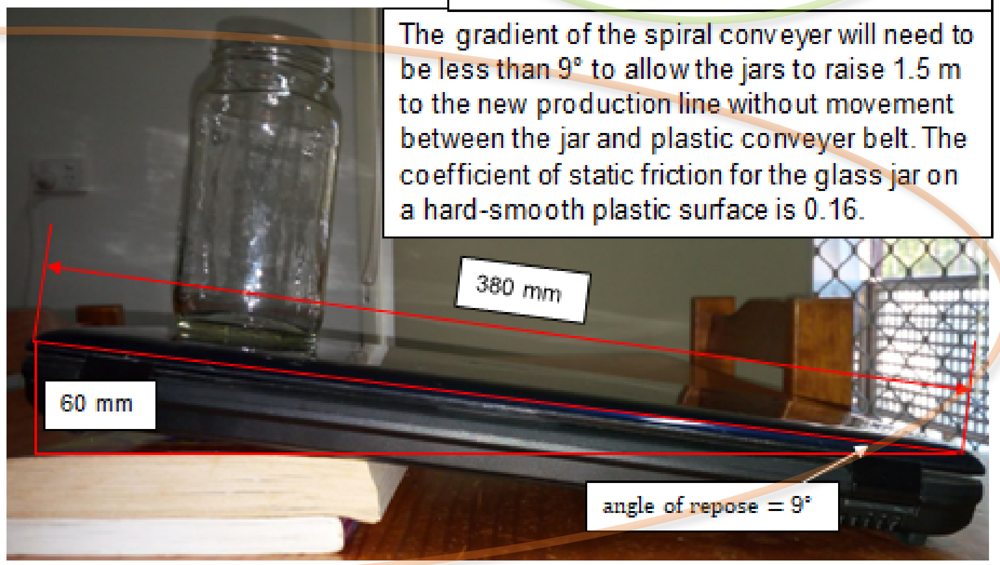
$$47.12 \times x = \frac{1500}{4} = 375$$

$$x = \frac{375}{47.12} = 7.96 \text{ mm rise per } 100 \text{ mm of spiral conveyer travel}$$

$\therefore$ calculating the gradient of the spiral

$$\sin\theta = \frac{7.96}{100} = 0.0796$$

$$\sin^{-1} \times 0.0796 = 4.57° \text{ gradient}$$



The gradient of the spiral conveyer will need to be less than 9° to allow the jars to raise 1.5 m to the new production line without movement between the jar and plastic conveyer belt. The coefficient of static friction for the glass jar on a hard-smooth plastic surface is 0.16.

Analysing [6–7]

insightful analysis of the mechanism problem, and relevant engineering mechanics to identify the relevant elements, components and features, and their relationship to the structure of the problem

The response includes evidence of testing used to calculate the coefficient of static friction for glass on a hard-smooth plastic surface. This information is relevant to the effective movement of jars up a gradient to the new production line 1.5 m above the existing production line.

5

Retrieving and comprehending [4–5]

adept symbolisation and discerning explanation of ideas and a solution in relation to mechanisms with sketches, drawings, diagrams, graphs, tables and/or schemas

The response provides evidence of a very high level of skill and proficiency when sketching or drawing ideas and solutions.

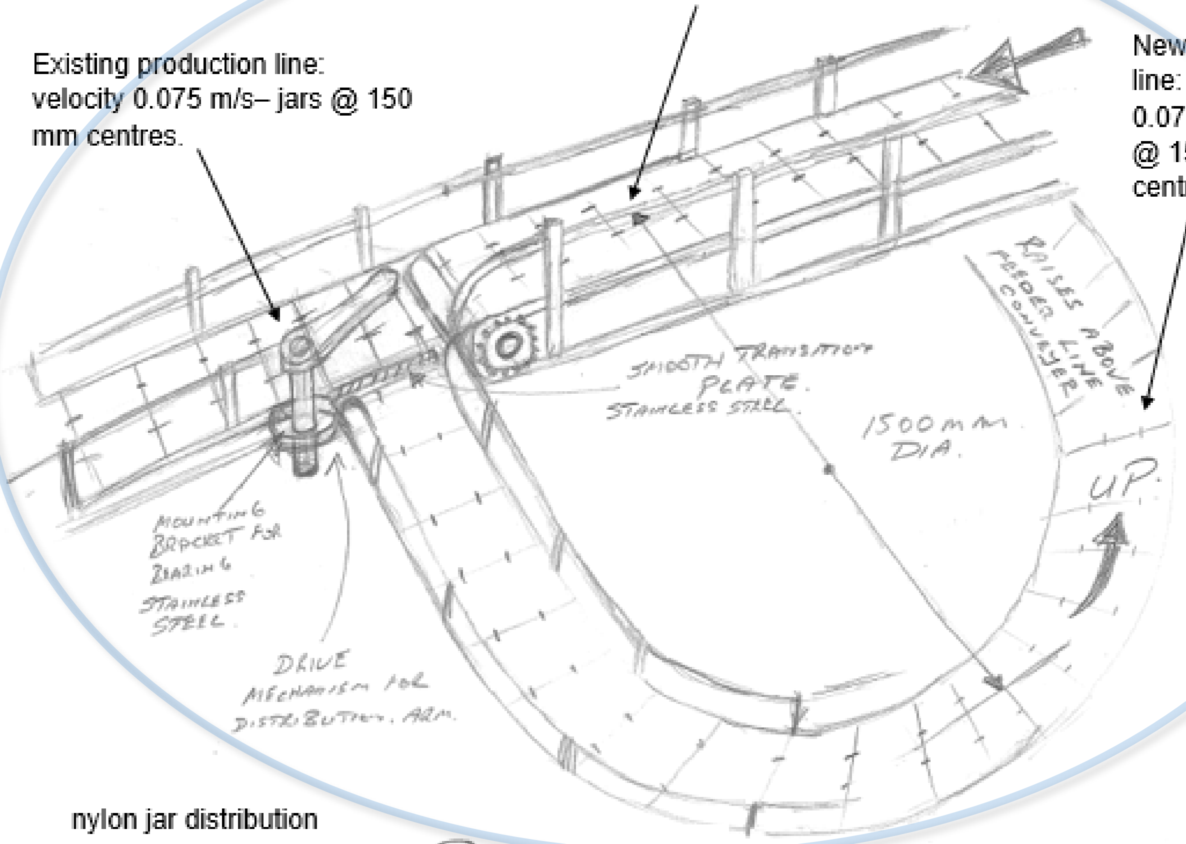
Annotations provide discerning explanations that clarify the decision-making about ideas and possible solutions.

