Assessment highlights 2021

Engineering

Internal assessment 3

Project — folio

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Assessment overview

Context

Students were provided with engineering specifications for an automated bagging system used by cement industries when filling 20 kg cement bags.

The students were given the scenario that a nominated cement company wanted to investigate the installation of a second bagging system and further engineering specifications were provided for the proposed upgrade.

The folio is comprised of two parts. Part A documents the development of an engineered solution and Part B communicates a summary report for the specified client that provides a concise account of the preferred solution, including key features and recommendations.

The syllabus conditions outlines the length the assessment should be:

- Part A — 7–9 single-sided A3 pages or equivalent digital media (excluding table of contents and reference list)
- Part B — 2–3 single sided A4 pages or equivalent digital media (excluding table of contents and reference list).

Task

Part A

Students were required to create a folio to document the development of an engineered solution to the cement bagging and distribution problem.

In the folio, students were expected to:

- document the problem-solving process used to develop a real-world related solution, including
  - recognition and description of the problem, engineering technology knowledge, mechanics, materials science and control technologies concepts and principles
  - symbolising and explaining ideas and a solution using annotated sketching, drawings including basic drawing standards (hand or CAD), diagrams, graphs and tables
  - analysis of the problem and information in relation to machines and/or mechanisms
  - determination of success criteria for the solution to the problem
  - synthesis of engineering mechanics, materials science, control technologies, technology and research information and ideas to predict a possible solution
  - generation of the prototype solution for testing to provide performance data
  - evaluation and refinement of ideas and a solution with reference to the determined solution success criteria and prototype performance data
  - recommendation and justification of future modifications or enhancements to ideas and the solution to the problem
- communicate the development of ideas and the real-world related solution using written and visual features, including pictures, sketches, drawings, diagrams, graphs and tables.

Part B

Students were required to develop a summary report that identified the preferred solution to the problem, characterising key features and recommendations to inform future solution development. The summary report was to include the use of key pictures, tables, graphs, sketches and drawings as part of the concise account.

Student response

Note: The following sample is an unedited authentic student response produced with permission. Any images or sources that do not have copyright approval have been redacted from the response. The response may contain errors and/or omissions that do not affect its overall match to the characteristics indicated in the top performance levels of the instrument-specific marking guide (ISMG).

Table of Contents

What is known about the Problem?

- Cement industries use automated bagging systems to fill 20 kg bags with an overall time of 14 seconds (3 seconds for installing, 8 seconds for filling and 3 seconds to seal and discharge the bag on the conveyor belt)
- Company also wants to make an addition of filling 10 kg bags along with current system – using the same conveyor belt.
- The production rate of 20 kg bags has to be maintained however the overall output needs to increase by 50%.
- The velocity of the conveyor belt is set at 0.2 m/s – however, this can be altered if required.
- The cement bag material is to be changed from paper to plastic – company wants to explore this change in terms of mass reduction and improved sealing.
- Dimensions of the 20 kg bags are: 390 x 275 x 115 mm
- Dimensions of the 10 kg bags are: 320 x 335 x 115 mm
- The conveyor belt is elevated at 36º - till the height reaches 1.2 m

Assumptions

- The time taken to install and seal the bag remains the same for 10 kg, but the time taken to fill the bag halves. This is because the dimensions of the bag are similar, therefore, installment and sealing time would remain unchanged – however, the bag will be filled to halve of its original mass (20 kg), which will make the new time of filling 4 seconds.
- There will be a separate cement bagging machine for 10 kg bags to ensure the production of 20 kg bags remain constant and is unaffected with the addition of the new system. There will also be a worker available to install the bags at the new 10 kg station and ensure it is working efficiently and safely.
- The conveyor belt has a slip-resistant surface or coating to prevent the cement bags drifting off it while production.
- The width of the conveyor belt accompanies all three dimensions of the 10 kg and 20 kg cement bags – this ensures that the bags can travel effortlessly on the belt.
- The company would like two separate discharging stations for easier separation of the 10 kg and 20 kg bags.
- The baggage filling station is at 0.5m above ground-level and will meet the inclined ramp from that height – because starting at ground-level would not be feasible (refer to diagram for visual representation).
- Some method of logic/control system will be required to ensure effective discharging of cement bags and ensuring the right time to drop the sealed bags on the conveyor belt.
- The mass of the bag is the overall net mass (bag + cement) – this is important because in order to perform calculations – the overall mass is required.

Australian Standards

The conveyor system must align with the requirement and safety conditions of AS 1755—2000. These outline the following criteria:

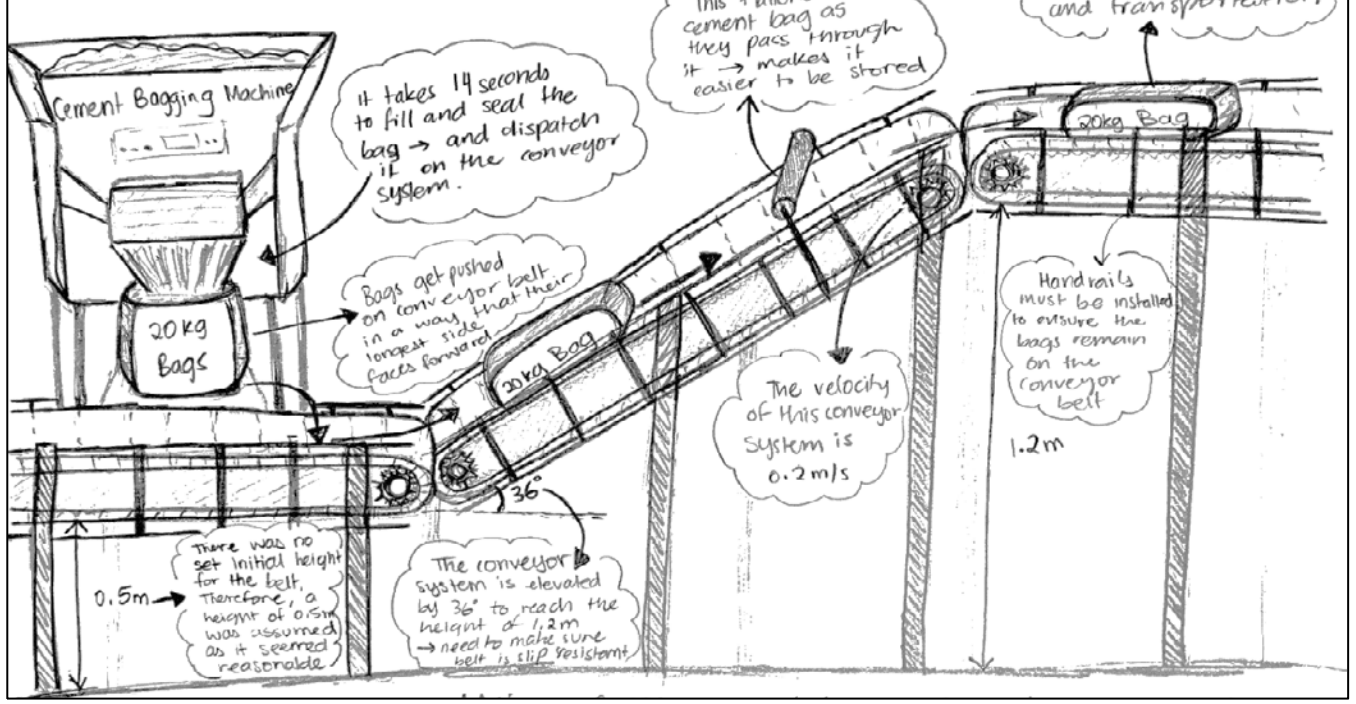
- Requirement for design and construction,
- Operating clearance,
- Electrical requirements,
- Fire/hazard protection,
- Guards, etc.

However, as the project requires the addition of 10 kg cement bags on existing conveyor. Therefore, an assumption would be that the existing conveyor system conforms to the Australian Standards mentioned. If there are any misalignments, they should be repaired through these standards – to ensure safety.

Important Considerations

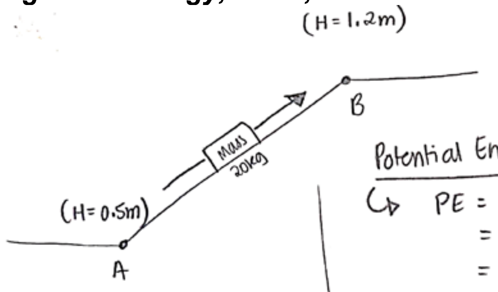
- The conveyor belt is on an inclined plane, at 36º to the ground – which reaches 1.2 m high. This means that the bags are to be discharged at that height when separated (possibly for easier transportation).
- There is no need for the addition of another conveyor belt system, as the original belt will be used for both 10 kg and 20 kg bags. However, 10 kg baggage station will be required to maintain the constant production rate of the 20 kg bags.
- The system operates at a constant velocity of 0.2 m/s however, this can be altered if a faster production rate is required.
- The malfunction of any equipment in the automated bagging systems can cause delays, changes in placement of bags, etc. This situation would then have to be manually resolved – the bagging system will have logic/control gates, assisting in overcoming any of these circumstances.
- The discharging of the bags will be at separate station on either side of the conveyor belt into a storage area – if in case the lever at the discharging point fails to operate, the bags will follow the belt till the end, where they will manually be sorted into their appropriate categories.
- As the dimensions of the conveyor system are not provided – the width will be set to 690 mm (so there is extra 150 mm each side of the longest dimension of the bag – which is 390 mm). The length of the whole conveyor belt will be 3.2 m – 1.0 m on either side of the 1.2 m incline. (Figure 1).

