UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

Industrial Scanner Design Report

Machine Design A314

Group 16

Authors:

Branden van der Colff – 21959862
Corné van Dyk – 21752710
Merrick Hughes – 21712662
Michael De Lange – 21584575

Faculty of Engineering
Fakulteit Ingenieurswese

Department of Mechanical and Mechatronic Engineering
Departement Meganiese en Megatroniese Ingenieurswese

Privaat Sak / Private Bag X1, Matieland, 7602, Suid-Afrika / South Africa · Banghoek Weg / Road, Stellenbosch, 7600, Suid-Afrika / South Africa

Tel: +27 21 808 4376 · Epos / Email: mmchair@sun.ac.za

Plagiarism declaration

I have read and understand the Stellenbosch University Policy on Plagiarism and the definitions of plagiarism and self-plagiarism contained in the Policy [Plagiarism: The use of the ideas or material of others without acknowledgement, or the re-use of one's own previously evaluated or published material without acknowledgement or indication thereof (self-plagiarism or text-recycling)].

I also understand that direct translations are plagiarism, unless accompanied by an appropriate acknowledgement of the source. I also know that verbatim copy that has not been explicitly indicated as such, is plagiarism.

I know that plagiarism is a punishable offence and may be referred to the University's Central Disciplinary Committee (CDC) who has the authority to expel me for such an offence.

I know that plagiarism is harmful for the academic environment and that it has a negative impact on any profession.

Accordingly all quotations and contributions from any source whatsoever (including the internet) have been cited fully (acknowledged); further, all verbatim copies have been expressly indicated as such (e.g. through quotation marks) and the sources are cited fully.

I declare that, except where a source has been cited, the work contained in this assignment is my own work and that I have not previously (in its entirety or in part) submitted it for grading in this module/assignment or another module/assignment.

I declare that have not allowed, and will not allow, anyone to use my work (in paper, graphics, electronic, verbal or any other format) with the intention of passing it off as his/her own work.

I know that a mark of zero may be awarded to assignments with plagiarism and also that no opportunity be given to submit an improved assignment.

- Branden van der Colff (21959862) ....
- Corné van Dyk (21752710) ....
- Merrick Hughes (21712662) ....
- Michael De Lange (21584575) ....

Date: 18/05/2020

Abstract

The following design report serves to summarise the detailed design process of an industrial package scanner. Included in this report is a comprehensive breakdown of the design's engineering requirements (generated from client/customer requirements), a summary of the chosen design concept as well as the basic evolution process which lead to its final design. Additionally, the report concludes with a systematic comparison of the design's engineering requirements against the results of the design analysis, illustrating the extent to which the design meets these engineering requirements.

Table of Contents

List of figures

List of tables

List of symbols

1 Introduction

1.1 Background

As the rate of worldwide goods transportation and globalisation rapidly rises, so does the necessity for logistics companies and governments to be able to identify the contents of packages in transit without the necessity to open them. This task can be met through the use of industrial package scanners, capable of revealing the contents of a particular package without ever having to open the package or compromise its protective housing. However, with even the smallest commercial airport-grade luggage scanners in the price range of R 500 000 (www.idssecure.co.za), clients are left financially restricted in terms of obtaining a scanner large enough to scan packages of significant sizes. Additionally, commercially available scanners are generally loud, extremely visible and immobile - making them inconvenient for clients operating internationally with frequently changing locations.

1.2 Objectives

With the above limitations of commercially available scanners in mind, the design process highlighted in this report serves to illustrate how an industrial scanner can be created which is cost-effective, transportable, accommodating of large packages and is discrete in its appearance and operation. This scanner must be able to be assembled and disassembled by a small team of individuals without any specialised equipment and must be considered as a portable device.

1.3 Motivation

Through the design and production of an industrial scanner possessing the properties listed above, the economics of global package transportation and logistics can be revolutionised. Clients will be able to determine with certainty the contents of almost all transportable packages. The result of this is that more packages will be delivered to their intended destinations (even if errors in their transport administration occur), illicit goods will be easily identified and cut off from their destination, packages can be more carefully organised in transportation vehicles based on the nature of their contents and finally, the safety of the package handlers is enhanced as dangerous and potentially life-threatening contents can be identified and destroyed. In addition, the extreme portability and discrete nature of the proposed scanner design allows clients to dispatch the scanner to almost any location around the globe in order to identify the contents of a package.

2 Literature review

Through comprehensive research of existing scanner designs, many products from various companies had features identified which served as inspiration to the design of the concept highlighted in this report. However, the most notable of these products was the HISSCO PX 15.17-MV200 – a large-package, mobile cargo scanner (www.hisscoint.com).

2.1 HISSCO PX 15.17-MV200

HISSCO is an international security detection company specialising in a host of scanners and other security equipment, with a 25-year old reputation of quality machinery. A description of one of their most sophisticated products, the PX 15.17-MV200 is provided below, along with an image of the machine in Figure 1.

"Designed as the ideal freight screening solution for air cargo, L-3's PXTM15.17-MV200 can be used in environments such as seaports, warehouses, manufacturing centres and military bases. The system eliminates the need to unpack contents for inspection and accelerates the screening of consolidated cargo in skids and pallets while maintaining the highest levels of security. With high-energy scanning, convenient operator controls and real-time image manipulation, operators have the comprehensive information and tools needed to quickly identify explosives, weapons, drugs and misrepresented goods. Operator proficiency is complimented by the Threat Image Projection (TIP) feature.

Superior penetration and image quality are ensured by L-3's 200 kV X-Ray source. The system is highly adaptable, allowing customers to choose either dual or single-view configuration. The PXTM15.17-MV200 includes, heavy-duty conveyors with narrow pitch rollers expressly designed to facilitate easy loading and unloading of pallets via a forklift."

Perhaps one of the most relevant features of the PX 15.17-MV200 which inspired the design of the concept in this report are the narrow pitch rollers along the base of the machine. Considering the size and weight of the largest package required to be scanned, these rollers allow for the effortless sliding of large components through the scanning section of the machine. Other notable design features of the PX 15.17-MV200 are its large and accommodating scan tunnel, heavy-duty conveyors, underside wheels and its overall rugged design. All of these features along with some additional elements from other existing products served as inspiration to the design concept generated in this report.

Figure 1 – HISSCO PX 15.17-MV200

3 Specifications

The contents of this chapter serve to illustrate the nature of the initial design problem posed to the team by the client and show how the boundaries and scope of the design were formulated and quantitively defined.