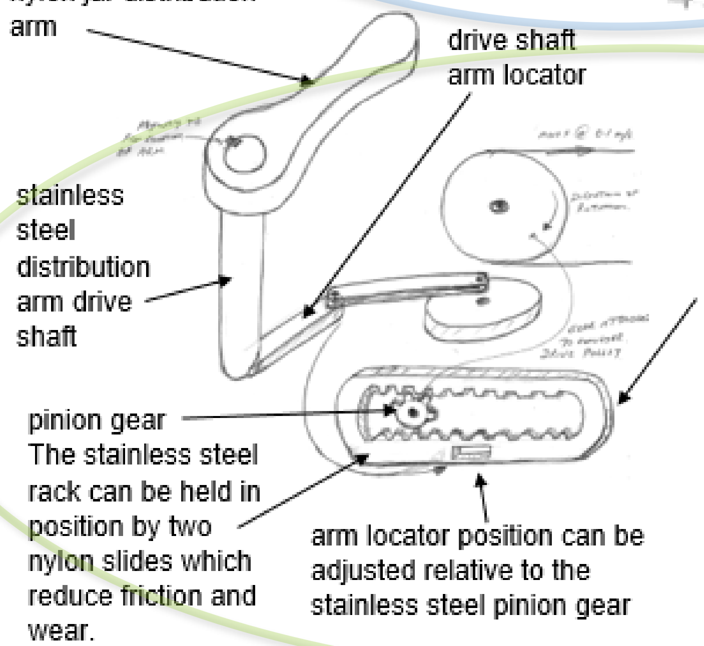
Synthesising and evaluating [8–9]

critical evaluation and discerning refinement of ideas and a solution using success criteria to make astute recommendations justified by data and research evidence

The response provides critical evaluation of an idea using the success criteria. A range of recommendations are proposed that accurately assess the problem with reference to the success criteria.

Refining ideas





The mechanism could function through either reciprocating or oscillating motion to move the arm that distributes every second glass jar to the new production line conveyer. The arm should move at a consistent velocity rather than have variability during movement.

This would suit the reciprocating rack and pinion rather than the oscillating mechanism as it would provide consistent velocity, while at the same time converting the rotary motion of the adjacent new production line conveyer to linear motion required to drive the jar distribution arm. This mechanism requires less moving parts and has reliability, repeatability and facilitates adjustment through the position of the drive shaft arm locator relative to the pinion gear.

Figure 6

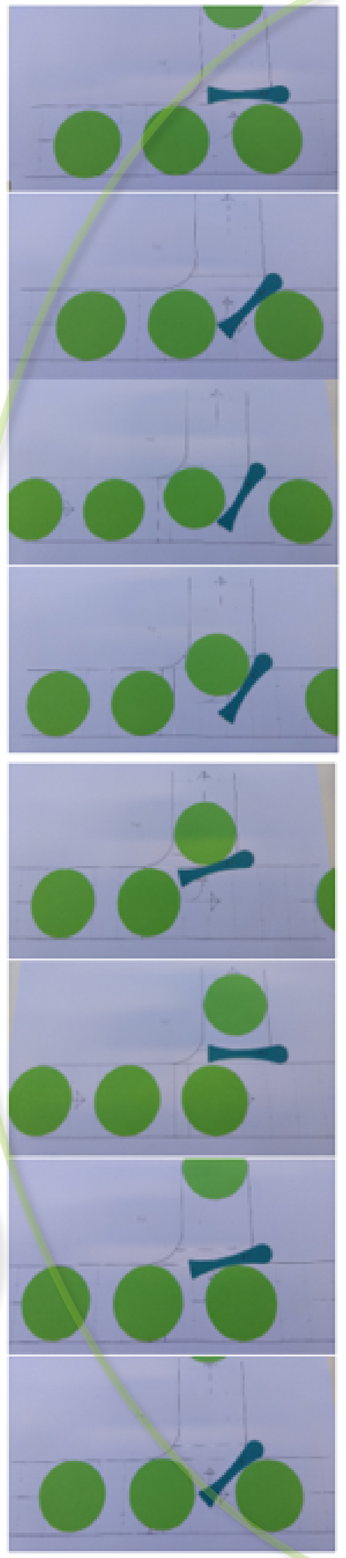


Figure 6 provides a simulation of the distribution of round jars using the mechanism that oscillates to guide and then push jars to each of the two production lines. The shape of the rails and nylon distribution arm assist with this function. This principle will apply to hexagonal jars also and so has not been virtually tested.

The simulation has identified that the distance between the jars will need to be increased from 100 mm centres to allow for the mechanism to function without contacting the following jar. The distance between centres will be increased to 150 mm, which will change the velocity of the jars on the jar feeder line and production lines.

Refined jar velocities

Jar feeder line

$\therefore v_{av}$round jars $= 0.15$ m/s

$\therefore v_{av}$hexagonal jars $= 0.15$ m/s

Production lines

$\therefore v_{av}$round jars $= 0.075$ m/s

$\therefore v_{av}$hexagonal jars $= 0.075$ m/s

Round jars will now have 75 mm clearance space and hexagonal jars will have 68 mm.

The production line's 10 mm drive shafts will rotate at 0. 6 m/s given the ratio between the shaft diameter and the outside diameter of the conveyer. The velocity ratio of the conveyer to the drive shaft is 8:1. One turn of the driving conveyer = 8 turns of the driven shaft.

6

Synthesising and evaluating [8–9]

coherent and logical synthesis of relevant engineering mechanics, materials science, control technologies, technology and research information, and ideas to predict a possible machine and/or mechanism solution

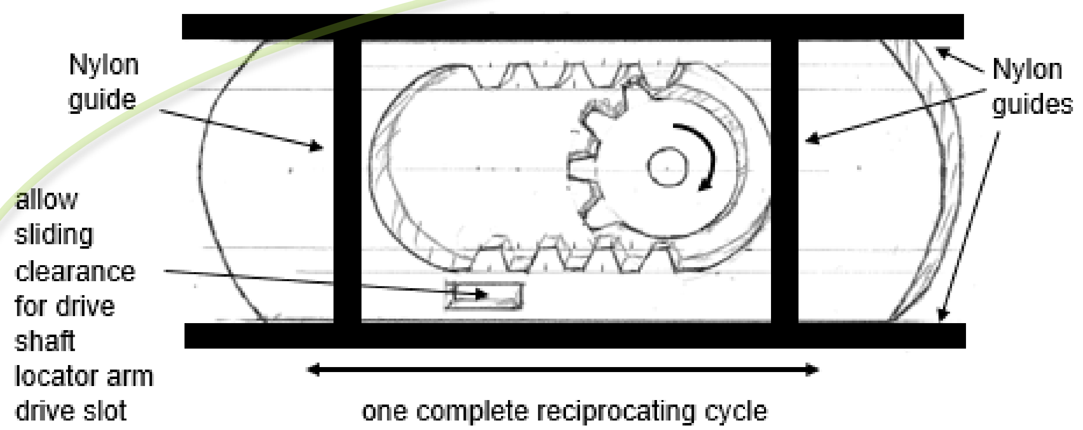
The response provides evidence of sound reasoning and an ordered well-structured synthesis of mechanics and technology information to propose a mechanism solution.

critical evaluation and discerning refinement of ideas and a solution using success criteria to make astute recommendations justified by data and research evidence

The response evaluates the predicted solution with reference to the success criteria.