Basic Sketch of the Problem & Key Issues – Figure 1



Basic Calculations & Mechanical Considerations

Figure 2: Energy, Work, Force and Power Calculations



Potential Energy at A

↳ PE = mgh
= 20 × 9.8 × 0.5
∴ = 98 J

Potential Energy at B

↳ PE = mgh
= 20 × 9.8 × 1.2
= 235.2 J

Work = change in energy
W = Δ Energy
= $PE_B - PE_A$
= 235.2 − 98
= 137.2 J

Work = Force × distance
137.2 = F × 1.2
F = 137.2 / 1.2
∴ F = 114.3 N

Time taken to reach the height of 1.2m from 0.5m

↳ length of conveyor (incline) = 1.2 m
Velocity = 0.2 m/s (constant)
Time = distance / speed = 1.2 / 0.2
= 6 seconds

Power = work / time = 137.2 / 6
= 22.87 W

The calculation for 10 kg bags were performed identically; the values are stated below:
ΔPotential Energy = 68.6 J (Work)
Power = 11.43 W
F = 57.17 N

As the bag travels up on the incline, the potential energy changes (figure 2) – however, kinetic energy remains the same as the velocity is consistant. The change in energy means there is 'work' that is taking place; this is occuring at the gears of the inclined conveyor. The force, 114.3 N, is representative of the gear's effort. Figure 2 also shows the power required for the gears to maintain the constant veocity of 0.2 m/s. However, this power only includes one scenario (only 20 kg bag); it does not include the scenario of when the 10 kg bag is also on the conveyor, which will increase the power required.

Figure 3: Production Rate

* Assuming the company operates for 18 hours each day

Total time: 18 hrs × 60 mins × 60 secs = 64800 seconds

20kg Bags

↳ 1st bag takes 14s → 64800 − 14 = 64786 seconds
64786 / 14 = 4627.57 → 4627.57 / 20 ≈ 231 bags

10kg Bags

↳ 1st bag takes 12s → 64800 − 12 = 64788 seconds
64788 / 12 = 5399 → 5399 / 10 ≈ 539 bags

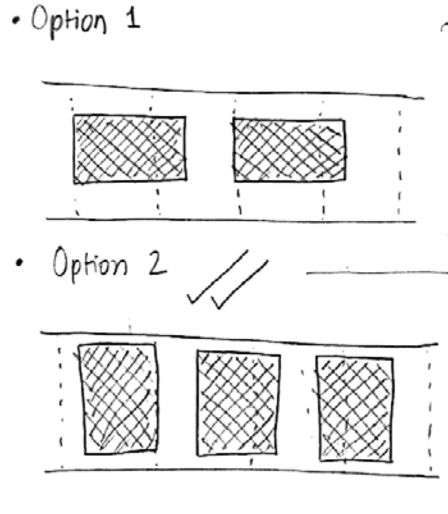
Percentage increase in Production

↳ (539 − 231) / 539 × 100 → 308 / 539 × 100 ≈ 57%

∴ The task required at least 50% increase in production. The solution to this problem provides an additional 7% overall outcome surge.

Figure 3 addresses the current and predicted production rate for 10 and 20 kg bags. The calculations reflect a 57% increase in the production by including 10 kg bags – if one bag is placed in between two 20 kg bags. The timings were retrieved from figure 7.

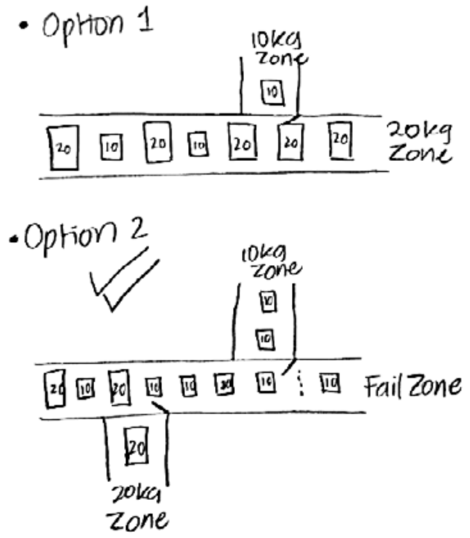
Figure 4: Placement of Bags



Option 1: If the bags are placed parallel to the conveyor (in terms of length – as shown) more area is occupied. This causes a slower rate of production, as less bags will be discharged from the system.

Option 2: If the bags are placed perpendicular to the conveyor (in terms of length – as shown) occupies less area over the belt. This causes the production rate to increase. This is because more bags will be discharged this method – than Option 1. ∴ This is most effective.

Figure 5: Separation of Bags



Option 1 shows one separation unit for 10kg bags, and the rest (20kg) bags continue and discharge at the end. This method effectively separates the bags & only requires building one zone – however, it does not account for any failures of the system. (If a 10kg bag is missed by the lever)

Option 2 shows 2 separation zones for 10kg & 20kg bags. It also includes a 'fail' zone which accounts for any bags missed by the lever, to be manually sorted later. Although this method requires building 2 zones (more labour, material, etc), it ensures the separation takes place without a mistake.

Figure 6: Positioning of the bag when dispatching

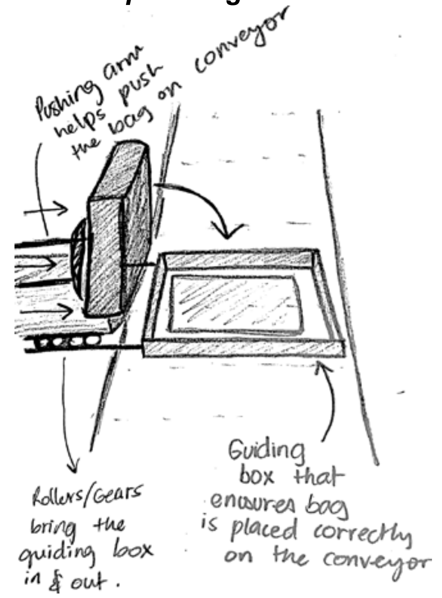
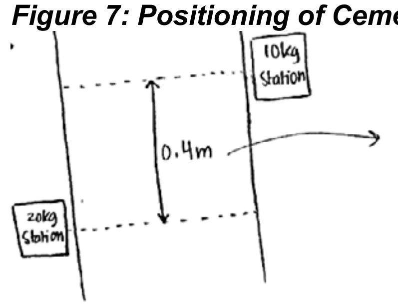


Figure 6 depicts a method that allows correct positioning of bags on the conveyor. Adding this under the machine with rollers/gears will assist the bags in falling in the correct place – moreover, this will eliminate the addition of handrails. This method forms a necessity after the inclusion of 10 kg bags because separation may not be as effective if the bags are placed in an improper manner. It will also allow for organised storage without the involvement of labour.

Figure 7: Positioning of Cement Bagging Machines



Time taken for the 10kg Bag to reach the equivalent distance as the 20 kg Station

d = s × t
0.4 = 0.2 × t
0.4 / 0.2 = t
∴ t = 2 seconds

• 10kg Bag takes 10 seconds initially to fill & discharge
↳ However, 2 seconds need to be added to reach the same distance as 20kg bags.
∴ TOTAL TIME = 10 + 2 = 12 seconds.

• 20kg Bag takes 14 seconds (as mentioned in the report)

Figure 7 represents the placement of the cement bagging machines, where the 10 kg machine is placed 0.4 m behind the existing machine. This effects the time taken by the 10 kg bag to reach the same distance as 20 kg. the calculations in figure 7 show that it will take 12 seconds for the 10 kg bag to fill and pass the 20 kg station.

Figure 8: Timings of the bags and key issue

10kg	20kg
12s	14s
22s	26s
30s	36s
42s	50s
54s	64s
66s	78s
78s	—
90s	92s
100s	104s
108s	114s
120s	124s

After continuing this pattern, the bags collide at the 12th bag, because they are at the same distance at the time.

To overcome this complication, two pathways can be considered:
↳ Changing the gear ratios of conveyor
↳ Adding Logic gates (electrical control)

Both bags collide at 78 seconds – which creates conflict. This has been highlighted in the table.

Figure 8 shows the timings of when each bag will be dispatched on the conveyor. These timings were based on figure 7. The overcoming the conflict will be done later in this project.

Materials and Methodologies incorporated in this Problem

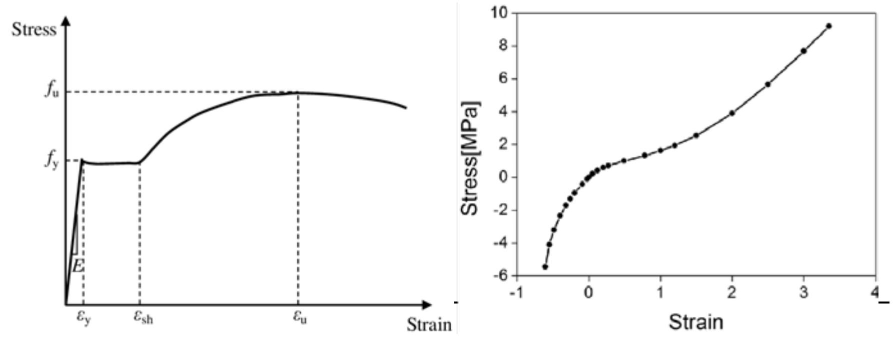
A conveyor system transports goods/materials over rollers, wheels, or a belt – which are "powered by a motor, by gravity or manually" (Mills, n.d.). They ease transportability of materials using mechanical and electrical devices. This task deals with a cement bagging system which follows this particular procedure: install an empty bag in the filling machine, filling the bag with cement, sealing the bag once filled and finally dropping the bag on the discharge conveyor system. An empty bag is placed at the nozzle of the machine, which is then activated either manually (using a foot pedal) or automatically – the cement is transferred into the bag until the specified time or once the required mass is achieved. Consequently, the bag is sealed and pushed onto the conveyor belt (manually or automated).
The materials used in the construction of the conveyor frame mainly consist of: stainless steel and aluminium. Stainless steel is composed of several alloys, which increase its heat and corrosion resistance properties, with a carbon content ranging between 0.03% - 1.2% (Fractory, 2021). Its composition contains at least 10.5% chromium, which provides enhances its ability of corrosion resistance. There are 4 major categories of stainless steel: austenitic (austenite as primary structure), ferritic (usually only have chromium as an alloy), duplex (mixture of austenite and ferritic) and martensitic (high carbon and lower chromium content). Stainless steel compares very well to carbon steels in terms of yield strength. It also delivers higher tensile strength than materials like aluminium, brass, etc (figure 9a). Other properties include: ductility, malleability, recyclability, electrical and thermal conductivity, etc. Aluminium also shares some of the following properties: ductility, high electrical conductivity, corrosion resistant, etc. (Azom, 2020). It is a very lightweight material, which has a more superior strength to weight ratio than steel. Pure aluminium has low tensile strength, but this improves when alloys are added to its composition. The belt of this system can be made of several materials, including rubber, polymers, nylon fabric, etc. (ScienceDirect, 2006). However, the most common and effective belt material for a cement bagging company would be rubber. This is because rubber is rigid yet flexible material, high heat resistance, etc (figure 9b). Additionally, cement bagging companies usually use rubber conveyor belts due to their advantages. Along with these materials and methodologies, some environmental considerations are also fundamental to acknowledge.