3.1 Initial Needs Statement

A brief summary of the initial task as posed by the client is provided below:

"A company requires a mobile industrial scanner that is able to scan products as large as $500\ mm \times 500mm \times 2000mm$*. This scanner uses proprietary technology and functions with a transmitter and receiver unit, with masses of* $60\ kg$ *and* $100\ kg$ *respectively. These units must maintain horizontal alignment with each other as well as a constant velocity throughout the scan but should not exceed a speed of* $0.5\ m/s$*. The maximum allowable scan time for one package is 9 seconds. The scanner must be able to be assembled and disassembled by a small team and without specialised equipment."*

3.2 Revised Needs Statement (Engineering Requirements)

Through a customer needs assessment, consisting of a detailed client interview as well as relevant research regarding the contents of their initial needs statement, a revised needs statement consisting of the engineering requirements for the design was formulated and is provided in Table 1 below:

Table 1 – Design Concept Engineering Requirements

Engineering Characteristic	**Description**	**Source**
Scan package size	The **minimum** space allocated to the package being scanned is **500 x 500 x 2000 mm**. Base area: 500 x 500 mm Height: 2000 mm	Customer interview
Scanning time	The transmitter and receiver must be linearly translated over 2000 mm within a **maximum** time of **9 seconds.**	Customer interview
Transmitter/Receiver scanning speed	The transmitter and receiver are to be moved at a **maximum** speed of **0.5 m/s** during scanning. Additionally, they are to move at a constant speed when scanning the package.	Customer interview
Transmitter/Receiver alignment	The **maximum** permissible **misalignment** between the centerline of the transmitter and the centerline of the receiver is **1°.**	Customer interview
Overall mass	The **maximum** overall mass of the industrial scanning system is **500 kg**.	Ford Ranger, Nissan Navara, Toyota Hilux and Chevrolet Corsa Utility maximum payload. **(See References)**

Mass per component	The **maximum** mass of any single component the client and an assistant are expected to lift off the transportation vehicle is **100 kg**. (2 people each carrying 50kg of the load)	Deadlift Weight Standards **(See References)**
Motor lifting capacity	A transmitter (60kg) and a receiver (100kg) with a combined mass of **160 kg** is to be lifted at the scan speed specified above.	Customer interview
Distance from transmitter/receiver to nearest face of package	The **maximum** distance from the transmitter or receiver to the nearest face of the package being scanned is **30 cm**.	Customer interview
Product lifespan	The product must be fully functional for 2 years, whilst being used for 5 hours per day. The total operating lifetime is **3650 hours**.	Customer interview
Package support capacity	The **maximum** package mass that must be supported is equivalent to the mass of a 500 x 500 x 2000 mm volume of water at room temperature. This is equivalent to **500 kg**.	Customer interview
Operating noise level	The **maximum** noise that the industrial scanner is allowed to produce during operation is **80 dB**.	Occupational Health and Safety Act of 1993, shopping mall noise level, table of sound comparison. **(See References)**

4 Concept Generation and Evolution

4.1 Initial Concept Generation

Once the basic list of engineering requirements had been completed, the design team created multiple initial concept designs based on these requirements, including sketches and basic concept descriptions. These concepts were compared and salient design elements from each were extracted in order for the first iteration of the design to be created.

4.2 Concept Evolution and Final Concept Technical Definition

Through the implementation of various design evolutions and changes (mentioned below), the final version of the design concept was created. Its assembled isometric view is shown in Figure 2 with key components numbered. A summary of the chosen concept is provided below:

Base and ramp:

A ramp with rollers (component 8) has been included to ensure that even the heaviest scan items can be slid onto the base with ease, eliminating the need for specialised lifting machinery. Additionally, the longevity of the design is enhanced by ensuring that even the heaviest package can be placed gently into the machine. The base itself also consists of similar rollers (component 4) and can support a package base area equal to that of the largest possible package (500 mm x 500 mm). This base also raises the package, allowing the transmitter and receiver to scan the entire package from top to bottom at constant velocity.

External structure:

The main design structure consists of a top connector (component 1) supported by four vertical guide rods (component 3). The top connector in turn supports the driveshaft along with its bearings. The guide rods are supported by the base which is placed at ground level.

Drive system:

An electric motor is placed near the outside of the structure (position of component 6) and is connected to the driveshaft sprocket by means of a drive chain. A step-down drive system is utilized in order to increase the supplied torque and reduce the rotational speed of the main drive shaft (component 5). The transmitter and receiver are each placed on their own slide which slide up and down the guide rods on linear bearings. These slides are individually connected to the driveshaft by means of a flat drive belt. As stated in the Design Analysis below, the drive system can complete a full scan within 6 seconds as opposed to the client's maximum required scan duration of 9 seconds. This affords the client the option of completing more scans per day or reducing the operational time of the machine per day.

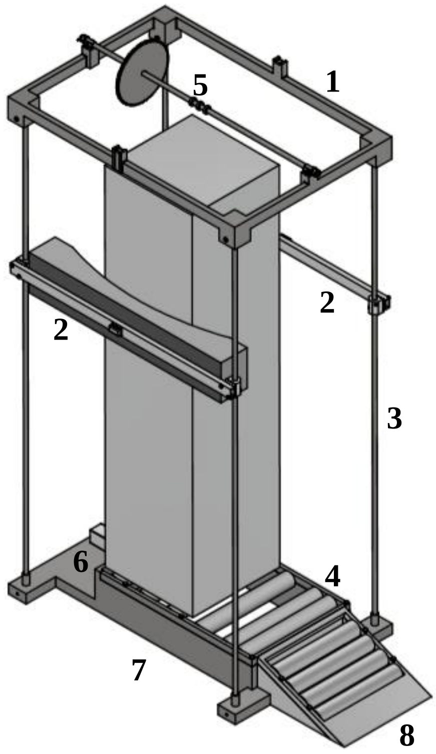

Figure 2 – Final Design Concept

Throughout the design process, many changes of varying significance were made to the design before arriving at this final product, all of which significantly enhanced its operational abilities. The major evolutions throughout the design process are summarised below:

- The location of the motor was changed.
- The size of the driveshaft sprocket was greatly increased (shown on component 5 in Figure 2).
- The diameter and wall thickness of the guide rods was reduced (shown as component 3 in Figure 2).
- The design of the top connector (component 1 in Figure 2) was simplified.

- The initial cable connecting the driveshaft to the transmitter/receiver slides was replaced with a flat belt.