A range of justifications are made that accurately evaluate the predicted solution with reference to the success criteria.

Reciprocating rack and pinion gear



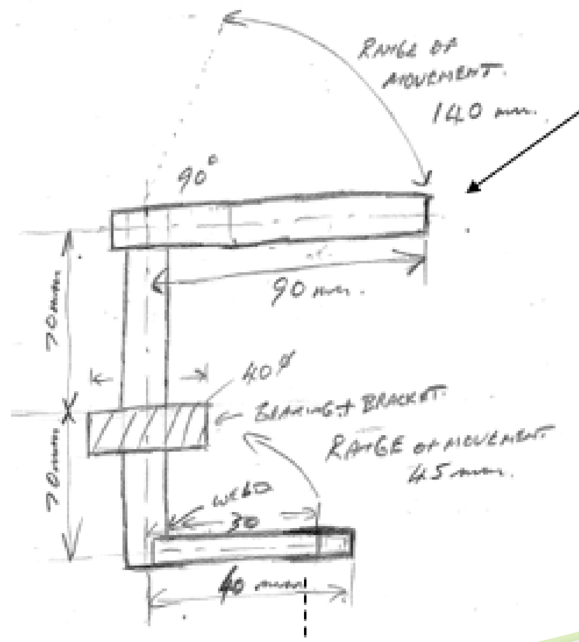
Rotary rotation of the shaft and pinion gear causes reciprocating movement of the rack gears. The rack will move 45 mm in each direction per one revolution of the drive shaft. The pitch centre diameter of the pinion gear is 45 mm and so the velocity of the rack in the nylon guides can be calculated.

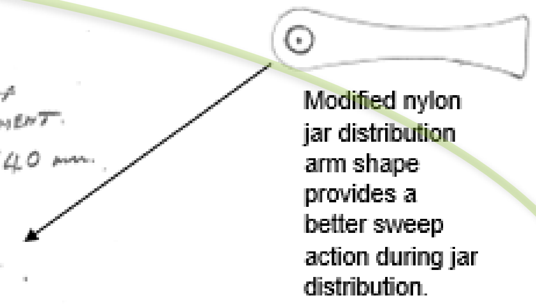
Velocity of the pinion gear $= 0.132$ m/s $=$ velocity of the rack

Time taken to move one cycle $= 0.132 \div 0.09$

$\cong 1.5$ cycles per second allowing for dwell between reciprocations

Nylon jar distribution arm





The rack displacement is 45 mm in 0.34 seconds = 1/3 of 1.5 cycles per second

The drive shaft arm locator velocity can be calculated knowing that the position of the rack will be located 30 mm from the distribution arm drive shaft.

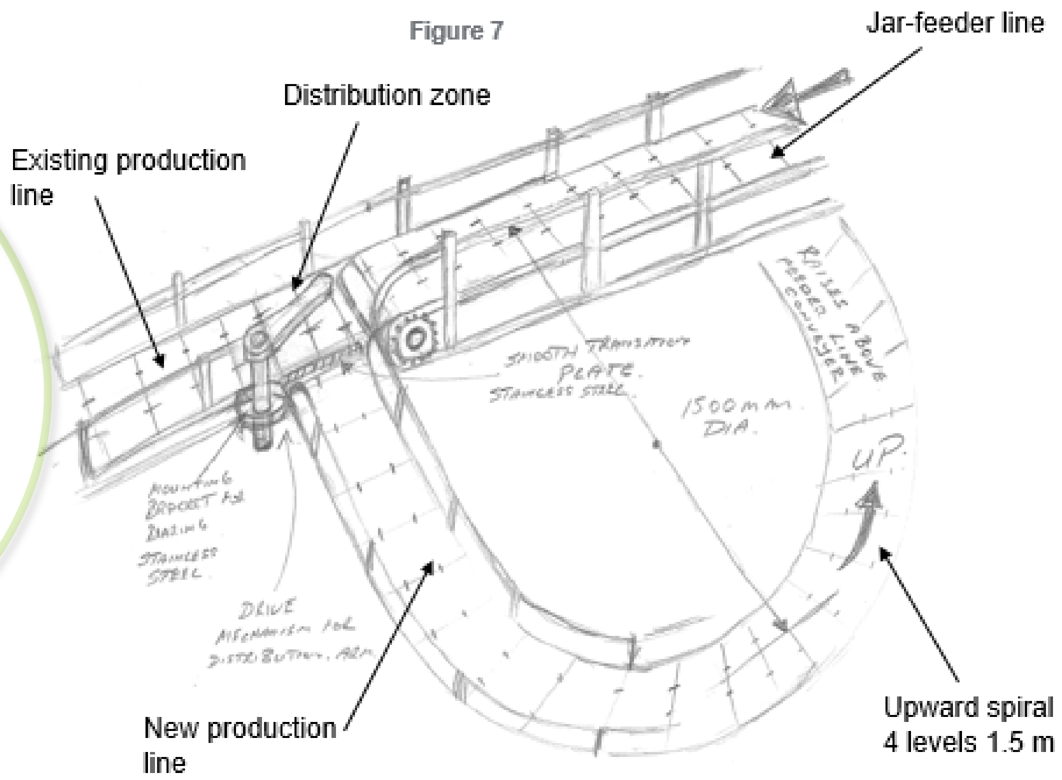
drive shaft locator arm velocity $= 0.045$ m per 0.34 s

nylon jar distribution arm velocity $= 0.14$ m per 0.34 s

Predicted solution

It is predicted that the solution illustrated in Figure 7 with some modifications to the distribution arm shape and mechanism mounting location will satisfy the success criteria and meet the requirements of the food processing companies need to increase production output. The spiral lifting conveyer with a gradient of 4.57° will safely and efficiently raise the glass jars 1.5 m from the existing jar-feeder line to the new production line. The spiral feeder system will move through 4 levels and use minimal factory floor space with a radius that allows the use of food grade plastic conveyer belt material. The rail will keep glass jars safely on the conveyer as they spiral upward.