Environmental Assessment and Life-Cycle Analysis

- Stainless Steel (SASSDA, 2021): it is 100% recyclable – it does not have any toxic coatings or harmful byproducts, which makes it a greener material. Stainless steel production uses scrap/raw material, from which 70% comes from recycled items. Due to advancements in technology, the manufacturing process of this material is becoming more efficient in terms of energy reduction. Furthermore, even if the material is found in a landfill, it will not have any harmful impact on the environment. In terms of life-cycle analysis, it is made from raw/recycled materials and can be fully recycled – giving it a potentially infinite life-time.
- Rubber: it is a recyclable and reusable material – however, if not recycled, it can cause harm to the environment through causing an increase in waste landfill. These conveyor belts, when reach the end of their lifespan, "are large and cumbersome waste items… placing them in landfill is costly, represents a loss of valuable resources and may contaminate the environment" (Business Recycling, n.d.). It has a life-cycle of approximately 10 years (Spark Belting, 2021), after which it can be recycled into surface mats, improving durability while lessening traffic noises, etc. (RecycledRubberFacts, n.d.)
- Paper (MTU, n.d.): these bags are made from trees and are a renewable source – its stages include timber harvesting, pulping, production, usage, disposal, or recycling. As paper is a heavier material than plastic, its transportation significantly increases – further as most processes, its main sources of environmental impact occur at the extraction of raw materials and production stage. Paper does have a reasonable lifespan, however, can be destroyed/damaged more easily than plastic – which reduces its performance and life.
- Plastic (MTU, n.d.): these bags go through raw materials extraction, manufacturing, distribution, usage disposal or recycling. The production stage of plastic requires the most energy and also causes the most carbon emissions out of all stages. Plastics have a large lifespan, out of which, immense environmental harm is caused if disposed/added to landfill. However, plastics are very versatile and can be used in multiple forms – making it a sustainable option.

Methodology

In terms of methodologies, the addition of another cement bagging machine and the discharging stations at the end of the conveyor belt will involve additional labour, materials, cost, etc. The instalment of these will cause environmental harm to a certain extent, however, this inclusion will be categorised into brown field construction. Brown field is contaminated or already utilised properties/places; redeveloping on these places minimises environmental impact (reduces destruction of greenspace construction) (Gray, n.d.). Greenspace construction happens on undeveloped, agricultural land – this causes more environmental harm compared to brownfield (Gray, n.d.). Therefore, as this construction is brownfield, this task becomes more sustainable. Other methodologies include the usage of control/interlocking systems, gear ratio alteration, etc. – these will be addressed later in this project.



(a) (b)

FIGURE 9: Stress-strain curve for Steel (a) and Rubber (b)

TABLE 1: Comparing Paper and Plastic Properties

MATERIAL	ADVANTAGES	DISADVANTAGES
Paper	• Low cost – economical packing option • Printable material & easily processed • Lightweight • Eco-friendly material – decomposes and is also recyclable	• Not a waterproof material – can damage/destroy the packed material • Prone to damage if contacted with sharp objects • Can only support limited load
Plastic	• Less wastage & easier to recycle • Lower packaging costs • Substantial longer life expectancy • Water and weather resistant, unprotected open air storage • Cleans storage (no leaks) and dust/spillage free	• Non-renewable resource – environmentally unfriendly • Causes air and water pollution • A lot of energy Is required to clean and further recycle plastics

As the qualities of plastic outweigh the paper, it would be the most efficient bagging material. In terms of plastic, the common plastic used for packing cement is polypropylene. This is because it is inexpensive, flexural yet high in strength, resistant to moisture, low friction coefficient, etc. (Staff, 2016). Paper bagging does not allow for outdoor storage of the cement bags, in case of wet conditions, unlike plastic bags. The wastage of cement in paper bags being stored in wet conditions, increase costs and other factors. Therefore, by using plastic bagging, the company reduces bag mass, along with increasing environmental sustainability and customer satisfaction.

Control Systems

Control systems are "devices that manages, commands, directs, or regulates the behaviour of other devices or systems to achieve a desired result" (Electrical4U, 2020). There are two types of control systems: mechanical and electrical/computational. Mechanical systems operate as such: input is provided by an effort, once the effort and is applied, it can set off a motion to move a load and the force applied to the load is the output of the mechanical system Whereas, electrical logic gates are a "type of amplifier, which is implemented in different forms within an integrated circuit… [it has] one or more(most often two) inputs and one output" (Digital Electronics, n.d.) and consist of 7 main operations (Table 2)

TABLE 2: Logic Gates

SYMBOL	NAME	USE OF THE LOGIC GATE – (Elprocus, 2021)
A, B – X	AND	The output of this gate is only true when all inputs are true. When one or more inputs are false, the output if also false.
A, B – X	OR	The output of this gate is only true when one or more inputs are true. If all inputs are false, that is when output is false.
A, B – X	NAND	This gate is a combination of AND and NOT gate – E.g. if the input of the NAND gate is true, then the output will be false.
A, B – X	NOR	This gate is a combination of OR and NOT gate – E.g. of the input of the NOR gate is true, then the output will be false.
A, B – X	XOR	Exclusive-OR: this gate performs the operation based on OR gate. If one of the inputs of the XOR gate is true, then the output will also be true.
A, B – X	XNOR	Exclusive-NOR: this gate performs the operation based on NOR gate. If one of the inputs of the XNOR gate is true, then the output will be false.
A – X	NOT	This gate has one input and one output. The output of this gate is the opposite of its input (e.g. if input is true, then output would be false)

Table 3 below shows truth tables that determine the performance of the logic gates. They perform on the basis of binary digits (0 and 1) – where 0 means false/off and 1 means true/on.

TABLE 3: Truth Tables for these logic gates

AND gate

Input A	Input B	Output
0	0	0
1	0	0
0	1	0
1	1	1

NAND gate

Input A	Input B	Output
0	0	1
1	0	1
0	1	1
1	1	0

OR gate

Input A	Input B	Output
0	0	0
1	0	1
0	1	1
1	1	1

NOR gate

Input A	Input B	Output
0	0	1
1	0	0
0	1	0
1	1	0

EX-OR gate

Input A	Input B	Output
0	0	0
1	0	1
0	1	1
1	1	0

EX-NOR gate

Input A	Input B	Output
0	0	1
1	0	0
0	1	0
1	1	1

In this task, they will serve the purpose of preventing overloading/collisions of cement bags and in the separation of 10 kg and 20 kg bags for dispatching.

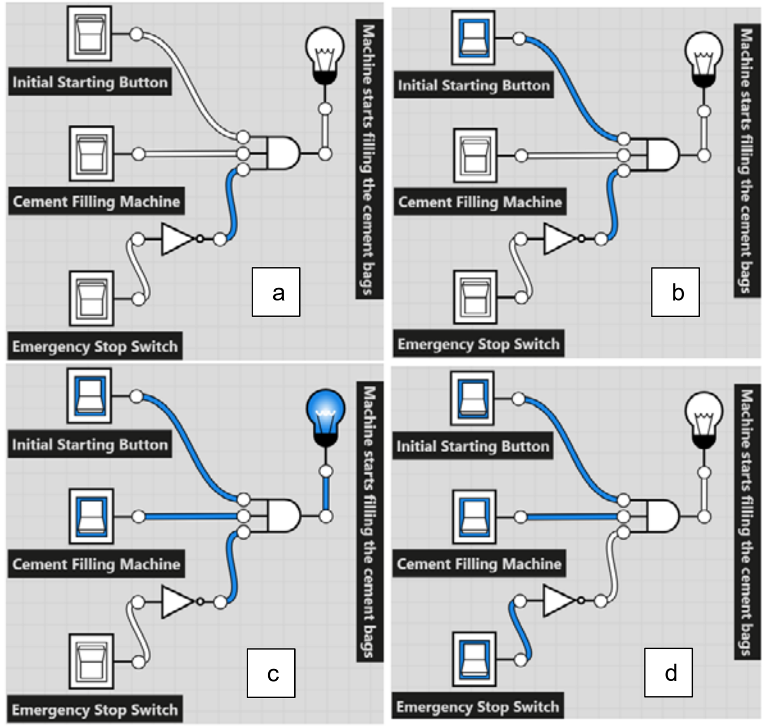


Figure 10: Initial stage control using logic gates

Figure 10 shows the initial stage of the bagging system. The system shows the use of two logic gates – AND & NOT. Theoretically, the output (light bulb) will light up when the first 2 switches are on. If the emergency stop switch is on, there will be no output. This has been included as a precautionary step. Part a depicts all switches are off – therefore no output is observed. Part c shows the typical procedure of this stage. Part d addresses what happens when the emergency switch is on – no output.