4.3 Concept Assembly Instructions

The structure was designed in such a way that it can be assembled from the ground up as well as disassembled from the top down. The assembly process is as follows: **1)** The base sub-assembly (base, base rollers and motor) and the ramp sub-assembly (ramp and ramp rollers) are joined and are placed on levelled ground. **2)** The transmitter/receiver slide assemblies are set in place on top of the base with the linear bearing holes in line with the holes in the base for the guide rods. **3)** The four guide rods are slid into their respective holes in the base and secured in place by means of treaded pins. **4)** The top connector assembly (including the driveshaft) is placed on top of the guide rods, securing each guide rod with a pin and split pin. **5)** The motor's drive chain is connected to the motor and the driveshaft sprocket, after which it is tensioned and lubricated as necessary. **6)** The flat belts are attached to the driveshaft and their respective slides by running them over the belt guide on the top connector. **7)** Once an inspection of the structure has been completed, the motor can be connected to its power source and operated.

4.4 Concept Cost Estimate

A rough cost estimate of the design was carried out by considering only the cost of the materials, the motor and the bought-out bearings.

- Material cost: Based on the design being made from an almost equal split between aluminium and structural/mild steels, the cost estimate for the materials was determined to be approximately R 10 000. This estimate was calculated using the South African scrap metal prices per kilogram for aluminium and steel (www.priceofscrapmetals.com/south-africa).

- Motor cost: Research of similar motors to the one used in the design yields prices in the range of R 16 000 (www.em.co.za).

- Bought-out bearings: Three types of bearings are used in the design, with the total cost of all bearings coming to approximately R 18 700. This figure consists of the prices for the four linear bearings (R 2 075 each), the two driveshaft bearings (R 1 750 each) and the 20 base and ramp roller bearings (R 345 each). These price estimates were obtained from the online store: shop.eriks.be.

Based on these figures, the total estimated design cost comes to **R 44 700**.

5 Design Analysis

5.1 Results of Design Analysis

5.1.1 Structural Strength

The main structural elements of the design which are subject to significant stress conditions during the operation of the machine are the top connector, transmitter/receiver slides and the guide rods. The positions of these components in the overall design can be seen in Figure 2 where they are labelled as components 1, 2, and 3 respectively.

1) Top connector:

As stated in Appendix G (p. G14), it is clear that structural failure of the top connector at a point of constant cross-section is highly unlikely, with a liberal safety factor of 9.8 achieved using the conservative Tresca static failure criterion. However, the welding joints on the top connector were identified as possible stress raisers and points of fatigue failure in the component and were subsequently analysed. The weld failure analysis carried out (p. G14-15) using standards from *AISC Code for Weld Metal* and content from *Shigley's Mechanical Engineering Design (p. 479-482)*, indicated a minimum safety factor of 26.9 against weld failure (both static and fatigue failure), considering all weld types on the component.

2) Transmitter/receiver slides:

Appendix F (p. F10) explains that the bending and twisting of the transmitter and receiver slides is well below the magnitude that will cause the component to yield. Hence, the weld joints on the components were identified as the only threat to the component's structural strength and were therefore analysed using the same process as for the top connector mentioned above (p. F11), resulting in a liberal safety factor of 4.94.

3) Guide rods:

As seen in Appendix H (p. H4), the guide rods are classified as long columns due to their slenderness ratio. This means that their failure mechanism under large axial loads would be in the form of column buckling. Through use of the Euler column formula, the critical load of the guide rods was calculated to be 1160.15 N, leading to a safety factor against buckling of 1.32 (p. H5). This safety factor is considered to be fairly liberal as the load condition of the guide rods is accurately know. Additionally, it indicates that the guide rods are not overdesigned – saving material cost and weight.

5.1.2 Scan Misalignment

The component deflections having the largest effect on the design's functionality would be those of the transmitter/receiver slides and the top connector (shown as component 1 and 2 in Figure 2). This is because deflection in these components has a direct effect on the relative alignment of the scanner and receiver during a scan. Hence, a comprehensive deflection analysis of these components was carried out in an attempt to determine the largest resulting misalignment angle between the scanner and transmitter (Appendix F (p. F7-10) and Appendix G (p. G8-13)). From this analysis, it is evident that the worst-case scan misalignment from deflection of the transmitter/receiver slides is 0.7051° (p. F10), and the worst-case misalignment due to deflection of the top-connector is 0.00022° (p. G13). Using the principle of superposition, it is evident that the maximum possible angle of misalignment between the scanner and receiver during a scan is 0.7053°.

5.1.3 Scan Speed, Duration and Distance

Through consultation of Figure B2 in the Drive Selection (Appendix B), the chosen velocity profile for the movement of the transmitter and scanner can be seen. From this velocity profile, it is evident that the duration of a complete scan motion is only 6 seconds. In this time, the transmitter and receiver cover a total distance of $2.2\ m$, with $2\ m$ being covered at constant velocity (p. B3). Additionally, the maximum linear speed achieved by the transmitter and receiver during a scan is $0.4\ m/s$.

5.1.4 Motor Capacity & Operational Noise Level

Pages B6-7 in the Drive Selection (Appendix B) contain a full assessment of the motor selected to drive the movement of the transmitter and receiver – the FESTO EMME-AS-100-M-HS Servo Motor. From this assessment as well as consultation of Figure B7 (the motor's speed/torque characteristic curve illustrating its operating point), it is evident that the motor is operating well within its limits without being overpowered. The maximum speed (2853 rpm) and torque (4.00 Nm) required from the motor are both an appropriately sized portion of their respective maximum values (3941 rpm and 7.50 Nm). Additionally, the inertia matching of the motor produced an inertia ratio of 9.45 (p. B7), just below the maximum recommended value (10). Seeing as the motor's peak torque requirement exists for a relatively small portion of the entire scan duration, this inertia ratio will undoubtably be much lower for the majority of the motor's lifespan.

Additionally, due to the FESTO EMME-AS-100-M-HS being a servo motor, it is exceptionally quiet in its operation as compared to other motor types such as stepper motors. According to www.techbriefs.com, "Properly tuned servo motors are ninja-quiet. The biggest source of noise in servo-driven applications is often either the drive train or bearing. Stepper motors will typically emit around 68 dB during operation." As the design's motor will be its primary source of noise generation, it can be concluded that the maximum noise levels generated will be significantly less than 68 dB.

5.1.5 Package Support Capacity

With the maximum mass of a single scan package being up to $500\ kg$, the rollers in the base and base ramp of the design (shown as component 4 in Figure 2) are subject to considerable stresses when supporting this load. For the sake of overdesign and safety, each roller and its bearings were designed to withstand the weight of the heaviest possible scan package individually. As seen in Appendix I (p. I5), the maximum bending stress in the rollers of 134.04 MPa was determined using Macaulay functions, from which a liberal safety factor of 3.66 is still achieved despite the conservative assumptions made throughout the analysis. Additionally, the Bearing Selection (Appendix D) illustrates that the magnitudes of the radial loads applied to the bearings of the rollers (TIMKEN 30mm bore 6006 deep groove ball bearing) are insignificant in comparison to their rated values (p. D8).