Figure 7



Justification

Materials

- stainless steel, nylon and food grade plastic conveyer materials are
  - heat and chemical resistant, which will allow for sanitisation of the distribution system
  - workable during manufacture and maintainable
  - durable, reliable and have the strength and wearing properties to resist the forces involved in the jar distribution system.

7

Synthesising and evaluating [8–9]

critical evaluation and discerning refinement of ideas and a solution using success criteria to make astute recommendations justified by data and research evidence

A range of justifications are made that accurately evaluate the predicted solution with reference to the success criteria.

Analysing [6–7]

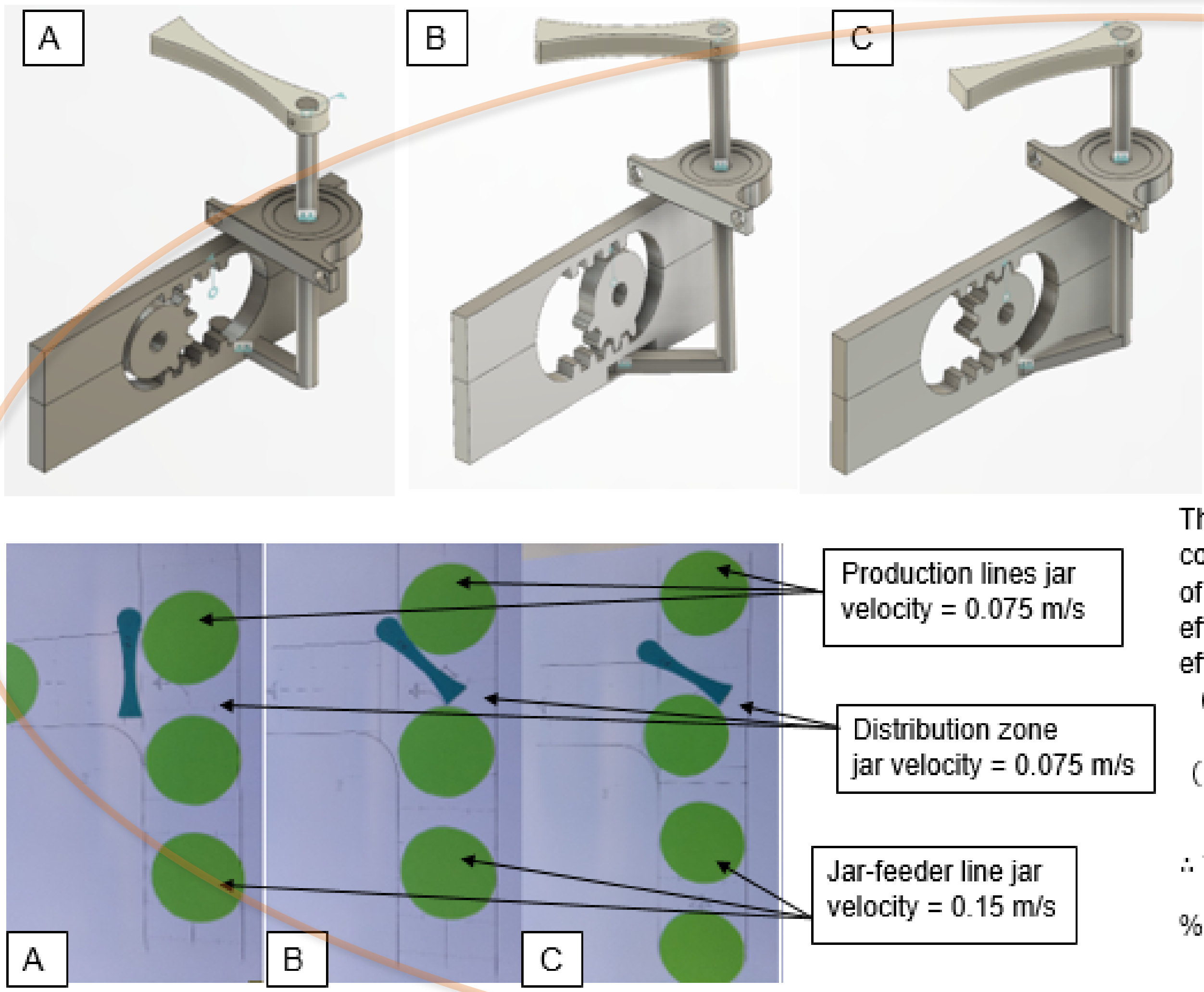
insightful analysis of the machine and/or mechanism problem, and relevant engineering mechanics, materials science, control technologies, technology, and research information in relation to machines and/or mechanisms, to identify the relevant elements, components and features, and their relationship to the structure of the problem

Analysis of the predicted solution provides virtual performance data to objectively analyse the solution's merits and faults and assess the accuracy of the prediction.

Environmental impacts

- The use of steam cleaning methods reduces the environmental impacts of the cleaning process, because residual run off is more easily reclaimed for future use or safe disposal.
- The materials used are recyclable at all stages of production and readily available i.e. commonly used and therefore recycling is cost effective.
- The predicted jar distribution system solution uses only the energy of the driven conveyer line which saves energy i.e. energy efficient in terms of the overall system energy consumption.
- The distribution mechanism includes minimal moving parts and requires less space, which can be easily guarded for improved worker safety during use and steam cleaning.

Figure 8



Jar distribution mechanism

Glass jars on the feeder line travel at 0.15 m/s with a clearance space of 75 mm for round jars and 68 mm for hexagonal jars. At this velocity jars displace 0.05 m (50 mm) in 0.34s. This time is the allowance for one movement of the reciprocating rack.
The movement of the nylon jar distribution arm each 0.34 s includes allowance for

- the constant movement of jars on the jar-feeder line at 0.15 m/s
- the sweeping action of the jar distribution arm
- the slight dwell between jar distribution arm movements caused by the function of the pinion gear and rack mechanism
- the clearances between the drive shaft locating arm and the rack drive slot which allows for the range of movement required to move the nylon jar distribution arm.

Figure 8 illustrates the range of movement required by the jar distribution mechanism at the various positions relative to the two production lines.