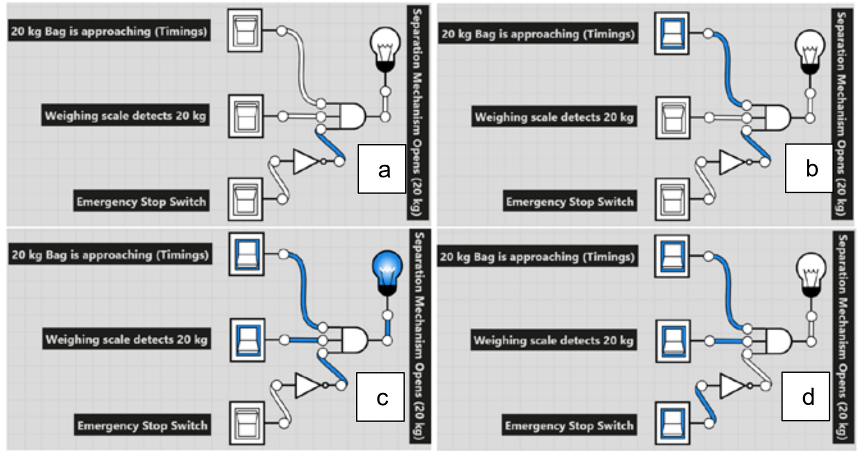


Figure 12: Operation of Separation mechanism through Logic gates (e.g. 20 kg)

Figure 12 outlines the electrical control system for the possible new solution for this problem. The bags need to be separated at the end of conveyor – this will be done through the separation mechanism. When the weighing scale detects a mass and timings also reflect the same mass – the mechanism will open and start operating. Once again, the emergency switch has been placed for any sudden mishappening.

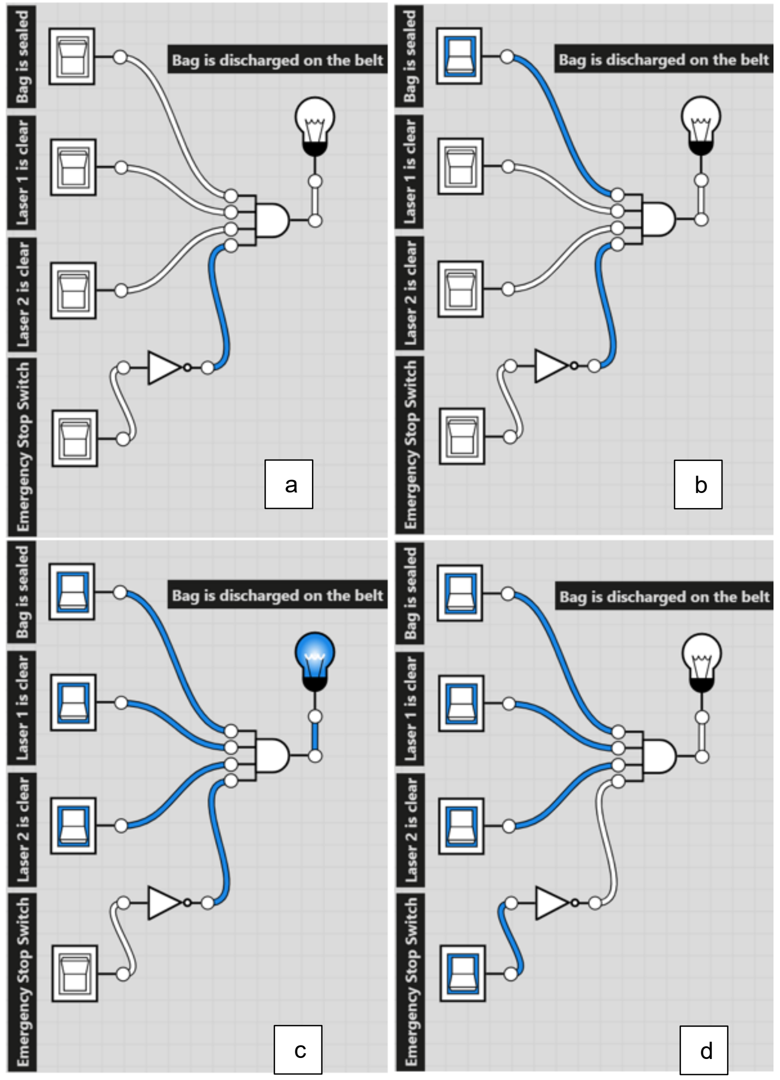


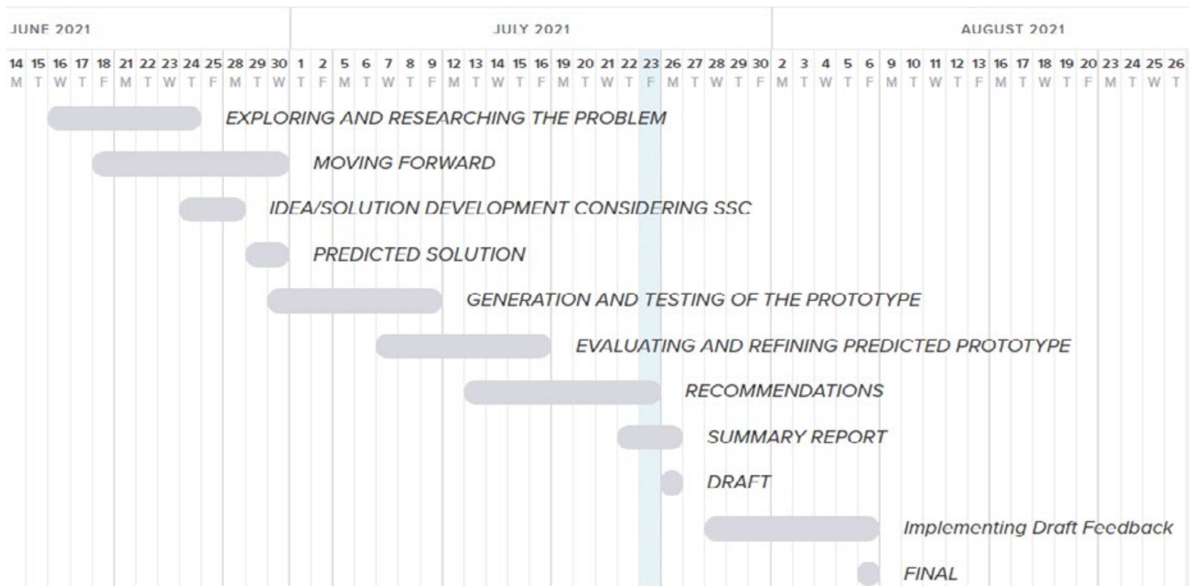
Figure 11: Bag dispatching control using logic gates

Figure 11 shows the stage when the bag is ready to be discharged on the conveyor belt. The same logic gates were used in this stage – it has 4 inputs and 1 output. Once the bag is sealed, both lasers are clear and the emergency switch is off, the bag is discharged on the belt. The emergency switch uses a NOT gate, which means the first three inputs conclude whether the bag will be discharged. The four parts (a, b, c, d) outline the scenarios and their respective outputs.

There were other options of arranging and using multiple logic gates, however, the addition of more logic gates increases cost and also misunderstanding in circuit building. Therefore, the most basic design was suggested.

MOVING FORWARD

PROJECT MANAGEMENT



Exploring Different Mechanisms to Separate Bags

1

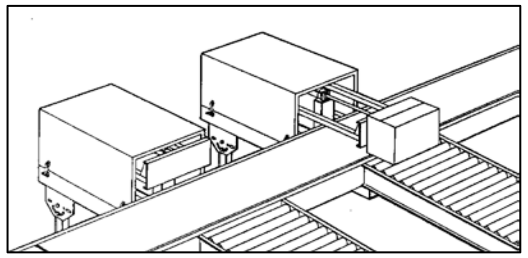


Figure 13: Option 1

Pros	Cons
Effective separation of bags along with a 'fail zone'.	The edges could potentially damage the bag – causing wastage.
Small mechanism, will not require a lot of labour/cost.	Position of bags may be altered if not detected properly by the sensors.

2

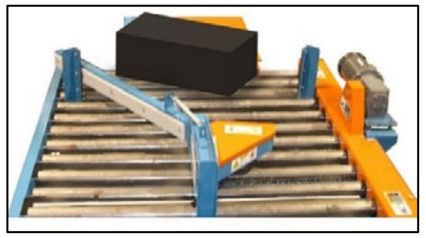


Figure 14: Option 2

Pros	Cons
One arm operates both discharging stations – reduces labour, cost, and construction time.	Could fail to separate and cause obstruction by colliding with approaching bags.
	No fail zone – meaning bags can be discharges in any zone if malfunction occurs.

3

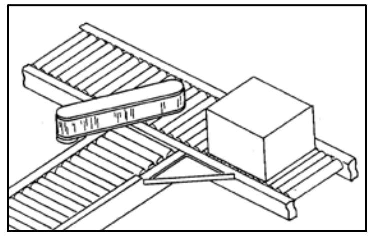


Figure 15: Option 3

Pros	Cons
Smooth gliding surface for bags to follow and discharge	May malfunction if detecting is performed poorly.
Simplistic, yet effective design for the separation of bags (while also providing a fail zone option)	Could also lead to separating bags in different areas (10 kg in 20 kg – example).
Does not hinder in other bags on the conveyor belt.	

