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DESIGN AND IMPLEMENTATION OF A SAMPLING SYSTEM FOR SOLID FLOW ON CONVEYOR BELTS IN INDUSTRY

THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES OF
ATILIM UNIVERSITY

BARIŞ SEZER

A MASTER OF SCIENCES THESIS
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Approval of the Graduate School of Natural Applied Sciences, Atilim University

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ABSTRACT

DESIGN AND IMPLEMENTATION OF A SAMPLING SYSTEM FOR SOLID FLOW ON CONVEYOR BELTS IN INDUSTRY

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In industrial production facilities, determining the quality of the produced material is of great importance. There are two types of methods to examine the content and quality of the material. These methods are physical and chemical analyses.

The facilities have test analysis laboratories to perform these quality control processes. In these laboratories, starting from the raw state of each product,, samples are taken and then, tested and analyzed at certain stages. During these tests, the content and quality of the material are observed.

The results of these tests and analyses contribute to the increasing of the production quality, to the reduction of production costs and energy costs, to the production of the desired products and therefore help increasing the reliability of companies.

In order to achieve this, at each stage of the production phase, samples must be taken in such a way that can fully represent the material physically and chemically.

There are many types of sampling techniques available in the industry. At this stage, applying the correct technique to the correct sampling point is extremely important to ensure that the sample taken represents the entire product.

In this study, a prototype was produced after observations, theoretical studies and engineering calculations. Many tests were carried out on this prototype and after these tests, the parameters to be used were decided. With this new sampling machine, it is aimed to achieve a sampling system that works with a better performance, requires minimal maintenance whilst the sample taken can fully represent the entire product.

Keywords: Sample, Sampling System, Quality Control, Representative

ÖZ

ENDÜSTRİDE KONVEYÖR BANTLAR ÜZERİNDEKİ KATI AKIŞINA YÖNELİK BİR ÖRNEKLEME SISTEMİNİN TASARIMI VE UYGULANMASI

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Endüstriyel üretim tesislerinde, üretilen malzemenin kalitesinin belirlenmesi çok büyük bir önem taşır. Malzemenin içeriğini ve kalitesini incelemek için yapılan iki tür yöntem vardır. Bu yöntemler fiziksel ve kimyasal analizlerdir.

Tesislerin bu kalite kontrollerinin yapılabilmesi için bir takım test analiz laboratuvarları vardır. Bu laboratuvarlarda, üretilen her bir ürün için ham halinden başlayarak belirli aşamalarda numuneler alınır ve sonra testler ve analizler yapılır. Yapılan bu testler sırasında malzemenin içeriği ve kalitesi gözlemlenir.

Test ve analizler sonucunda çıkarılan veriler tesislerin üretim kalitelerini arttırmalarına, üretim maliyetlerini düşürmelerine, enerji maliyetlerini düşürmelerine, doğru ürün üretimine katkıda bulunurlar ve böylece firmaların güvenilirliklerinin artmasını sağlarlar.

Bu hususların gerçekleştirilebilmesi için üretim esnasında gerekli görülen her aşamada malzemeyi fiziksel ve kimyasal olarak tam temsil edebilecek şekilde numune alınmalıdır.

Endüstride birçok türde numune alma teknikleri uygulanmaktadır. Bu aşamada, doğru numune alma noktasına, doğru tekniği uygulamak alınan numunenin tüm ürünü temsil etmesi açısından son derecede önemlidir.

Bu çalışmada, gözlemler, teorik çalışmalar ve hesaplamalar sonrasında bir prototip üretilmiştir. Üretilmiş olan bu prototip üzerinde birçok test yapılmış ve yapılan bu testler sonrasında, kullanılması gereken parametreler kararlaştırılmıştır. Bu yeni numune alma makinesi ile çok daha iyi performansta çalışan, en az seviyede bakım isteyecek, alınan numunenin tüm ürünü tam temsil edebileceği bir numune alma sistemine ulaşılması hedeflenmiştir.

Anahtar Kelimeler: Numune, Numune Alıcı, Kalite Kontrol, Temsili

To my Family…

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CHAPTER 1

INTRODUCTION

1.1. Background

One of the biggest problems in industry is to ensure that the composition of each part of the material produced is the same as the whole of the material. In order to solve this problem, samples are taken from the produced materials at regular intervals and tests and analyses are carried out. However, these samples must be taken at certain standards and be representative of all materials. In this way, the manufacturer will be able to check the quality of the material it produces, regularly, and may even intervene for improvements.