At position **A** the jar distribution arm allows a jar to move into the distribution zone (dwell condition between strokes) after which the arm engages with the glass jar and distributes the jar with a sweeping action to quickly clear the zone to the existing production line seen in position **B**. The clearing of the zone with the 0.34s sweep is important because jars approach the zone from the jar-feeder line at a faster velocity (0.15 m/s) than the jars on the production lines and in the distribution zone where the jar velocity is 0.075 m/s. Jars move into the distribution zone at a rate of 50 mm per 0.34s which provides clearance time for the sweep of the previous jar and for the following jar to move into the distribution zone seen in position **C**. The cycle continues when the nylon distribution arm sweeps this following glass jar to the new production line and the arm moves back to position **A**.

The nylon distribution arm's movement from A to B to C and back to A represents one complete revolution of the pinion gear and the corresponding two reciprocating movements of the rack. The pinion gear is driven by the new production line conveyer. To establish the efficiency of the mechanism it is necessary to identify the ratio of the distance moved by effort (new conveyer belt) and the distance moved by load (distribution arm drive shaft).

$$(80\times\pi) \div 8 = \text{the distance moved by the conveyer to rotate the pinion gear one revolution}$$
$$= 31.42 \text{ mm}$$
$$(10\times\pi) \div 2 = \text{the distance moved by the distribution arm drive shaft in one } \mathbf{A} \text{ to } \mathbf{A} \text{ cycle}$$
$$= 15.7 \text{ mm}$$
$$\therefore VR \text{ of the machine to distribute glass jars } = \frac{31.42}{15.7} = 2$$
$$\% \text{ machine efficiency} = \frac{\text{mechanical advantage of the conveyer to pinion gear PCD (80 mm} \div \text{45 mm)}}{2} \times \frac{100}{1}$$

$\text{machine efficiency} = \frac{1.78}{2}\times 100 = 89\%$ (Note that this is a theoretical value only. It would be expected that energy would be lost through friction in the form of heat and reduce the machine's efficiency. Lubricants will be used to minimise this loss).

8

Synthesising and evaluating [8–9]

purposeful generation of a machine and/or mechanism prototype solution to provide valid performance data to critically assess the accuracy of predictions

The response provides evidence of a prototype solution that has the intended and desired result. The prototype provides legitimate and defensible virtual performance data to objectively analyse the solution's merits and faults to assess the accuracy of the predictions made.

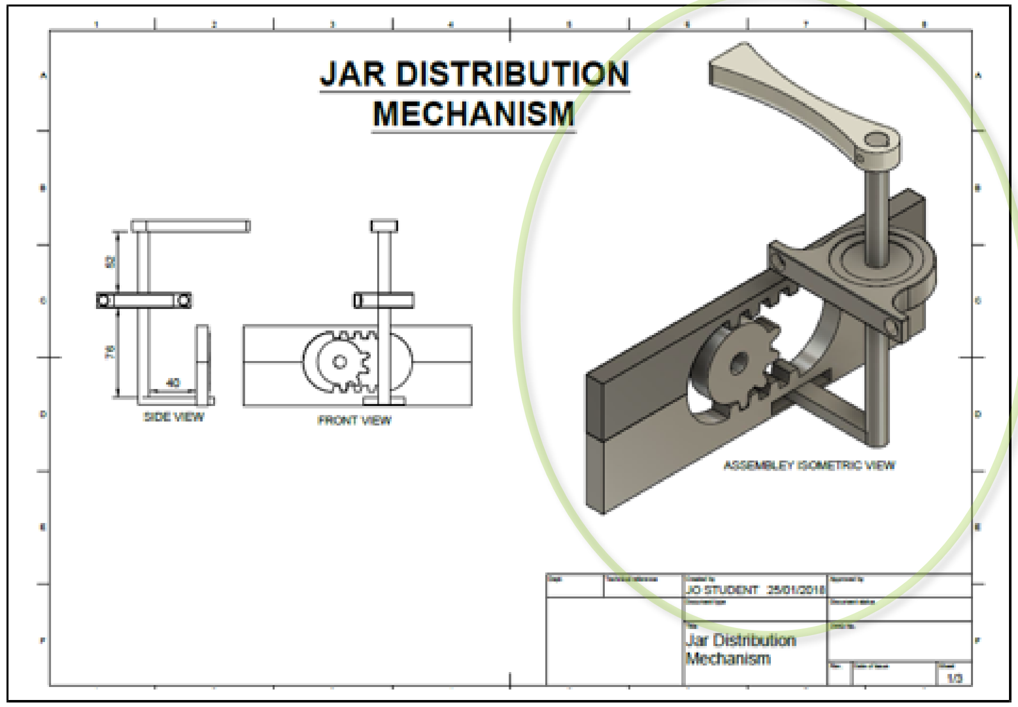
Retrieving and comprehending [4–5]

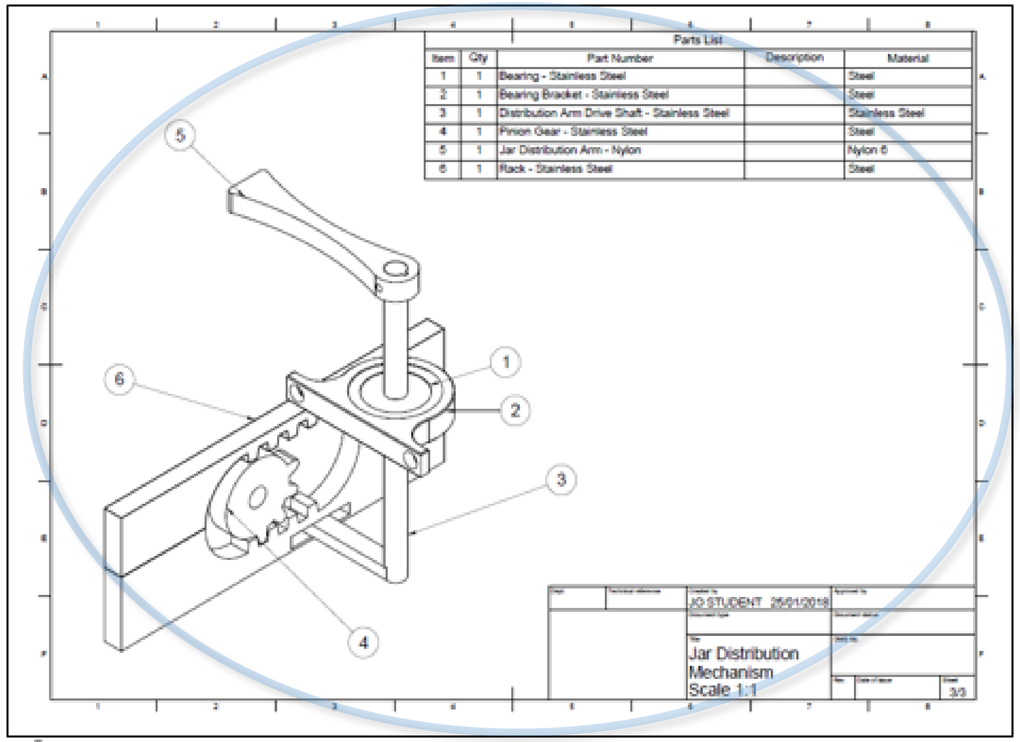
adept symbolisation and discerning explanation of ideas and a solution in relation to mechanisms with sketches, drawings, diagrams, graphs, tables and/or schemas

The response provides evidence of a very high level of skill and proficiency in CAD drawing. The engineering drawing uses appropriate basic drawing standards to fully and clearly provide relevant information to generate a virtual prototype for testing.