The most effective mechanism for separation of bags will be option 3. It offers more advantages than disadvantages – making it the most suitable for the task. To modify/refine this idea, option 1 and 'rack and pinion' models will also be included in the final design. the final outcome will incorporate rotary and linear motion, which is converted into reciprocating. The lever arm will turn 90^{o} and will have a rack and pinion core – this will have an arm attached, to push the bags on the discharging station.

Solution Success Criteria (SSC)

First Priorities: most essential qualities that must be included for the completion of the task.

- The solution must accommodate the addition of 10 kg cement bags in the original system because the task is to increase their production rate by at least 50%.
- The conveyor belt must have two separate discharging areas for 10 kg and 20 kg bags with a mechanical control system. It should also provide a 'fail area', where if in case the system fails to operate, the bags disembark in an area where they would be manual separated. This would minimise the chances of any bags being separated in a different zone (e.g., if 10 kg bags accidently are sorted in the 20 kg zone).
- There must be at least one electronic logic gate system incorporated in this report – to ensure the bags from the bagging machines do not collide with each other and are only dropped on the conveyor belt when all the hazards are assessed.
- The addition of a guiding box under both cement bagging machines (according to their dimensions). This will assist in correct placement of bags on conveyor and also ease the separation process.
- The task requires the exploration and possibly the change of paper bags to plastic bags – this reduces mass, enhances sealing and provides greater benefits (especially in outdoor storage – wet conditions).

Second Priorities: these are qualities that would enhance the solution and its performance.

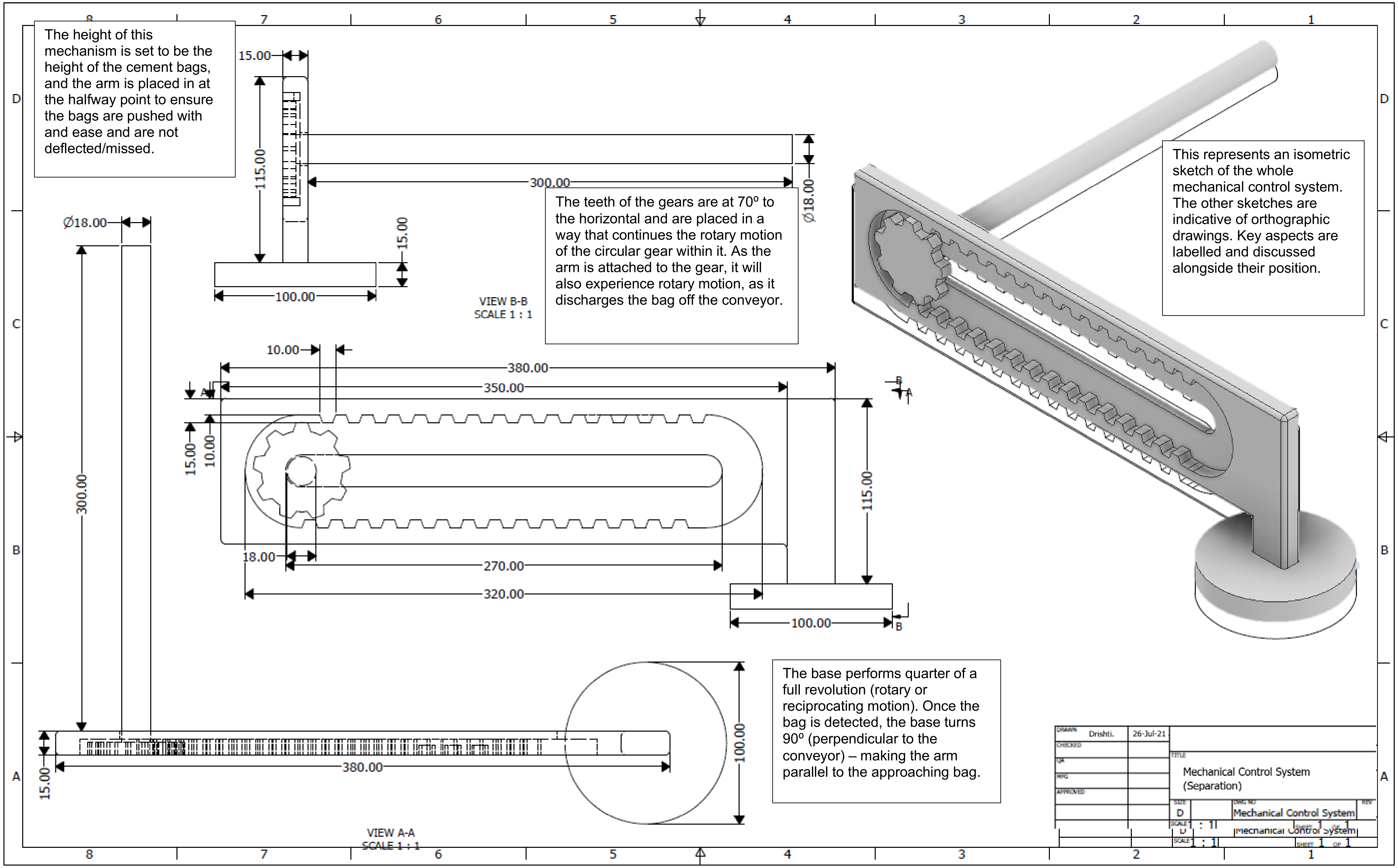
- Materials used in this project (such as conveyor materials, bags, etc.) must be environmentally friendly, in terms of recyclability and increased material lifespan.
- By adding a mass detecting device/scale, the quantity of the cement bags can be ensured; additionally, it could also assist in easing the operation of the mechanical control arm for separation (if the device detects the mass to be 10 kg, then the mechanical arm to discharge those bags will operate – instead of relying on time).
- Doubling the velocity (from 0.2 to 0.4 m/s) by altering gear ratios (as the task offers) will increase production and assist in achieving the 50% in output.

Analysing Ideas Using Solution Success Criteria

First priority		As shown by the timings and production rate calculations, this criteria has been achieved. The outcome increased by 57% - exceeding the set target of at least 50%. However, this is only a theoretical calculation.
		The predicted and the most effective method for discharging the bags was concluded to be as outlined previously (Separation of Bags). It mentioned that there will be a 10 kg, 20 kg and a final zone off the conveyor to accommodate the 2^{nd} criteria of the SSC
		This point is also considered by adding a 'NOR' gate as an interlocking system – in order to overcome the issue of the bags colliding. It will ensure that both stations dispatch the bags at different time to ensure no obstruction occurs.
		The guiding box was explored in figure 6 and will be a suggestion for the company to implement – however, this criteria is unable to be prototyped and tested – which limits making justified conclusions on its practical performance.
		As the task suggested to explore the properties of plastic bagging, this forms an important aspect of the solution success criteria. Through the comparison performed earlier, it can be concluded that plastic, specifically polypropylene, is more advantageous in terms of greater sealing, less mass and better performance in unusual/wet weather conditions.
Second Priority		As outlined in the environmental considerations section, all the materials used in this task are sustainable – they can be recycled, which increases their lifespan.
		This point has not been considered up to this point, however, will later be considered. This criteria cannot be prototyped, it can only be mention and recommended for the company to take action.
		This aspect has not been considered so far because the addition of 10 kg bags already increased the output by 57% - therefore, this criteria may become a future consideration but is not ruminated.

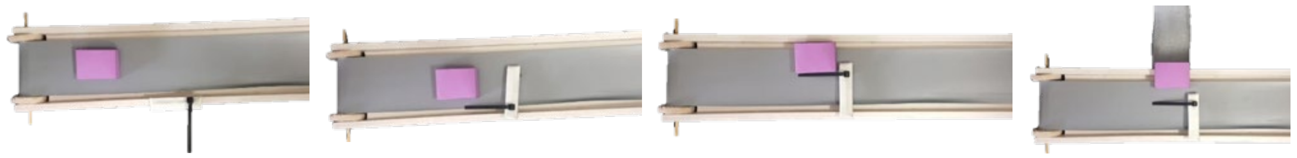
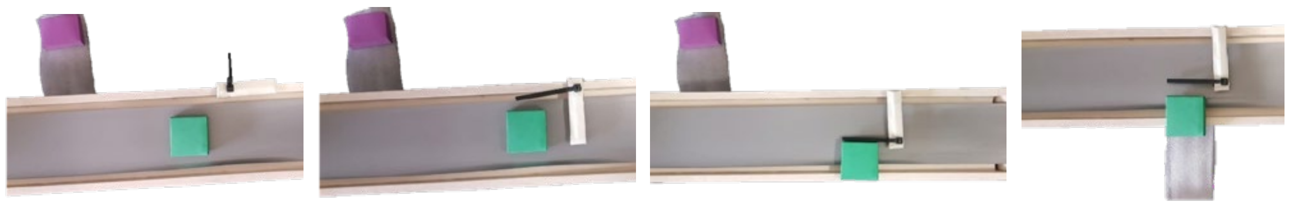
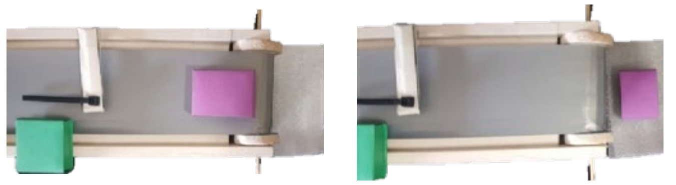
PREDICTED SOLUTION CONSIDERING THE SOLUTION SUCCESS CRITERIA

To create a separation mechanism for the bags, a solution has been developed below. It is a refinement of idea 1 and 2 with other minor additions. The internal shows a rack and pinion device with an arm connected to it. The rack box is connected to a cylindrical base, which rotates up to 90º. When the bag is approaching the separation zone, the base will turn, so it is perpendicular to the conveyor. Then the arm will move from the right to the left when in contact with the bag (it moves right to left if placed on the right side – and vice versa). The arm assists in directing the bag to the designated zone and consequently, discharge off.