Sampling is an important method that is used to collect a representative mass of material from a larger mass. This collected mass of material, known as a "sample", is then prepared for physical testing and/or laboratory analysis. The specific tests and analyses depend on the properties that are needed to be measured to classify the material [1].

The approach for collecting samples, the frequency of collection, and the accuracy of the samples collected vary according to the nature of the material being sampled. For a completely homogeneous material, a single sample is sufficient to determine its properties accurately. However, for a lumpy and heterogeneous material, multiple small samples or increments must be collected to accurately represent the total mass or batch. These increments should be collected from all parts of the batch, and the number of increments depends on the variability of the material [1].

All particles in the batch should have an equal chance of being included in the final sample. To achieve this, it is recommended to sample the batch while it is in a dynamic state. This ensures that the batch is totally accessible and allows for a more representative sample. Sampling in a dynamic state helps to meet the requirement of collecting increments from all parts of the batch and ensures fairness in the sampling process [1].

Sampling is crucial for obtaining a manageable mass of material that represents the entire mass accurately, and the sampling approach depends on the homogeneity or heterogeneity of the material being sampled.

In this study, a new sampler machine that can be used in industrial facilities has been designed and a prototype has been manufactured. Many cement and various mining factories throughout Turkey were visited and observations were made. Unfortunately, in many factories visited, many sampling methods that did not comply with the standards and did not have a full representative capacity were observed. Sampling locations and demands in these facilities were observed in line with the standards. Some of the problems mentioned during the factory visits are:

- Reduction in sampling frequency due to frequent malfunctions of the devices used for sampling,
- The samples taken do not represent the whole material,
- Not choosing the right device for the place where the sampling system will be applied,
- The safety of the samples while transferring to the place where the test and analysis will be carried out,

The designed system was focused on eliminating or minimizing the basic problems mentioned above.

Within the scope of this thesis, a sampling machine has been designed. With this machine, it was planned to perform the sampling process by completely taking sample on a certain area over the conveyor belt and directing it to the sample buckets.

1.2. Scope

Sampling systems started to gain widespread application in the early 1980s. Over the past 40 years, materials handling facilities have become larger, with higher throughput capacity and faster conveyor belt speeds. This fact, coupled with the increased emphasis on accuracy and precision, has led to a proliferation of sampling systems throughout the quality control chain [2].

The sampling machine is designed to work synchronously with many systems. Sampling periods can be selected as a specific time interval. For example, taking a sample every 6 hours can be automated. Another method is that a weighing system can be installed on the conveyor system to be sampled, and it can be automated to take samples after certain weight of material passes.

This thesis has been written about a sampling system that will provide a representative sampling of coals poured from conveyor belts with predetermined parameters. When deciding on these parameters, situations frequently occurred in the industry were observed. After these observations, the sampling system, will proceed with the following parameters.

- conveyor belt width 1200 mm
- conveyor belt speed 3 m/s
- largest piece of coal 100 mm
- capacity is 1000 t/h
- density of coal is 1200 kg/m^3

Using these parameters, it is aimed to design and manufacture a sampling machine to represent the whole product while taking into account the sampling and coal sampling standards in Section 2.2.

CHAPTER 2

LITERATURE SURVEY

2.1 General Overview for Sampling

Sample and sampling systems are universal concepts in the fields of test, analysis, and statistics, in industry where mass production is high. The purpose of sampling is to represent all products and to reveal the product quality by performing analyses on the sample using the standards. Taggart defined sampling as:

> "The operation of removing a part convenient in size for testing, from a whole which is of much greater bulk, in such a way that the proportion and distribution of the quality to be tested (e.g. specific gravity, metal content, recoverability) are the same in both the whole and the part removed ." [3].