As shown by the free body diagrams of the top connector and guide rods in Appendix G (Figure G1) and Appendix H (Figure H1) respectively, the dimensions of the machine easily allow for a package of $500\ mm \times 500\ mm \times 2000\ mm$ to be accommodated. The guide rods are $2412.25\ mm$ long which connect into the top connector approximately $720\ mm$ apart from each other, leaving ample room for the biggest possible package. Additionally, scan package surfaces will never be more than $110\ mm$ away from the transmitter and receiver.

5.1.6 Design Lifespan Analysis

Two major components were identified as potential areas of fatigue failure: the driveshaft and the top connector's dry film lubricant. The Shaft Design (Appendix C) illustrates the comprehensive process for design against fatigue failure of the driveshaft (shown as component 5 in Figure 2). Page C7 illustrates the calculation of a fatigue failure safety factor of 4.345 according to the modified Goodman equation, indicating that the shaft will indeed have infinite life. Additionally, the operational speed of the shaft was shown to be significantly lower than its critical speed (p. C8), increasing the likelihood of infinite life. In order to achieve the intended lifespan (3650 hours), the dry film lubricant on the top connector will ideally have to be recoated every 9 days for maximum effectiveness (p. G2).

5.1.7 Design Mass

Through the use of CAD software (Autodesk Inventor Pro 2020™), the total assembly mass as well as the mass of the heaviest single component was obtained:

Assembly Mass: 328.219 kg

Heaviest Component Mass (Base): 57.656 kg

5.2 Systematic Comparison of Engineering Requirements and Design Analysis Results

Table 2 – Comparison of Engineering Requirements and Design Analysis Results

Engineering Characteristic	**Required Value**	**Obtained Value**	**Relevant Appendix**
Scan package size ✓	500x500x2000mm	≈500x720x2412.5mm	G, H
Scanning time ✓	<9 s	6 s	B
Transmitter/Receiver scanning speed ✓	<0.5 m/s	0.4 m/s	B
Transmitter/Receiver misalignment ✓	<1°	0.7053°	F, G
Overall mass ✓	<500 kg	328.219 kg	N/A
Mass per component ✓	<100 kg	57.656 kg	N/A
Motor lifting capacity ✓	>160 kg	220 kg	B
Distance from transmitter/receiver to nearest face of package ✓	<30 cm	11 cm	G
Product lifespan ✓	3650 hours	Infinite life	C, G
Package support capacity ✓	500 kg	500 kg per individual roller with a SF of 3.66	I
Operating noise level ✓	<80 dB	<< 68 dB	B

6 Conclusions

It is evident through consultation of Table 2 that all engineering requirements as posed by the client have been met to a satisfactory extent. In addition to this, it has been shown that the design contains features to address issues which the client may not have considered, such as a significantly reduced scan duration as well as a ramp with rollers to facilitate easy placement of large packages into the machine. The design analysis revealed liberal safety factors for all components which experience significant stress conditions during operation, ensuring that failure of the design is highly unlikely. Component deflection was shown to have negligible effect on design functionality. Additionally, design against fatigue failure was illustrated in components with cyclical loading, where it was predicted that the design will have infinite life, surpassing the client’s required lifespan. Lastly, the design is made primarily from locally sourced products, with a few specialised exceptions, ensuring cost effective production and maintenance.

7 References

Em.co.za. 2020. Servo Drives & Motors. [online] Available at: <http://www.em.co.za/Servo-Drives-and-Motors/> [Accessed 17 May 2020].

Group, T., 2020. *Advantages Of Servo Motor And Direct Drive Technology*. [online] Techbriefs.com. Available at: <https://www.techbriefs.com/component/content/article/tb/supplements/mcat/features/articles/25416> [Accessed 17 May 2020].

Imperial Toyota. (2020). *TOYOTA HILUX SC 2.4 GD-6 D/CAB RB SRX*. [online] Available at: https://www.imperialtoyota.co.za/vehicle/toyota-hilux-sc-24-gd-6-dcab-rb-srx-toyhx3224 [Accessed 16 Feb. 2020].

Marlborough Ford. (2020). *2019 Ford Ranger Engine Specs and Towing/Payload Capacity*. [online] Available at: https://www.marlboroughford.com/blog/2019-ford-ranger-engine-specs-and-towing-payload-capacity/ [Accessed 16 Feb. 2020].

media.gm.com. (2020). *CHEVROLET CORSA UTILITY – BUYERS CHOICE IN SUB 1-TON PICK-UP MARKET*. [online] Available at: https://media.gm.com/media/za/en/gm/news.detail.html/content/Pages/news/za/en/2010/Chevrolet/08_11_chevrolet_corsa_utility.html [Accessed 16 Feb. 2020].

Nissan Vehicles at Group 1 Motors. (2020). *Nissan Navara Price & Specs*. [online] Available at: https://www.group1nissan.co.za/nissan-navara/ [Accessed 16 Feb. 2020].

Sengpiel, E. (2020). *Table chart sound pressure levels SPL level test normal voice sound levels pressure sound intensity ratio decibel comparison chart conversion of sound pressure to sound intensity noise sound units decibel level comparison of common sounds calculation compression rarefaction loudness decibel dB scale ratio factor unit examples - sengpielaudio Sengpiel Berlin*. [online] Sengpielaudio.com. Available at: http://www.sengpielaudio.com/TableOfSoundPressureLevels.htm [Accessed 16 Feb. 2020].

Scrap Metal Prices - South Africa. 2020. *Scrap Metal Prices - South Africa*. [online] Available at: <https://www.priceofscrapmetals.com/south-africa/> [Accessed 17 May 2020].

Shop.eriks.be. 2020. *ERIKS | Bestel Online Technische Producten Voor De Industrie*. [online] Available at: <https://shop.eriks.be/> [Accessed 17 May 2020].

Strengthlevel.com. (2020). *Deadlift Standards for Men and Women (kg) - Strength Level*. [online] Available at: https://strengthlevel.com/strength-standards/deadlift/kg [Accessed 16 Feb. 2020].

System, Z., 2020. *Zkteco ZKX6550A Single Energy X-Ray Inspection System*. [online] IDS Secure. Available at: <https://www.idssecure.co.za/products/zkteco-zkx6550a-single-energy-x-ray-inspection-system?variant=29433210994782&sfdr_ptcid=32707_617_516835199&sfdr_hash=82974c01dc77

7345932137cdb3ede634&gclid=EAIaIQobChMIvoW89f2p6QIVmLPtCh1G1gWAEAYYASABEgL23PD_BwE> [Accessed 17 May 2020].