GENERATING AND TESTING THE PREDICTED SOLUTION

A model conveyor system and bags were created – these formed a simulation of the problem and the implemented solution. The bags were prepared from paper; conveyor was designed from balsawood; and the conveyor belt is shown with tape. Images have been taken by placing the bags at the intended place to effectively demonstrate how the solution is successful.

A prototype of a conveyor system has been modelled to replicate the task. It shows the inclined section of the system.		The purple bags replicate the 20 kg bags and green ones show the 10 kg cement bags.
This shows the discharging of 20 kg bags with mechanical control system. It pushes the bag on the area off the conveyor for further storage (on the opposite side of the mechanism itself).		
This shows the discharging of 10 kg bags with another mechanical control system. It pushes the bag on the area off the conveyor for further storage (on the opposite side of the mechanism itself).		
FAIL ZONE	If a bag is missed by the control system, then it will reach a fail zone – from there, a worker will be appointed to manually sort those bags in the designated section. 	In this simulation, an example of a 20 kg bag is shown to reach the fail zone.

Refining Solution & Further Calculations

During the prototype simulation stage, it was seen that it takes more energy to push the bag to the separation zone when it is parallel to the ground. To ease this process, it was decided that the separation zone would be set on an incline – however, this would impact the final height set by the project. To resolve this issue the total height by the end of the conveyor would be 1.5m. The decline at the separation zone will from 1.5 m to 1.2 m, at an angle of 30º. This will allow gravity to assist with the separation of the bag. In terms of slowing the bag's velocity (to get it to rest), the friction of that surface will be increased. The calculations and diagrams in figure 18 show the refined and enhanced solution to the task. In order to perform the calculations using the equations of motion, the velocity of the bag after contacted by the mechanism is important to determine; this is done in figure 17.

Figure 17: Separation Mechanism – angle and velocity of the bag

Figure 17 shows the steps taken by the separation mechanism along with the velocity and angle at which the bag will be discharged off the conveyor. The bag will move off at 25º from the normal to the arm. Figure 18 outlines the decline at separation zone and key information – along with force, velocity, acceleration calculations. The initial velocity of the bag will be 0.47 m/s instead of 0.2 m/s (conveyor) – this is because there are two velocities acting perpendicular to each other. Part a shows the overall approach to the scenario; part b represents the force diagram for the inclined section (0.6 m).

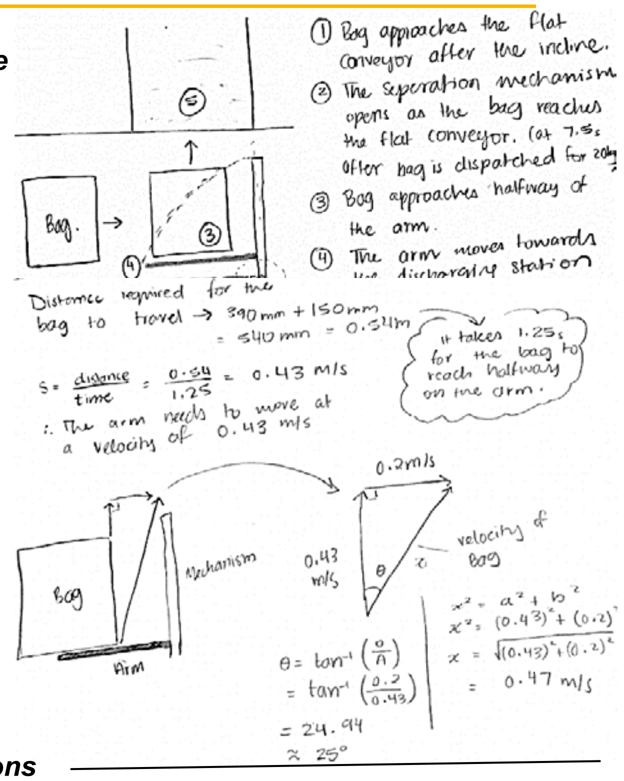
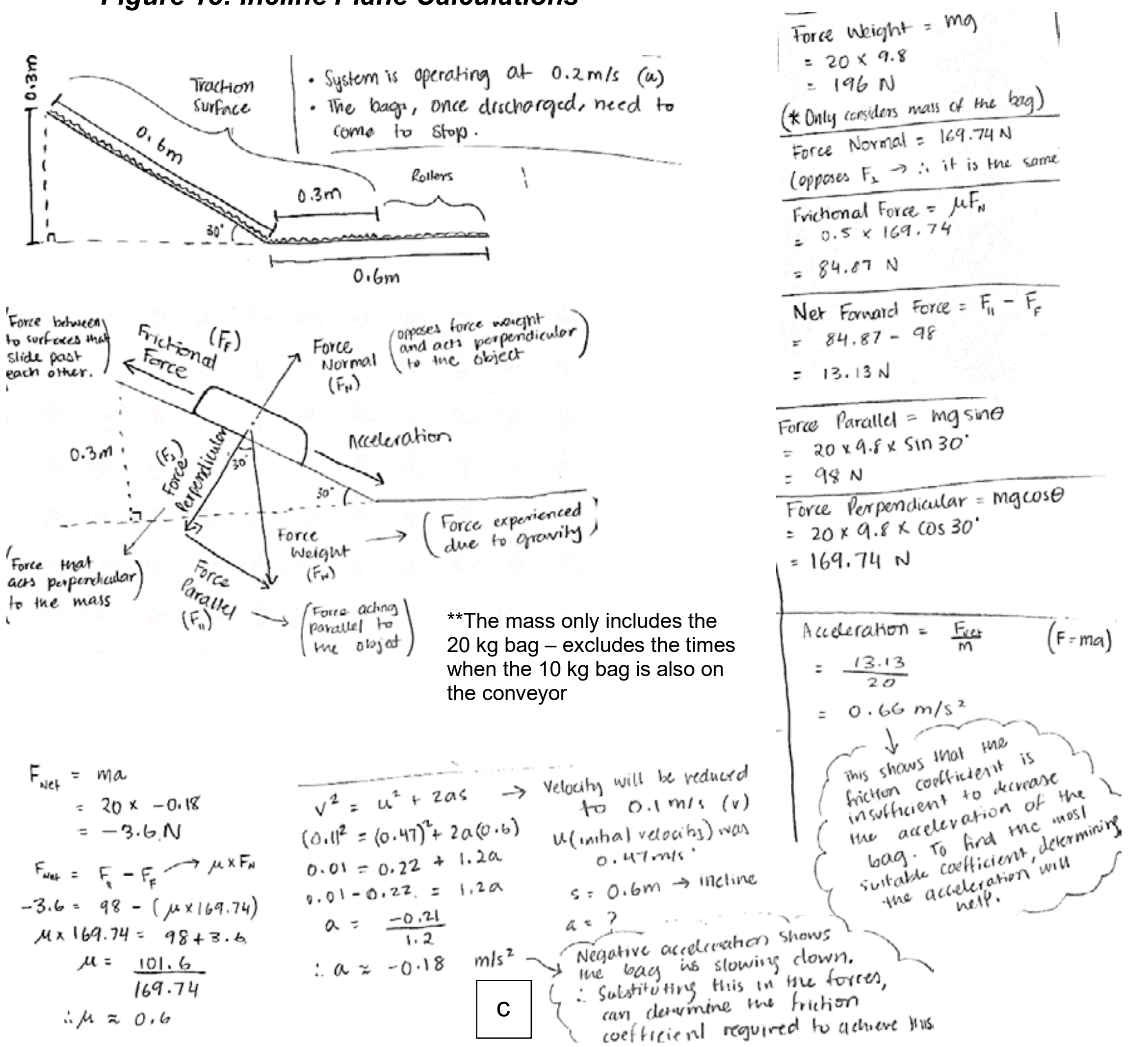
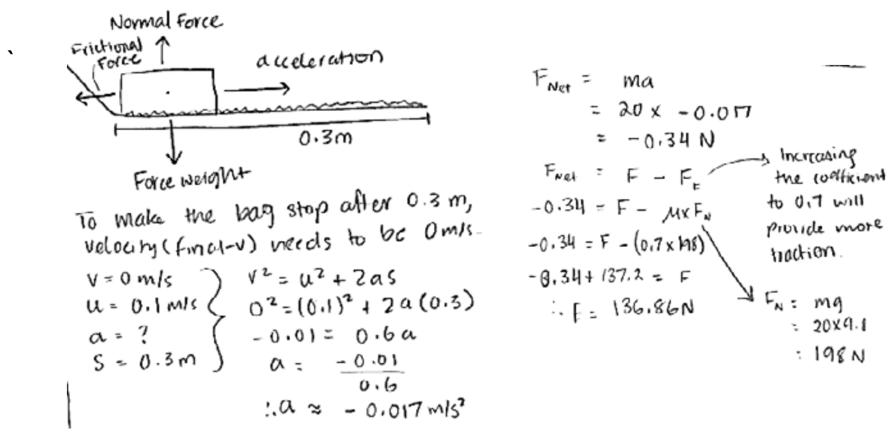
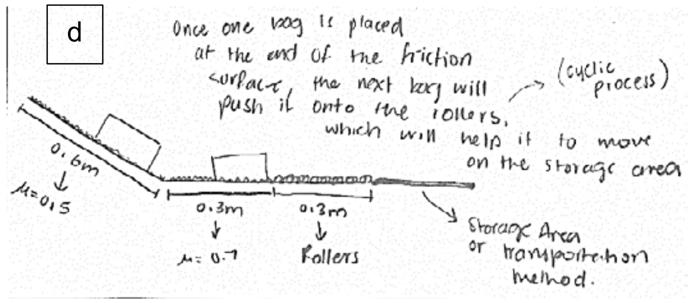


Figure 18: Incline Plane Calculations







As mentioned in the calculations (figure 18), friction coefficient is the measure of friction between two surfaces that are in contact. As the belt is made from rubber and cement is in plastic bags, the coefficient is 0.5. However, the calculated coefficient was 0.6 (incline) and 0.7 (flat). To achieve this, the rubber belt can be customised to have an uneven surface to allow for more traction.