The best location for sampling from a moving stream is at the discharge point of a conveyor belt or chute where the complete stream can be intersected at regular intervals. Sample increments are taken by an automatic mechanical sampler from the whole cross-section of a continuously moving stream at a transfer point. The mechanical cross-stream cutter type is widely accepted and used to obtain a representative primary sample increment.. Various standards recommend that when samples are taken using a cross-stream cutter, the following design criteria should be met in order to have a representative and correct sampling:

- The sample cutter should cut a complete cross-section of the stream.
- The plane or surface of the cutter aperture should preferably be normal to the mean trajectory of the stream to maximize the effectiveness of the cutter aperture.
- The speed of the cutter should be constant and not exceed 0.6 m/s.
- The ratio of the cutter aperture to maximum coal size should be not less than three, and the cutter opening should be wide enough to prevent bridging.

- The cutter opening should have parallel edges.
- The flowing stream to be sampled should be in free fall.
- The sample cutter should completely take or entirely pass the increment without loss or spillage and without any part of the cutter aperture ever being blocked or restricted by the material already collected.

It is relatively straightforward to ensure that the cutter intercepts the complete stream. Also, it is easy to check visually whether the cross-stream cutters are operating correctly. As a result, the need for bias tests is reduced [2].

After the samples are collected, various chemical and physical analyses are performed. There are important techniques and standards in sample collection. Samples collected without complying with these techniques and standards will not be representative samples. Only the comparison of samples which are taken in accordance with the standards will give accurate results. The sampling standards will be mentioned in more detail, in Section 2.2.

The requirements of sampling include:

- The sampling system should be sufficient to allow the largest part to be taken freely.
- A sufficient number of coal particles should be collected to reflect the variability of the coal.
- The coal particles on the conveyor belt should have access to the sampling equipment and each coal particle must have an equal probability of being selected and included in the sample.

Incremental sampling is the procedure of collecting a group of particles from the lot in a single operation of a sampling device, usually from the conveyor [4]. This is usually done as the material passes over the conveyor belt or as the material is poured off the conveyor belt.

Lot is a quantity of material which may be used to determine the overall quality of the product to a particular precision [1].

Sub–lot is the equally sized parts of a lot, whose properties are to be determined [1].

2.2 Standards Used in Sampling

The most common standards used for sampling machines, primarily for coal, are listed below.

- ISO 13909 Hard Coal and Coke – This standard consists of 8 parts. Part 2: Coal — Sampling from moving streams, Part 4: Coal — Preparation of test samples, and Part 8: Methods of testing for bias
- TS 2390 Hard Coal-Sampling

These standards define many aspects such as minimum sampling amount, cutter width, cutter speed, sampling terminology, minimum number of lot/sub-lot calculations. All calculations in Chapter 3 are based on these standards. Within the scope of this thesis, calculations and designs were made using the above standards. Technical data such as sampling method, number, and amount are designed considering the conditions and guidelines specified in these standards.

2.3 Available Sampling Systems

Nowadays, there are many types of sampling methods used in factories according to the conditions of the application place. While determining these types, which sampling method will be more representative should be considered, as well.

The samplers described below are among the most widely used ones in industry. The advantages and disadvantages of these machines are discussed. In this thesis, the shortcomings of the available samplers were taken into consideration.

2.3.1 Free-Falling Sampler

The main purpose of this type of sampler is to take a sample when material leaves a conveyor belt or chute (Figure 2.1 - 2.4). Some of these systems are conceptual designs whereas the others are used in industry.

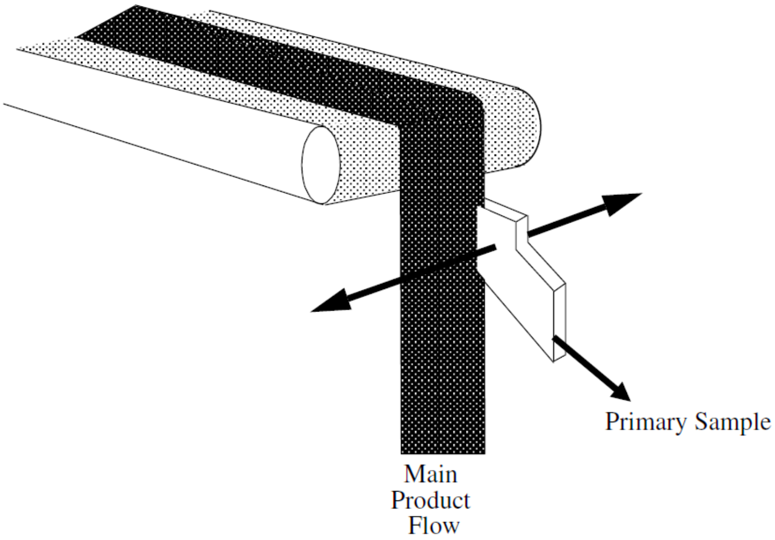


Figure 2.1: Free-falling sampling system example 1 [5].