Web.fe.up.pt. (2020). [online] Available at: https://web.fe.up.pt/~carvalho/nc16.pdf [Accessed 16 Feb. 2020].

15.17-MV200, P., 2020. PX 15.17-MV200 - Hissco. [online] Hissco. Available at: <https://www.hisscoint.com/product/px-15-17-mv200/> [Accessed 17 May 2020].

Group Work Documentation

Team members:

- Branden van der Colff – 21959862
- Corné van Dyk – 21752710
- Merrick Hughes - 21712662
- Michael De Lange – 21584575

Code of Conduct:

By signing this document, all team members agree to uphold the following values throughout the course of the project:

Respect

Team members are to always let each other communicate their views, feelings and ideas without interruption or judgement. No member should be made to feel that their contribution is not valued or be intimidated to share their thoughts in group meetings. All communication forums are to maintain a professional tone and not be used for sharing irrelevant/offensive content. Members are to respect and acknowledge cultural and religious values and no derogatory comments will be tolerated.

Diligence

Members are to adopt an attitude of diligence with regard to their individual aspects of the report and ensure that their work is of the highest possible quality. Work should always be completed before the required deadline and not be reduced to a poorer quality due to a fast approaching deadline.

Work Ethic

Members are encouraged to have a highly driven attitude towards the completion of their tasks. It is acknowledged that the assigned project will require a significant effort from all members in terms of hours put in and intellectual effort and members are expected to always try go over and above what is required of them.

Communication

Group members are encouraged to frequently and effectively communicate between each other and ensure that everybody is always in agreement on all topics. Should a member not be able to make a certain deadline, this must be communicated to other members well in advance and not right before the task is due so that necessary provisions and reassignment of the task can be carried out. If any member feels unhappy in the group environment they are encouraged to voice their feelings and not let silent negativity become detrimental to the functioning of the group.

Accountability

Once a task has been assigned to a member, it is assumed that this will be completed by the required date. Members are completely accountable for their individual tasks once they have signed the meeting minutes which allocated this task to them. There should be no doubt that a task will be completed by a certain member and the group should not have to worry if the necessary assignments will in fact be done.

Group contact information:

Member	Cell number	Email address
Branden van der Colff	074 913 4447	21959862@sun.ac.za
Corné van Dyk	061 477 3524	21752710@sun.ac.za
Merrick Hughes	072 726 3475	21712662@sun.ac.za
Michael De Lange	072 180 7600	21584575@sun.ac.za

Group member agreement:

In addition to the values mentioned in the group code of conduct, the group members agree to abide by the following terms:

- Members are to try their best to be punctual to all meetings and give notice should they be running late.

- Group meetings should be attended by all members who are available and those who are unavailable are to provide an acceptable excuse in advance. It is the responsibility of members who miss meetings to access the meeting minutes and ensure that they catch up missed information.

- Meeting minutes are to be signed by all members present after the meeting to verify the document as an official record of decisions made and work allocated.

- Members agree to be contactable by phone call between the hours of 8am and 10pm. Messages and emails may be sent at any hour but replies are not expected at unreasonable times.

- Microsoft Teams is the agreed upon official communication and shared work platform. Informal arrangements can be made on the Machine Design A314 Group 16 WhatsApp group but these are not considered to be official documented information.

BY SIGNING BELOW, MEMBERS AGREE TO ABIDE BY THE ABOVE TERMS AND CAN BE HELD ACCOUNTABLE SHOULD THEY NOT.

Branden van der Colff .... Corné van Dyk ....

Merrick Hughes .... Michael De Lange ....

Group Roles:

Each group member is to contribute to the project as best they can and in as many ways as possible. The team will always try their best to distribute the workload as evenly they can. However, certain specific roles are assigned to each member so that routine tasks are made more efficient and each member gets more competent in their specific roles. These roles are:

- **Corné:** Responsible for all CAD requirements. Produces work breakdowns and coordinates team meetings. Assigned with detailed component calculations.

- **Branden:** Responsible for all CAD requirements as well as CAD complex analyses. Assigned with detailed component calculations.

- **Michael:** Meeting minute taker. Responsible for all bought-out components and catalogues, as well as all calculations involving motor selection. Compiles final versions of documents.

- **Merrick:** Compiles final versions of documents. Assists with component calculations. Responsible for all calculations involving motor selection.

Work Breakdown:

During the design process, numerous work breakdowns were created by Corné. These breakdowns had the goal of ensuring that group members were completely aware of which tasks were assigned to them and by which deadlines these tasks needed to be completed. These work breakdowns were posted on Microsoft Teams and are provided below:

- <u>24/03/2020</u>

"**Appendices:**
Each of us will have to fully analyse a few components of our design. Please go read through the project brief as well as the rubric to make sure you cover all the bases with your analysis. Additionally, sit with the component and think about all the information we can possibly need. I trust in each member's intuition.
If you find anything that has to be changed in terms of our design or if the stresses in a specific member are too high, double check your calculations, otherwise make changes on the CAD files in such a way that the entire design does not have to be changed and let the group know.

Here are a few things I think we should include in our analysis:
3D Free Body Diagrams (This is compulsory)
Component Weight
Component Inertia
Component Dimensions
Shear Force Diagram
Bending Moment Diagram
Maximum Stress Conditions in Component
Principal Stresses and Maximum Shear Stress
Von Misses, Tresca, Euler, etc.
Double Check Material
Double Check Dimensions
Double Check Selected Components (Bearings, Cable, Motor, etc.)

If you can think of anything that I might have missed that should be included in our analysis, please let me know. Additionally, when doing your FBD, name your forces in pencil. We will start with the final naming from the top downwards. Please analyse the following components:

De Lange, MS, Mnr [21584575@sun.ac.za]:
Motor
Main Drive Shaft
MDS-Bearings
Base
Base Top Plate
Pins
Van der Colff, BH, Mnr [21959862@sun.ac.za]:
Ramp Bottom
Ramp Top
Ramp Rollers
Ramp Bearings
Base Roller

Base Bearing
Hughes, MSM, Mr [21712662@sun.ac.za]:
Guide Rods x 4 (They are not symmetrically loaded, so watch out)
Make sure all the files from previous hand-ins are online
Compile our analysis
When everything is done, please read through all the rubrics and make sure that what we have is perfect, otherwise notify the group and we can polish it up.
I will be doing the following:
Top-Connector
Transmitter
Transmitter-Slide
Receiver
Receiver-Slide

Lastly, if you're unhappy about anything, let me know and I'll make changes to the work breakdown.