Part c from figure 18 shows the acceleration calculated using the equations of motion – it is a negative value, validating that the bag is slowing down. Part d above, shows the summarised version of the scenario. It will be suggested that in order to stop the bag and safely store it in the separation zone, the incline will have a friction coefficient of 0.6 and the flat 0.3 m will have a higher tractional force of 0.7. Once the bag comes to rest at the end of the 0.3 m, it will stay there until another bag pushes it on the roller section. The roller section makes the bag regain velocity, which allows it to be easily transported.

EVALUATION & FURTHER CONSIDERATIONS

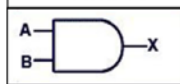
The solution for the separation mechanism effectively discharges the bags onto the designated zones; however, it bases this on the timings of the cement bags. For example, the control system will operate according to the timings deduced earlier (for the addition of the 10 kg bags). In order to strengthen this aspect, a device/sensor that detects the mass of the approaching bag could be added on the conveyor system. This allows the separation mechanism to operate with timings and knowing if 10 kg or 20 kg bag is approaching, reducing the possibilities of uncertainty or error. This new mass detecting device would be installed on the conveyor system in a way that is able to determine the mass of the bag as it travels through. Once it senses the mass of the cement bag, the respective separation mechanism will operate.

For instance, if a 20 kg bag is dispatched from the cement bagging machine, it will travel up the inclined plane and reach a sensor/electrical mechanism (possibly at the top of the conveyor – after the incline); this device would then signal the mechanical control system for the 20 kg bags. It would rotate 90º (becoming perpendicular to the conveyor) and move its arm once the bag is in close proximities to the arm. This will discharge the bag off the conveyor. For this mechanism to work, it will be linked with an electronic control system – logic gates. The logic gates that will assist the mechanical control system to work, will have two inputs and one output (for a 20 kg bag):

Input 1: the timing data shows that a 20 kg bag is approaching

Input 2: the mass detector confirms the mass to be 20 kg.

Output: the 20 kg mechanism will start operating

SYMBOL	NAME	USE OF THE LOGIC GATE – (Elprocus, 2021)
	AND	The output of this gate is only true when all inputs are true. When one or more inputs are false, the output it also false.

This shows that an 'AND' gate will be used to perform this aspect.

Another refinement would be to engineer a more effective separation mechanism with a higher mechanical advantage – this can be done through analysing the different classes of levers and what effects they have on its performance.

Overall, these mechanism successfully provides an effective solution to the conflict faced by the cement bagging company.

Figure 19 shows a third-class lever which represents the separation mechanism. An example of a third-class lever are tweezers. The arm will be fixed on one end of the mechanism (fulcrum), while the load will be on the other end. As calculated in the figure, the mechanical advantage of the lever, which is 0.05. A low means the force applied is greater than resultant force – making this system inefficient.

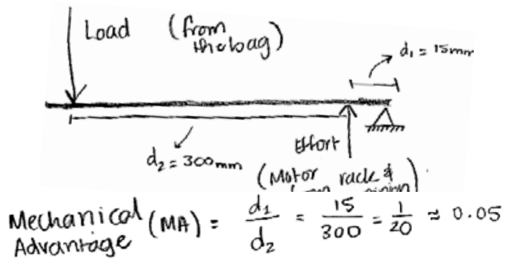


Figure 19: Mechanical Advantage

Assessing According to the Solution Success Criteria

The analysis of the obtained results is reflected in the table below; point will be given accordingly, which will help determining the success of the solution.

First priority	1	This criteria has been fully met, as more than 50% of overall increase in production is theoretically derived. Therefore, the company's requirement of wanting at least 50% increase has been achieved with 57% total outcome, through the addition of 10 kg cement bags.
	1	The system is successfully able to have a separation area for 10 kg, 20 kg and also include a fail zone – meeting another criteria point.
	1	In terms of logic gates, a NOR gate is added as an interlocking system to ensure bags do not collide – this gate works on two inputs (laser 1 and 2) and gives one output. If any of the two inputs are true, then the output will be to not push the second bag on the conveyor belt, indicating there is already another bag at that position.
	0.5	The guiding box has been explored in this project; however, a simulation/prototype was not created, which cannot determine the performance of this addition.
	1	A thorough comparison was conducted in this project, which concluded that plastic bags (specifically polypropylene) performs better and has more beneficial properties compared to paper bags.
Second Priority	1	This criteria outlined the environmentally friendliness of the materials in this report. Overall, these materials (stainless steel, rubber, plastic bagging, etc.) are all recyclable, which increases their lifespan.
	0	The velocity of the conveyor was not increased, which gives this criteria no points – the concept of gear ratios should be explored and further assessed for increase velocity and thereby, production of cement bags.

TOTAL MARKS: 5.5/7

Overall, the prototype engineered for this task meets almost all requirements, when compared with the solution success criteria – which strongly hypothesises the success of this predicted solution.

Solution Success Criteria – Recommendations

- Engineering and prototyping the second control system (mechanism at the separation zone), can help fulfil the last priority of the solution success criteria.
- By creating a prototype using electrical equipment for the 2 point in second criteria of the SSC (incorporation of a mass detecting devices), a more accurate representation of the solution can be established.
- By exploring the gear and velocity ratio for the inclined conveyor, the energy efficiency of the system can be calculated. As energy efficiency is mechanical advantage divided by velocity ratio, further improvements and success criteria can be developed. For instance, if the system is discovered to be 80% effective, considerations regarding materials/methodologies that are causing the energy loss can be performed – ultimately making it more efficient.

RECOMMENDATIONS

Materials, Fabrication, and Installation

As a recommendation, the cement bag mechanical control system should be engineered separately and then installed on the conveyor. The materials that should be used in the building of this mechanism are stainless steel and rubber; this is because, as explored previously, has multiple benefits and associating properties, along with being an environmentally friendly material. The distribution arm is a cylindrical shape, which will cause no damage to the bag while pushing it off into the separation zone. To maintain the gears involved in the solution, the rack and pinion along with the base of solution must be lubricated frequently to ensure it maintains its working conditions. The conveyor and other involved materials/systems must be cleaned regularly to ensure no equipment has any built residues that may obstruct its workability/performance.

The mechanical control system would be installed on the sides of the conveyor, with a section of the base attached at the bottom. There will be two of those systems to accommodate for 10 kg and 20 kg separation zones. These distribution systems can be bolted to the conveyor however, it would be suggested to weld the body of the mechanism. This will provide greater strength and rigidity; the bolting will ensure the system is flexible yet high in strength. In case of any mishappening with the mechanism not working correctly, it shouldn't cause any damage to the cement bags or the conveyor belt because of the smoothly curved edges – instead of sharp corners.

However, damage can occur to the conveyor belt due to excessive load placed by the addition of 10 kg bags. Therefore, to prevent the belt from this damage, regular maintenance and testing should be performed prior to implementing this solution.

A rubber covering will be placed on the distribution arm for further security that it will not damage the cement bags while discharging them off the conveyor. As discussed previously, rubber is a reusable material with a reasonable lifespan. Furthermore, as it is suggested to regularly cleanse the conveyor materials, the chances of damage reduces on all materials – increasing their longevity.

In terms of sustainability, the bagging materials (paper and plastic) explored, only show a limited number of options – therefore, to expand this, other materials should be researched. They would be evaluated through the criteria of mas, environment, expenses, and other properties. Another material that could be compared is polyethylene (PE), which is also a POLYMER. It has similar properties compared to polypropylene (PP); therefore, it can be concluded that plastic (whether PP or PE) is more advantageous than paper packaging.

The methodology used to solve this problem can be further utilised to create more opportunities for the company. By introducing another production line (options like 5 kg), the company opens prospects to other consumers looking into purchasing smaller quantities and minimising wastes. This will also conform to Australian Standards for manual lifting (suggesting a person should not lift any more than 25 kg - AS 1339-1974). If the introduction of bags with different mass is unavailable, production of another 10 kg or 20 kg bags would be introduced. This will increase the production rate and generate profit for the company.

Overall, these recommendations and considerations will enhance the final solution and the installment into the conveyor system of the cement bagging company.