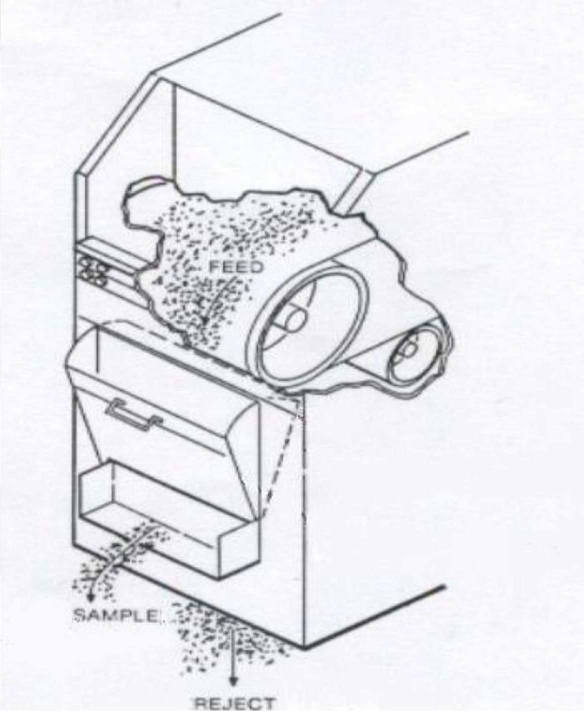


Figure 2.2: Free-falling sampling system example 2 [4].

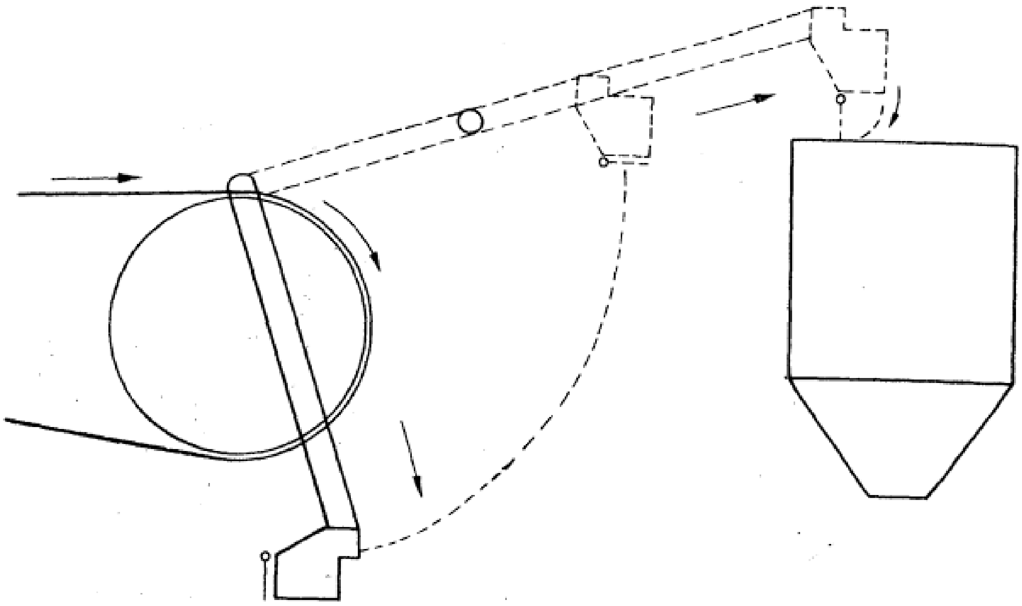


Figure 2.3: Free-falling sampling system example 3 [6].