Stay healthy"

- <u>04/04/2020</u>

"First of all, this is still to an extent holiday, so don't stress yourselves out and take some time to enjoy home. The idea is to finish all our work before 15 April, so that when lock-down is finished, we can all be out and about again, if we choose to do so. Therefore, I think it will be best to analyse and adjust one set of components per day. This will ensure that we can easily pass on the forces induced on the next component, as well as gives us the chance to take some time off when our assigned components are not up next. Additionally, we have to double check all the selected components such as the bearings, the drive system and the belt to make sure that everything works with the final design and is scale-able in the case of any additional alterations. Here is the breakdown:

Analysis:
Consider Manufacturability
Consider the component's functionality and identify the key aspects that might alter it's functionality during operation (deflection, fatigue, etc.)
Choose a reasonable, conservative safety factor or choose a conservative amount of deflection (Remember that deflection can accumulate if everyone is too lenient, so keep it conservative)
Choose a Material
Calculate the Required Dimensions of Critical Components (This will depend on your safety factor or maximum deflection)
Find a local supplier with similar standard sizes
Change the Part File
3D Free Body Diagram (Send me your FBD and I will create a 3D version on CAD. Please ensure that it takes all 3 dimensions into account)
Calculate Mass and Inertia

Shear Force Diagram
Bending Moment Diagram
Calculate Safety Factor
Calculate Deflection of Critical Points
It would be possible to find the critically stressed point through Inventor's stress analysis, but you should however still analyse the component by hand and find a way to prove that the specific point experiences the maximum stress. Otherwise, look for stress raisers or use the shear force and bending moment diagrams to find maximum stress points.
Throughout, make reasonable simplifying assumption where needed
Additionally, type out all considerations made and try to address as many aspects of the engineering requirement in your discussion as possible

Component Selection:
Ensure that all selected components are locally sourced or that the company has a large local presence
When selecting components such as bearings, please specify how they should be connected to the assembly
Try to use the same bearings as far as possible. For example, we should be able to use the same bearings for the all rollers throughout

De Lange, MS, Mnr [21584575@sun.ac.za]:
7 April: Double Check Drive Selection
8 April: Main Drive Shaft (Analysis)
9 April: MDS-Bearings, the two at the top and the one at the base (Analysis and Selection)
12 April: Select appropriate sliding bearings
13 April: Base and Base Top Plate (Analysis)
Help out Merrick where you can with SMath
Hughes, MSM, Mr [21712662@sun.ac.za]:
11 April: Guide Rods x4 (Analysis)
14&15 April: Finish the Appendices and update any previous documents that should be altered
Van der Colff, BH, Mnr [21959862@sun.ac.za]:
7 April: Shaft Design
Before 13 April:
Ramp Bottom (Analysis)
Ramp Top (Analysis)
Ramp Rollers (Analysis)
Ramp Bearings (Selection and Analysis)
Base Roller (Analysis)
Base Bearing (Selection and Analysis)
What I will be doing
5 April: Receiver and Receiver-Slide (Analysis)
6 April: Transmitter and Transmitter-Slide (Analysis)
10 April: Top-Connector (Analysis)

13 April: Adjust top-connector and slides for altered bearings and guide rods
I will make any design alterations that is needed on CAD
Additionally, I will create neat free body diagrams for all components

Let me know if you are unhappy about anything and I'll make changes as needed."

- 26/04/2020

"Make sure that all the work you've done so far is complete and is easy to follow, especially in terms of the forces "being carried over" to the next component. Also make sure that all the formulas that you use are referenced.
Hughes, MSM, Mr [21712662@sun.ac.za]: Please start compiling all the work that you know is final at this point.
Tuesday 28 April:
I will complete my analysis of the T*op Connector*.
Hughes, MSM, Mr [21712662@sun.ac.za]: Continue compiling.
De Lange, MS, Mnr [21584575@sun.ac.za]: Work on the analysis of the *Base* and *Base Top Plate*.
Van der Colff, BH, Mnr [21959862@sun.ac.za]: Work on the analysis of the *Ramp Bottom*, *Ramp Top*, *Ramp Rollers, Base Rollers, Ramp Bearings* and *Base Bearings.*
Wednesday 29 April:
Hughes, MSM, Mr [21712662@sun.ac.za]: *Complete the analysis of the guide rods.*
De Lange, MS, Mnr [21584575@sun.ac.za]: Continue the analysis of the *Base* and *Base Top Plate.*
Van der Colff, BH, Mnr [21959862@sun.ac.za]: Continue the analysis of the *Ramp Bottom*, *Ramp Top*, *Ramp Rollers, Base Rollers, Ramp Bearings* and *Base Bearings.*
Thursday 30 April:
De Lange, MS, Mnr [21584575@sun.ac.za]: Complete the selection of the *Sliding Bearings* and their mounts. Additionally, continue the analysis of the *Base* and *Base Top Plate.*
As soon as I have the final dimensions of the *Sliding Bearings*, I will update the CAD files of the *Transmitter and Receiver Slides* and upload their free body diagrams.
Additionally, all CAD alterations that you, De Lange, MS, Mnr [21584575@sun.ac.za], need, please let me know. I will also start altering the CAD of the *Top Connector*, depending on the size of the *Guide Rods*, and upload the free body diagram for this.
Van der Colff, BH, Mnr [21959862@sun.ac.za]: Continue the analysis of the *Ramp Bottom*, *Ramp Top*, *Ramp Rollers, Base Rollers, Ramp Bearings* and *Base Bearings.*
Hughes, MSM, Mr [21712662@sun.ac.za]: Continue Compiling.
Friday 1 May - Sunday 3 May:
Hughes, MSM, Mr [21712662@sun.ac.za] and De Lange, MS, Mnr [21584575@sun.ac.za]: This is your time to shine. Complete the compiling of the appendices.
Me and Van der Colff, BH, Mnr [21959862@sun.ac.za]: We will assists you during this time with all the CAD alterations that you need. Additionally, we will read through all the work you compile and help out in that regard.

If you have any questions, please let me know."

- 03/05/2020

"Hi all
Here follows the complete work breakdown for the next two weeks:
3 May - 10 May:
Van der Colff, BH, Mnr [21959862@sun.ac.za] and I will complete the drawing pack with all the relevant accompanying documentation. Hughes, MSM, Mr [21712662@sun.ac.za] and De Lange, MS, Mnr [21584575@sun.ac.za], please be ready to help out where you can. Additionally, double check our work before the hand-in on Monday 11 May.
10 May - 17 May:
Hughes, MSM, Mr [21712662@sun.ac.za] and De Lange, MS, Mnr [21584575@sun.ac.za], please compile the final design report from the documentation that we have already created. Van der Colff, BH, Mnr [21959862@sun.ac.za] and myself will be at hand for anything you need help with. Additionally, everybody should read through the report before the hand-in on Monday 18 May, as minor errors can always arise when compiling a large document such as this one.