Virtual generation of the predicted solution

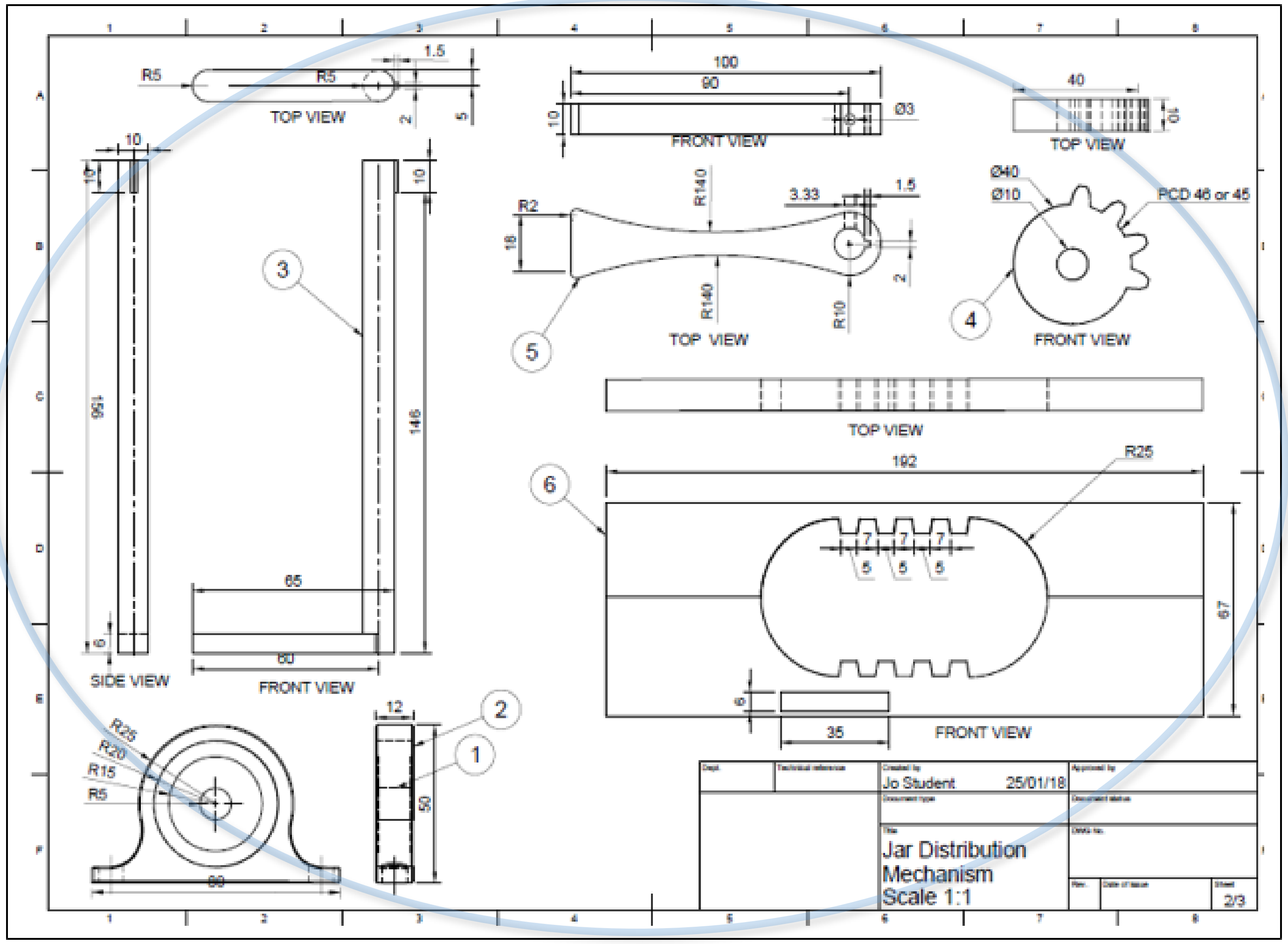
Engineering drawings





Item	Qty	Part Number	Description	Material
1	1	Bearing - Stainless Steel		Steel
2	1	Bearing Bracket - Stainless Steel		Steel
3	1	Distribution Arm Drive Shaft - Stainless Steel		Stainless Steel
4	1	Pinion Gear - Stainless Steel		Steel
5	1	Jar Distribution Arm - Nylon		Nylon 6
6	1	Rack - Stainless Steel		Steel

9



Virtual testing

Virtual testing of the glass-jar distribution system indicates that the system will operate as intended. The movement of round and hexagonal jars will be regulated by the nylon distribution arm. The movement of this arm is regulated by the velocity of the new production line which drives the reciprocating rack and pinion gear mechanism. The speed of the reciprocating cycle and the relationship between the diameters of the drive shafts provides a nylon distribution arm movement cycle time that allows for even distribution of both round and hexagonal glass jars at 30 per minute to each production line (new and existing). Further actual testing will need to be performed during installation of the jar distribution system to fine tune the timing of the arm and the dwell between movements.

The weight of each jar (2.45 N) and the coefficient of static friction (0.16) of the plastic conveyer belt material requires minimal force to be applied by the nylon distribution arm to sweep jars through the distribution zone to each production line because the coefficient of kinetic friction of glass jars through the zone will be less than 0.16.

Synthesising and evaluating [8–9]

critical evaluation and discerning refinement of ideas and a solution using success criteria to make astute recommendations justified by data and research evidence

The response provides a detailed evaluation of the predicted solution using the success criteria. A range of recommendations are made that accurately assess the problem situation with reference to the success criteria.

The response provides evidence of intellectual perception in the refinement of the predicted solution to recommend future developments or considerations.