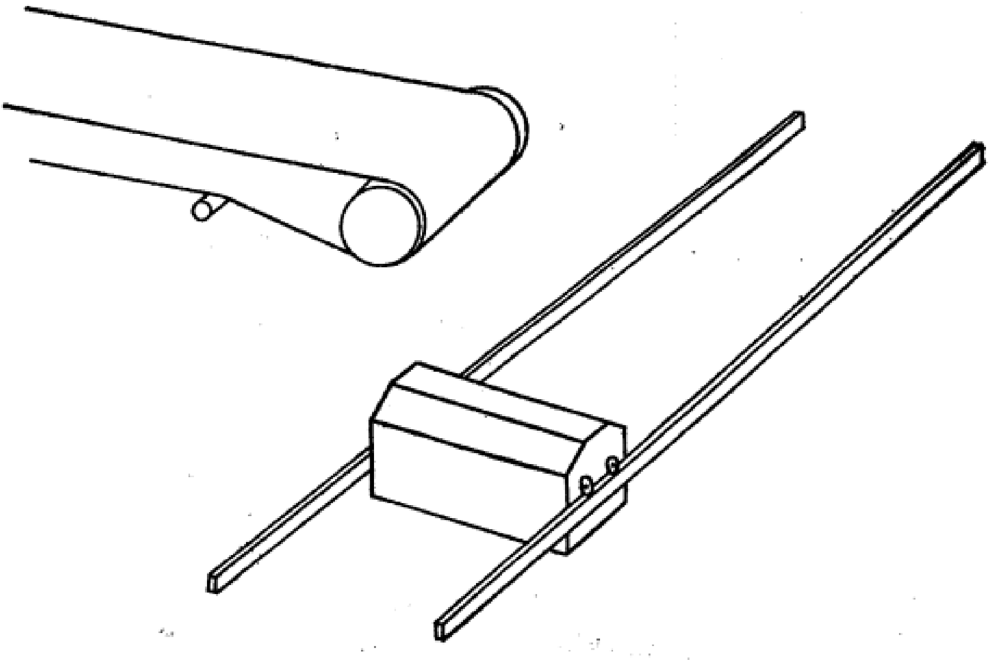


Figure 2.4: Free-falling sampling system example 4 [6].

2.3.2 Air Cannon Sampler

This sampling system is preferred when solid and granular materials pass over the conveyor belt (Figure 2.5).

There is a pressurized vessel in the system. At certain time intervals, the compressed air in the pressurized vessel is applied to a section on the conveyor belt with the help of a diverter nozzle. To control the pressure in the vessel, a regulator, manometer, and pneumatic equipments are used. An electronic control panel with pneumatic solenoid valves is used for directing the compressed air. The materials are directed to the sample buckets with the compressed air pulse [4].

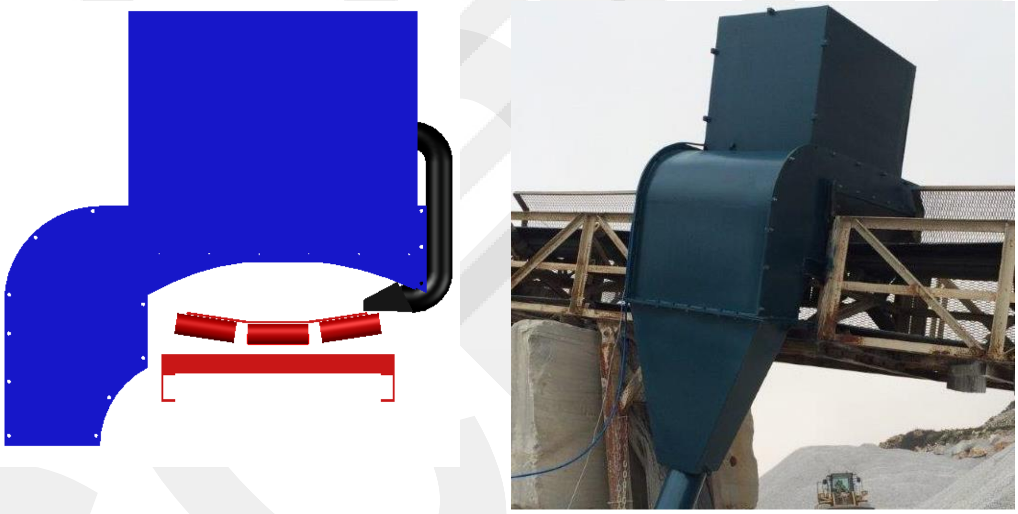


Figure 2.5: Air cannon sampler [7].