Stay safe."

Specifications Report Gantt Chart:

In the days preceding the Specifications Report hand-in, Conré produced a Gantt Chart in order for the group to track their work progress:

Task Num.	Task	People Assigned	% Complete	14 February 2020				15 February 2020						16 February 2020				
				10:00	14:00	18:00	22:00	02:00	06:00	10:00	14:00	18:00	22:00	02:00	06:00	10:00	14:00	18:00
1.1	Engineering Requirements – Group Input	Merrick, Michael, Branden, Corné		■	■	■	■	■	■	■								
1.2	Engineering Requirements – Final Compilation	Corné									■							
2	Organization of Group Documentation	Merrick									■							
3	Writing of Report Introduction	Michael									■							
4	Functional Decomposition	Branden										■	■					
5	Concept Generation	Merrick, Michael, Corné										■	■	■	■			
6.1	Final Concept Design - Description															■	■	■
6.2	Final Concept Design - CAD Drawings															■	■	■
7	Report Finalization	Merrick														■	■	■

Meeting Minutes:

Meeting 1:

Date: 13 February 2020

Duration: 6.30pm to 7.00pm

Meeting number: 1

People attended: Group 9 and 16

Meeting minutes:

- Michael De Lange (21584575) was moved from group 9 to group 16.
- A basic plan was set out for the following weekend.
- Friday was to be the second meeting. This was where the work was going to be split up between the 4 members.
- Members are to complete their assigned work on Saturday and then the group is to meet on Sunday to compile the Specifications Report.
- A WhatsApp group was created.
- A Microsoft Teams team was to be set up on Friday.

Meeting Problems: None

Excuses: None

Other points: None

Meeting 2:

Date: 14 February 2020

Duration: 8.30am to 9.15am

Meeting number: 2

People attended: All members

Meeting minutes:

- Previous meeting minutes were reiterated.

- Each member was assigned their specific task for the weekend:

  - Corné: Concept design and description as well as compile the engineering requirements. Set up Microsoft teams.

  - Branden: Functional decomposition and engineering requirements.

  - Michael: Concept design and description as well as keep track of all group meeting minutes.

  - Merrick: Compile the final report and create all group work documentation.

- By Saturday at 10am all engineering requirements need to be completed.

- The Sunday meeting was planned for 9pm to 5pm (may end early).

- Concept design is to contain a rough sketch and description.

- Chosen concept is to have a CAD drawing for the specifications report.

<u>Meeting Problems:</u> None

<u>Excuses:</u> None

<u>Other points:</u> None

Meeting 3:

<u>Date:</u> 18 February 2020

<u>Duration:</u> 11.55am to 12.15pm

<u>Meeting number:</u> 3

<u>People attended:</u> 3 (Michael, Corné, Merrick)

<u>Meeting minutes:</u>

- Re-visited the specifications report. Talked about how to refine the reports in the future and how improve writing style and consistency. One of the aspects was to not any values in the introduction or the conclusion. The introduction should be written in such a way that if someone random were to read it, it should give them enough information to know exactly what the aim of the report is.

- The tasks for the following week were set out. These were:

1. Actuator selection

2. Free body diagrams

3. Design report

- It was decided to do the Actuator selection on Sunday 23rd of February. Each member is to do their own part of the calculations, then on Sunday the team is to come together and check the accuracy of all calculations.

Meeting Problems: None

Excuses: Branden van der Colff had a doctor's appointment and could not attend the meeting.

Other points: None

Next meeting: Sunday. Time to be confirmed.

Meeting 4:

Date: 19 February 2020

Duration: 8.30am to 9.30am

Meeting number: 4

People attended: All members attended

Meeting minutes:

- Reminder to the group members that were doing the CAD to update their Inventor as there were problems with compatibility between the different years.

- Sunday is the next scheduled meeting. Tasks assigned to be completed by 9am on Sunday:

1. Do the example shown in class to get a good idea of what is meant to be done for the motor selection.

2. Outline a predicted procedure for determining the motor selection as well as all critical component FBDs.

- It was decided that the meeting will start at 9.00am on Sunday at the Chalkboard and go on no longer than 5.00pm.

- Michael and Merrick are to oversee the SMath writing and so Michael needs to download SMath on his computer.

- Group members should start thinking about which materials are going to be used.

Meeting Problems: None

Excuses: None

Other points: Michael will miss most of the Sunday meeting due to his ‘innaweek’ at residence, however he will attend when available.

Next meeting: 9.00am on Sunday at the Chalkboard.

Meeting 5:

Date: 23 February 2020

Duration: 9.00am to 4.00pm

Meeting number: 5

People attended: 3 (Branden, Corné, Merrick)

Meeting minutes:

- Merrick: Completed most of the motor selection, drew the velocity profile and did all the calculations needed for the selection procedure. Decided a triangular velocity profile is a superior choice and could bring the time of scanning down to around 8 seconds instead of the required maximum of 9 seconds. Wrote up all the calculations he did in Smath.

- Branden/Corné: Allocated material properties in Inventor and then calculated the moments of inertia of each of the components. Drew force diagrams for the 14 necessary components. Printed out all the 14 diagrams on A4. Edited the previous design of the structure in Inventor.

Meeting Problems: None

Excuses: Michael De Lange could not attend. ('Innaweek' at his residence with many residence activities on the Sunday).

Other points: None

Next meeting: Monday in Chalkboard at 9.00am.

Meeting 6:

Date: 24 February 2020

Duration: 9.00am to 10.00am

Meeting number: 6

People attended: All members attended.

Meeting minutes:

- Corné/Branden: Made sure all force labels were the same on different components. Reduced the mass of the one slider as it had been erroneously assigned a mass which was too large.

- Merrick/Michael: Worked further on the calculations with everything written in terms of symbols. Also decided that since most of the motors in the catalogues given on SUNLearn run at a minimum speed of approximately 2000 rpm, a stepper motor would be a more appropriate choice for the speed requirements of the design.

Meeting Problems: None

Excuses: None

Other points: None

Next meeting: Tuesday 25 February 2020 from about 11.00am to 12.00pm.

Meeting 7:

Date: 26 February 2020

Duration: 4.00pm to 5.00pm

Meeting number: 7

People attended: All members attended

Meeting minutes:

- Drawings and force diagrams of each component was completed. Each member was given a certain critical component to draw.
- After completing the shear force diagrams as well as the bending moment diagrams for each of the parts, work was given to Merrick to compile and hand in.