Recommendations

Materials, fabrication and installation

It is recommended that the glass-jar distribution system be fabricated from the food grade materials, stainless steel, nylon and food grade plastic conveyer belt. These materials are readily obtainable and safe for use in food preparation environments. They have properties that allow appropriate environmental friendly cleaning methods to be used. Steam cleaning reduces the potential negative impacts of the use of alkali or acidic cleaning solutions when sanitising the food production machinery. The components of the glass-jar distribution system can be manufactured off-site and assembled on location to reduce production down time. The distribution mechanism drive input from the new spiral conveyer allows for the development and fine tuning of the timing of the nylon distribution arm prior to installation. The mechanism will need to be guarded and access will be required to support regular maintenance and lubrication without significant production down time.

It is recommended that the glass jars be positioned at 150 mm centres on the feeder and production lines and that the production process fill jars with product at these intervals. It may be necessary to modify this spacing to fine tune the distribution movement of jars evenly to the two production lines. The distribution mechanism allows adjustments to be made during installation if the timing of the mechanism is slightly incorrect. Additionally, the motor that drives the new upward spiralling conveyer can be installed with a variable speed drive to fine tune the movement of glass jars on the conveyer and the sweeping action of the nylon distribution arm as it directs jars to each production line.

Figure 9

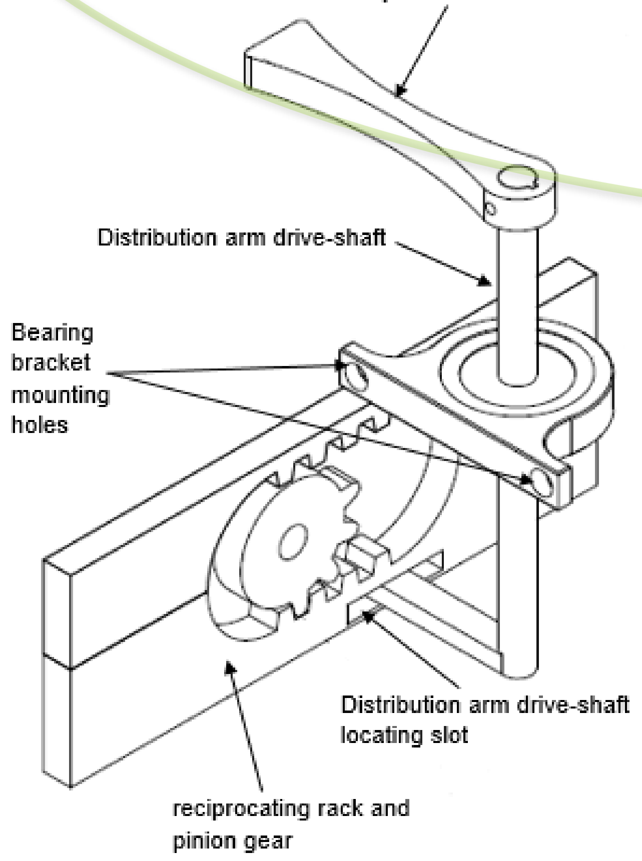


Figure 9 indicates how the installed position of the mechanism can be used to regulate the nylon distribution arm movement. The positioning of the bearing bracket mounting holes moves the distribution arm drive-shaft relative to the reciprocating rack and pinion gear and so changes the speed and range of movement of the arm. If the arm is mounted closer to the rack the arm will move further and quicker. If the arm is moved away from the rack the arm will move slightly less and slower. The distribution arm drive-shaft locating slot can also be modified to increase or decrease the range of movement of the nylon distribution arm and of the dwell time between arm movements. These adjustments provide for the fine tuning required to allow for indeterminate factors that may impact on the even distribution of the glass jars to each production line.

Future considerations

The glass-jar feeder-line and two production lines will allow for 60 glass jars per minute to be moved and filled with product, which doubles the factory's current production of 30 jars per minute. The inclusion of the distribution mechanism as predicted, allows for an increase in future production without the need for major modifications. It may be necessary to monitor the wear characteristics of the reciprocating rack and pinion mechanism and lubrication processes to determine the working life of the mechanism. Future materials may become available that reduce the frictional forces between surfaces and therefore eliminate the need for maintenance and lubrication of the mechanism. For example, self-lubricating cast nylon plastics are reducing coefficients of friction between surfaces without the need for lubrication. Future research into these materials may improve the lifespan of wearing machine components (Architecture and Design, 2015).

It may be beneficial to consider the inclusion of adjustable height railing for the new spiral conveyer. The additional flexibility this would provide may allow the company to increase the height of the glass jars in the future without any significant re-manufacturing of the glass-jar distribution system. This would provide the company with the option to increase the volume of product deposited into the jars with minimal loss of output efficiency. The ability to increase the railing height if required, also reduces the potential for loss due to glass jar breakages.

10

Part B

Communicating [3–4]

discerning decision-making about, and fluent use of,

- written and visual features to communicate about a solution
- language for a technical audience
- grammatically accurate language structures

The response includes written and visual features selected for value and relevance to communicate about a solution.

The response includes good judgment concerning the use of grammatically accurate language structures.

Summary report

Glass-jar distribution system

Introduction

This document summarises the findings and outcomes of the glass-jar distribution system developed and virtually tested between January and February 2018.

Background

The project team was commissioned by the food processing company's production manager to develop and test a glass-jar distribution system that increases the production capacity of the existing production line from 30 to 60 glass jars per minute. The company has decided to increase its output capacity by introducing an additional production line above the existing one. Both production lines will be fed by the existing jar-feeder line and fill glass jars with product at 30 per minute. The company requires a mechanism that will evenly distribute glass jars from the jar-feeder line to each production line. A production run will only fill either round or hexagonal jars during that run.