2.3.3 Rotating Arch Path Sampler

The rotating arch path sampling method is divided into two groups: horizontal rotating arc path samplers and inclined rotating arc path samplers. The horizontal rotating ones are designed to take samples of fine material falling with low capacity. The inclined rotating ones are usually inclined about 30 degrees to overcome the difficulty in sampling moist and sticky materials (Figure 2.5) [4].

The rotating arch path sampler is usually installed to feed the excess sample back into the system. In this way, the factory does not lose material during each sampling.

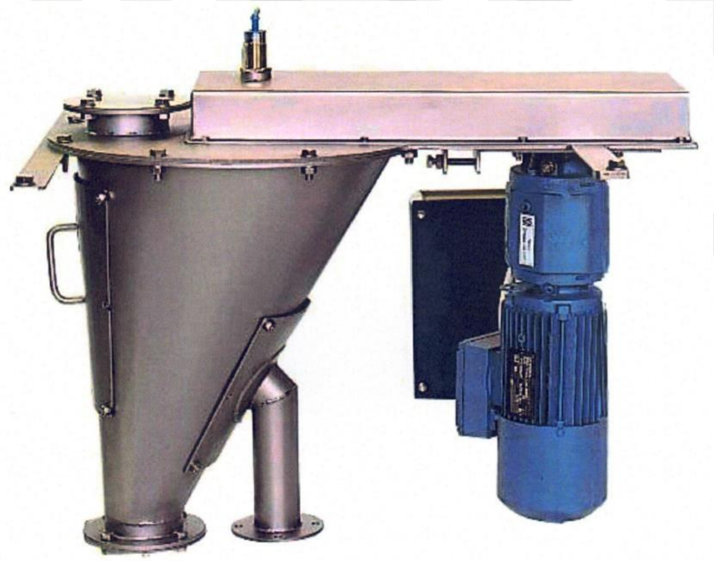


Figure 2.6: Rotating arch path sampler [4].

2.3.4 Swing Arm Cross Belt Sampler

Swing arm cross belt sampler is a sampler that can take samples without stopping the conveyor belt. It is mounted on the conveyor belt and there is a rotating bucket inside the sampler (Figure 2.7). This bucket should be placed according to the center line of the conveyor belt. Otherwise, the bucket may cause disruptions and abrasions on the belt during sampling [4].

Even if the rotating bucket passes very close to the surface of the conveyor belt, some material will remain on the belt and the bucket will not be able to take sample from all section. In such cases, equipment such as brushes may be attached to the bucket. It is not preferred for sampling small-sized materials such as powder with this method.