Meeting Problems: None

Excuses: None

Other points: None

Meeting 8:

Date: 28 February 2020

Duration: 8.40am to 9.15am

Meeting number: 8

People attended: All members attended

Meeting minutes:

- From the lecture, the team realised that the transmitter and receiver are to move at a constant speed of 0.5 m\s when scanning the package. This meant that a trapezium velocity profile was needed because the triangular one only allows the speed of 0.5m\s to be achieved briefly.
- Springs may need to be added to the top and bottom of the rods to allow for less jerk motion of the load when the motor is started and to aid in its deceleration when it reaches the top of the rods.
- A brake may be needed to help stop the movement of the sliders.
- Discussed the possibility of adding each member's initial concept drawings to the design process to show how the different design elements from each of the 4 concepts was used in the final design.

- Group was to decide if the use of a flat nylon belt would be better than a cable as it has the ability to wind up on itself when it is pulled by the driveshaft.

- Bearing selection still needed to be done for the rollers and the drive shaft.

- Ramp may need to be changed to fit with base.

- In summary the major changes needing to be implemented are as follows:

1. Check the velocity profile and use the new extended height of the rods in the calculations.

2. Investigate the flat belt and its viability.

3. Decide on pully diameters and how the belt is going to wind around the pully or shaft.

4. Calculate the new torques.

5. Calculate the bearings needed for the drive shaft and the rollers.

6. Do the shear force and bending moment diagrams again.

7. Check the height of the top connecter.

8. Maybe add a reference or bibliography.

Meeting Problems: None

Excuses: None

Next meeting: Sunday 1 May from 9.00am until required work is completed.

Meeting 9:

Date: 1 March 2020

Duration: 9.00am to 4.30pm

Meeting number: 9

People attended: All members attended

Meeting minutes:

From last week the following points were addressed:

1. Check the velocity profile and use the new extended height of the rods in the calculations:

Merrick and Michael re-did the velocity profile in order to get a constant speed from when the item starts being scanned to when the item is finished being scanned.

2. Check the flat belt and its viability:

Flat belt viability was checked and it was seen that it would indeed be sufficient to use, making the process simpler as a pulley was no longer needed and the belt could simply wrap around the driveshaft.

3. Decide on pully diameters and how the cable is going to wind around the pully or shaft:

Decided that the flat belt wouldn't need pulleys and so these were omitted in the finial CAD drawing.

4. Calculate the new torques:

The new torques of the motor with the new velocity profile were worked out as well as the maximum speed of the motor. Based on this a new motor was selected.

5. Calculate the bearings needed for the drive shaft and rollers:

Bearings for the rods as well as the rollers in the bottom plate were chosen based on the maximum load which they would each need to take.

6. Do the shear force and bending moment diagrams again:

The magnitudes of the forces acting on each of the components still needed to be decided and so the SFD and BMDs could only be done once those forces had been determined.

7. Check the height of the top connecter:

The height of the guide rods was found to be slightly too short and so a longer rod was added so that the sliders could accelerate less abruptly.

8. Maybe add a reference or bibliography:

This was to be done in the final report compiling.

- The CAD drawings as well the stress analysis done by Corné and Branden showed how the final complete structure would deflect with the loads applied.

Meeting Problems: None

Excuses: None

Next meeting: To be confirmed

Meeting 10:

Date: 6 March 2020

Duration: 8.20am to 8.40am

Meeting number: 10

People attended: All members attended

Meeting minutes:

- The following was decided as necessary for the design report appendices hand in:

1. Stress analysis on the individual parts as well as the whole structure.

2. Bearings for the drive shaft need to be selected.

3. Sprocket and chain selection.

4. Failure criterion.

5. Peer review needing to be done by Monday morning.

- The driveshaft specifications, material selections as well as a motivation to why certain materials for a part were chosen are to go into the appendices.

- It was decided to stick with aluminium because it is a lightweight material as well as the fact that it can be locally sourced.

- Screws and threads are to be added and for their specific purposes.

- The workload is to be divided into 4 equal parts over the recess.

- Stress analysis for each part entails: Free body diagrams, SFD and BMD, deflection analysis and maximum stress condition. Members are to use real physical values for the loads and not solve them symbolically.

Meeting Problems: None

Excuses: None

Next meeting: To be confirmed

Meeting 11:

Date: 8 March 2020

Duration: 15 minutes

Meeting number: 11

People attended: All members attended

Meeting minutes:

- Members split up the necessary work for the upcoming weeks.
- It was acknowledged that group members will be very busy during the test week period studying for their tests.
- It was decided that the best strategy would be to leave the rest of the work for the holiday after the exams.

Meeting Problems: None

Excuses: None

Other points: All the best for test week!

Meeting 12:

Date: 4 April 2020 (Microsoft Teams)

Duration: 30 minutes

Meeting number: 12

People attended: All members attended

Meeting minutes:

- Greetings from all different places in the country.

- Discussion about how the group is going to use teams to keep up to date and to make sure the project is continuously worked on. Getting used to the Microsoft Teams meeting system. Created a folder called ‘recess work’ where each member has their own folder to post all work which they have done during the break.

- Group realized that the entire design cannot be made exclusively out of aluminium since it would be over-designed and very expensive.

- Corné decided it was better to redo the calculations and the free body diagrams. This meant:

1. Motor selection will have to be redone since the weight of the drive shaft will change due to new material chosen.

2. The analysis of the individual parts will need to be redone as well since deflection will be different, the safety factors will change, and the maximum stress and shear will also be different.

3. The CAD will have to be changed regarding the part materials.

- It was then decided that the work was to be split up in a similar way as before. Corné formulated a comprehensive work breakdown detailing what each member was to do and by when.

Meeting Problems: None

Excuses: None

Other points: Corné posted the comprehensive work breakdown.

Meeting 13:

Date: 29 April 2020

Duration: 45 minutes

Meeting number: 13

People attended: 3 (Corné, Branden, Merrick)

Meeting minutes:

- Discussed the breakdown of the appendices where it was decided that one appendix with all the variables used shall be included. Group was to also check that all the variables match throughout the various calculations. A brief variable explanation is also to be included.

- The motor selection and the shaft design will each be given their own appendix. Thereafter, an appendix of each component will be provided which includes all calculations relevant to the analysis of that component.

- Free body diagrams need to be made understandable.

- Branden and Corné will update the CAD versions of each part and then complete a detailed free body diagram for each of these.

- Bending moment diagrams and shear force diagrams will be done in MATLAB since this is more accurate and easier to read (using the 'heaviside' function). Each axis must be labelled with a title for each graph.

- Merrick and Michael were given the task of compiling the report.

- Branden and Corné were tasked with updating all of the CAD files and making the free body diagrams for each

Meeting Problems: None

Excuses: Michael apologized as he was unable to attend the meeting.

Other points: Corné posted an updated work breakdown.