Project objectives

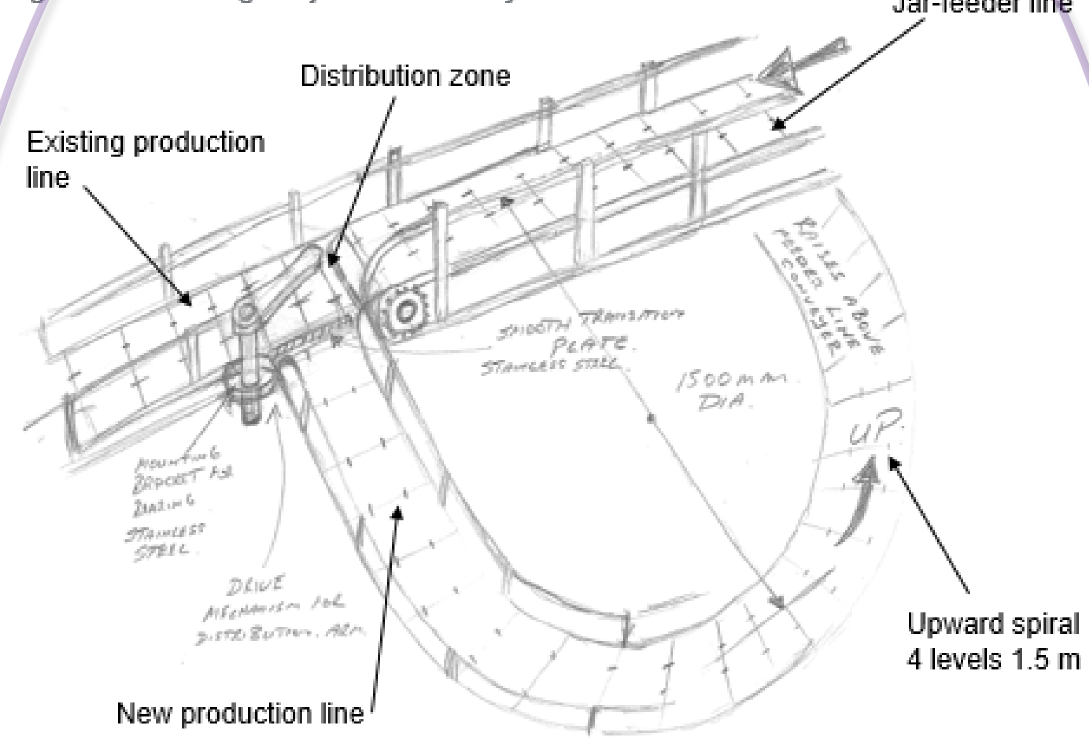
The project objectives were to document the development and virtual generation and testing of a glass-jar distribution system that meets the requirements of the food processing company's additional production output. The success criteria for the project were determined to be that the glass-jar distribution system should:

- be energy efficient
- include minimal moving parts
- have repeatability and reliability
- maintain the separation distance between jars when distributed to the two production lines
- allow jars to be raised to the required 1.5 m to the new production line
- function effectively for both round and hexagonal jars
- be easily cleaned and sanitised
- be developed considering maintenance requirements
- distribute jars without risk of damage
- acknowledge the sustainability and environmental impacts associated with the manufacture, function, cleaning and maintenance of the system.

Options considered

The project team conducted research to understand the nature of the problem and the types of materials and mechanisms that may be appropriate. The food industry requires the use of materials that are food grade and capable of being sanitised in a manner that minimises the environmental impacts of the cleaning process. The glass-jar distribution system and the included mechanism selected meets the requirements of the success criteria for the project. Figure 1 illustrates an overview of the main components of the system. The glass jars are evenly distributed to the new production line where they spiral upward 1.5 m to be filled with food product.

Figure 1: Predicted glass-jar distribution system solution



The predicted solution was virtually tested on Monday 22/01/18 to verify its capacity to distribute jars as required by the project objectives. Virtual testing of the glass-jar distribution system indicates that the system will operate as intended. The movement of round and hexagonal jars will be regulated by the distribution mechanism and the conveyer belt drive of the new production line, which drives the reciprocating rack and pinion gear mechanism seen in Figure 2. The speed of the reciprocating cycle and the relationship between the diameters of the drive shafts provides a nylon distribution arm movement cycle time that allows for even distribution of both round and hexagonal glass jars at 30 per minute to each production line (new and existing). Further actual testing will need to be performed to fine tune the timing of the arm and the dwell between movements during installation of the jar distribution system.

Further data analysis of the jar velocities and the included drive mechanisms provides evidence of the reliability and repeatability of the selected jar distribution mechanism as seen in Figure 2.

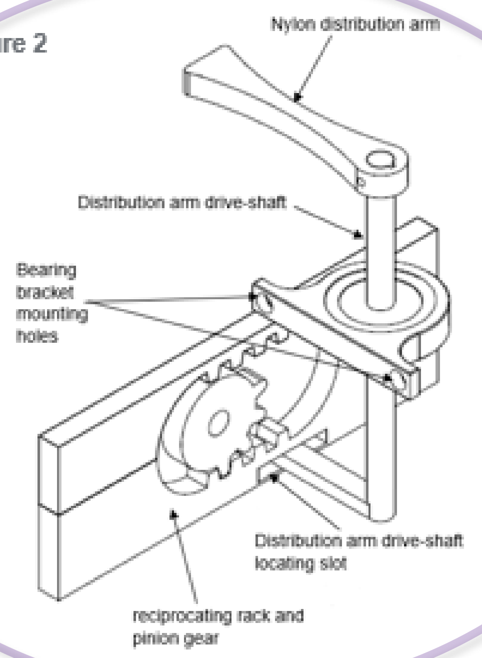
Communicating [3–4]

discerning decision-making about, and fluent use of,

- written and visual features to communicate about a solution
- language for a technical audience
- grammatically accurate language structures

The response demonstrates the thoughtful and astute choice of written and visual information to eloquently communicate about the solution to a technical audience.

Figure 2



Recommendations

Based on the findings of this investigation as documented in the folio Part A, the project team recommends that the glass-jar distribution system as seen in Figures 1 and 2 be adopted by the food processing company to increase production.

- Materials, fabrication and installation

It is recommended that the glass-jar distribution system be fabricated from the food grade materials, stainless steel, nylon and food grade plastic conveyer belt, as these materials are readily obtainable, maintainable and safe for use in food preparation environments. They have properties that allow appropriate environmental friendly cleaning methods to be used, which reduces the costs associated with and the impacts of disposal methods of caustic chemical cleaning agents. The mechanism includes two bearing bracket mounting holes which locates the distribution arm drive shaft relative to the reciprocating rack and pinion gear. These holes can be positioned to adjust the speed and range of movement of the arm. Additionally, the distribution arm drive-shaft locating slot can also be modified to increase or decrease the range of movement of the nylon distribution arm and of the dwell time between arm movements.

- Future considerations

The glass jar feeder-line and two production lines will allow for 60 glass jars per minute to be moved and filled with product, which doubles the factory's current production of 30 jars per minute. The distribution mechanism (Figure 2) and adjustable height spiral conveyer railing provides the company with options to further increase production if need be. Future materials may become available that reduce the frictional forces between surfaces and therefore eliminate the need for maintenance and lubrication of the mechanism, further reducing the company's associated running costs.

13

Communicating [3–4]

discerning decision-making about, and fluent use of folio and referencing conventions

The response includes the folio convention of a reference list and a recognised system of in-text referencing used in a way that shows intellectual perception and good judgment.

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14