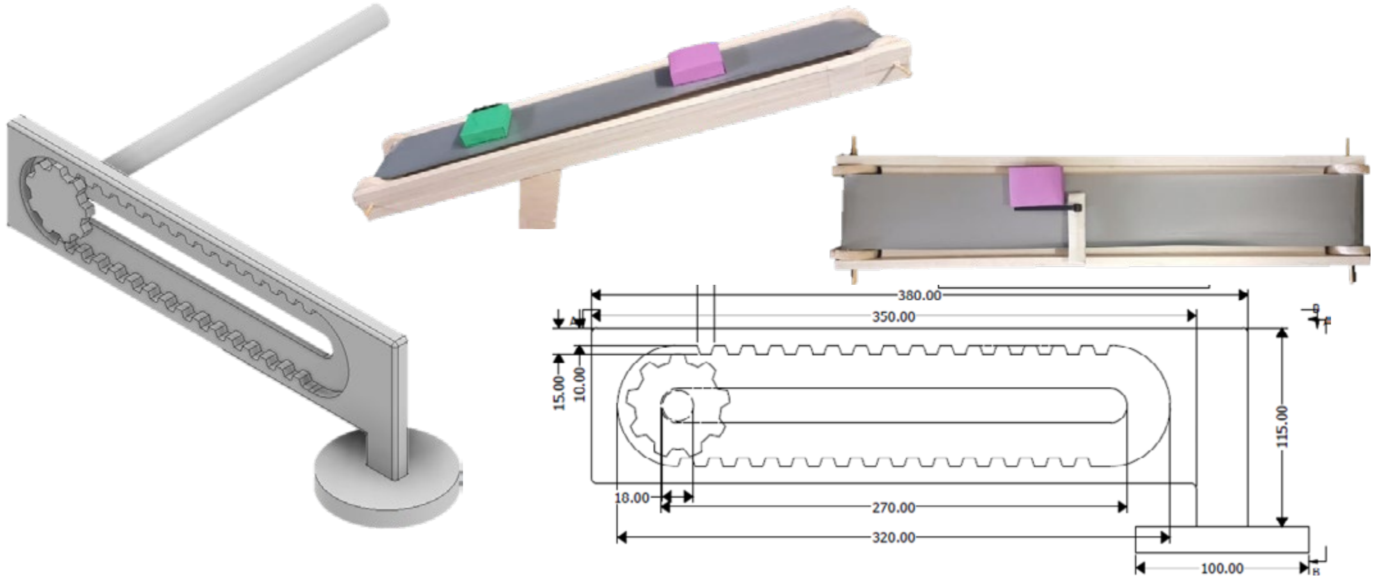


Figure 21: Summary – Prototype, CAD and Simulation

Future Considerations for Suggested Solution

Some future considerations for the suggested solution include:

- Considering the costs and feasibility of this solution would be considered to create a real-life model, which is bounded with the limitations and budget of the company – if this solution is not feasible, than it provides minimal help to resolve the company's conflict.
- During all of these process, efficiency is essential; a major contributor of energy loss is heat. To reduce the amount of heat lost to the surrounding – through using materials with low friction coefficient, frequently checking motors and other heat generating machined/equipment.

By exploring the option of changing gear ratios to increase the velocity of the conveyor system, production rate can be significantly increased. An increase in production rate benefits the company. There is an input and an output gear; if the output gear is larger than the input gear, then the gear ratio will be less in comparison to having a smaller output gear. This is because in figure 20a, input turns 'n' times for 1 revolution of the output however, in figure 20b, output turns 'n' times in 1 rotation of input. This means that there will be an increase in velocity if a scenario like in figure 20b would be used, but the gear ratio will decrease. Increasing velocity will also increase the production rate of cement bags – overall making profit for the company.

FIGURE 21: Relation Between Gear Ratio and Velocity

Overall, these future considerations upgrade the properties of the suggested solution, which will benefit the overall performance of the company.

SUMMARY REPORT

CEMENT BAGGING SYSTEM UPGRADATION

Introduction

This document outlines the final results for the development of Cement Bagging Machine Upgradation. Company also wants to make an addition of filling 10 kg along with current system – using the same conveyor belt. The production rate of 20 kg bags has to be maintained; however, the overall output needs to increase by 50%. The velocity of the conveyor belt needs to be changed from paper to plastic – company wants to explore this change in terms of mass reduction and improved sealing. To solve this assigned task, the engineering problem solving process was used – exploring, develop, generate evaluate and refine.

Background

This project provides some contextual information regarding its conditions that would be required for the task to be successful. Cement industries use automated bagging systems to fill 20 kg bags with an overall time of 14 seconds (3 seconds for installing, 8 seconds for filling and 3 seconds to seal and discharge the bag on the conveyor belt). The time taken to install and seal the bag remains the same for 10 kg, but the time taken to fill the bag halves. This is because the dimensions of the bag are similar, therefore, installment and sealing time would remain unchanged – however, the bag will be filled to halve of its original mass (20 kg)., which will make the new time of filling 4 seconds. Therefore, it was necessary to make some assumptions prior to solving the problem.

Project Objectives and Considerations

The following aspects were also important to consider:

- The conveyor belt is on an inclined plane, at 36 DEG to the ground – which reaches 1.2 m high. This means that the bags are to be discharged at that height when separated (possibly due to easier transportation).
- The malfunction of any equipment in the automate bagging systems can cause delays, changes in placement of bags, etc. This situation would then have to be manually resolved – the bagging system will have logic/control gates, assisting in overcoming any of these circumstances.
- The discharging of the bags will be at separate station on either side of the conveyor belt into the storge area – if in case the lever at the discharging point fails to operate, the bags will follow the belt till the end, where they will manually be sorted into their appropriate categories.
- As the dimensions of the conveyor are not provided – the width will be set to 690 mm (so there is extra 150 mm on each side of the longest dimension of the bag - which is 390 mm). the length of the whole conveyor belt will be 3.2 m (1.0 m on either side of the 1.2 m incline).

Options Considered

Prior to finalising the final predicted solution, many options were considered. These consisted of assessing the placement of the bags, separation techniques, control systems, environmental impacts, etc. Overall, the predicted solution was chosen to be as in figure 1, which was deemed the most effective and appropriate when compared to the given conditions.

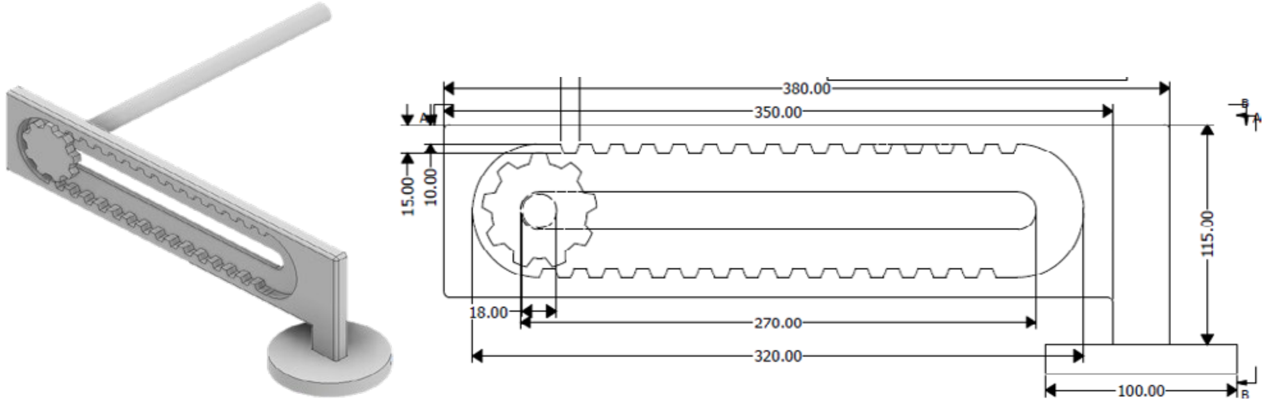


FIGURE 1: Predicted Solution

Each component of the predicted solution was assessed in regard to the solution success criteria (objectives) – and it was concluded to achieve most of the points. The prototype is shown in figure 2.

FIGURE 2: Prototype Simulation

This solution is effective in satisfying the requirements for this task because it efficiently uses a mechanism that separates both cement bags and also achieves almost all points mentioned in the solution success criteria. Along with mechanics, the materials used for the real system and methodologies are environmentally friendly – they are all recyclable, have long lifespans and have very beneficial properties. Moreover, the comparison between paper and plastic also revealed that the company would benefit more if plastic bags were used than existing paper bags. The calculation performed in the report cover a range of aspects including work, force, power, etc. Additionally, the interlocking system provides the desired outcome, of preventing bags from colliding with each other. However, a prototype was not created to assess the overall workability of the logic gates. Overall, the requirements of this task have been effectively addressed.

Recommendations

- The solution for separation mechanism effectively discharges the bags onto the designated zones; however, it bases this on the timings of the cement bags. ………………
- Another control system that would be helpful and could ease the reliability on labour and potentially cost, is to include a pushing mechanism that drives the bags from the separation zone to a storage place.

Materials, Fabrication, and Installation

- The cement bag mechanical control system should be engineering separately and then installed on the conveyor. The materials that should be used in the building of this mechanism are stainless steel and rubber; this is because, as explored previously, these have multiple benefits and associating properties, along with being an environmentally friendly material.
- The distribution arm is a cylindrical shape, which will cause no damage to the bag while pushing it off into the separation zone. To maintain the gears involved in the solution, the rack and pinion, along with the base of the solution must be lubricated frequently to ensure it maintains its working conditions.
- The conveyor and other involved materials/systems must be cleaned regularly to ensure no equipment has any built residues that may obstruct its workability/performance.
- These distribution systems can be bolted to the conveyor however, it would be suggested to weld the body of the mechanism. This will provide greater strength and rigidity; the bolting will ensure the system is flexible yet high in strength.
- However, damage can occur tot eh conveyor belt due to excessive load placed by the addition of 10 kg bags. Therefore, to prevent the belt from this damage, regular maintenance and testing should be performed prior to implementing the solution.
- The methodology used to solve this problem can be further utilised to create more opportunities for the company. By introducing another production line (options like 5 kg)

Future Considerations

- Considering the costs and feasibility of this solution are important aspects when creating the real model – which is bounded with limitations and budget of the company.
- To reduce the amount of heat lost to the surrounding – through using materials with low friction coefficient, frequently checking motors and other heat generating machines/equipment.
- By exploring the option of changing gear ratios to increase the velocity of the conveyor system, production rate can be significantly increased. An increase in production rate benefits the company.

Overall, these improvements would assist in enhancing the qualities and performance of the cement bagging problem.

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