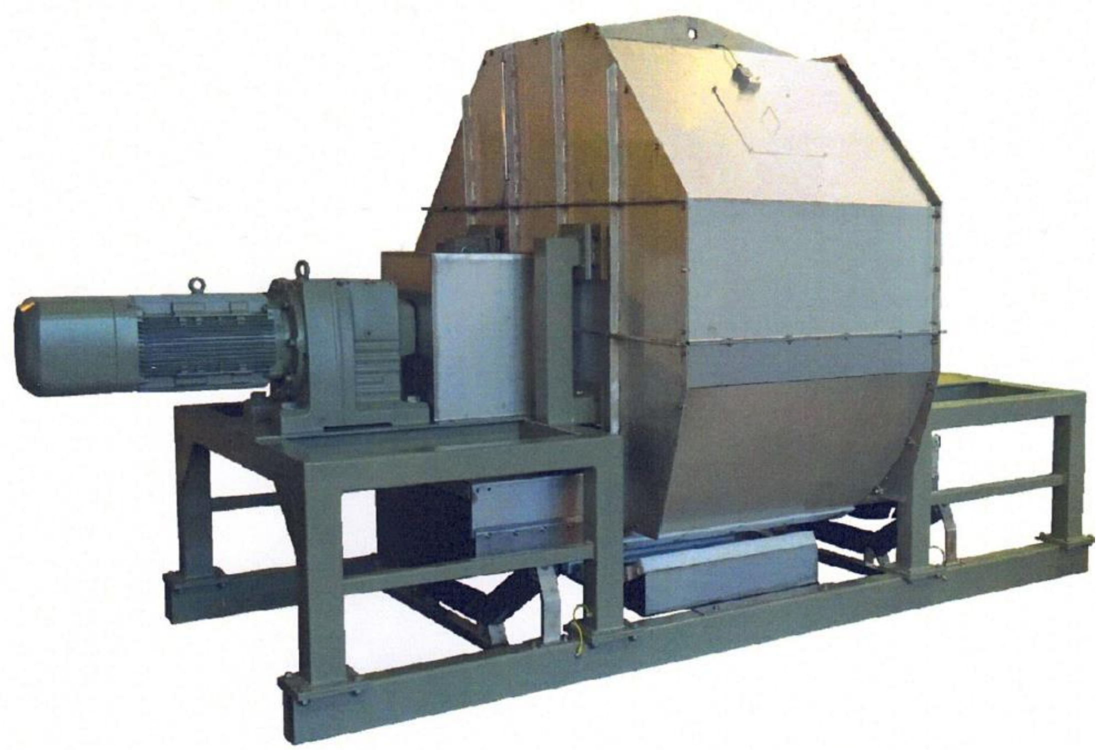


Figure 2.7: Swing arm cross belt sampler [8].

2.3.5 Slotted Belt Linear Sampler

When slotted belt linear sampling method is used, the materials flow regularly on a conveyor belt (Figure 2.8). There is a hole on the rubber belt. When the material flow coincides with this hole, the material is poured through the hole into the sampling bucket. This method has a simple design, and its representativeness will be reduced when the conveyor speed is high [4].

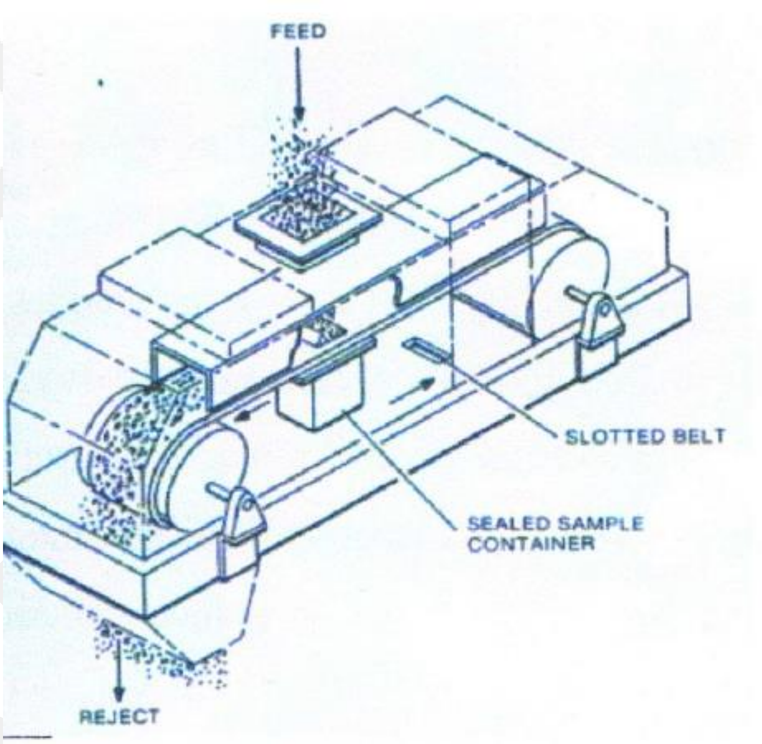


Figure 2.8: Slotted belt linear sampler [4].

2.3.6 Screw Sampler

A screw sampler is used in the presence of fine dry and non-sticky materials. The system is driven by a geared motor. The sampler is mounted in a silo or chute and contains a screw conveyor (Figure 2.9). It transports the sample from the silo or chute to another point with the screw conveyor at certain time intervals. The opening in the silo or chute should be compatible with the standards and should have a size that can accommodate the entire flow. The sampler works with a maximum inclination of 30° in cases where it needs to work inclined. Since there is a possibility of materials remaining in the system after sampling, it should run idle for a while after each sampling [4].

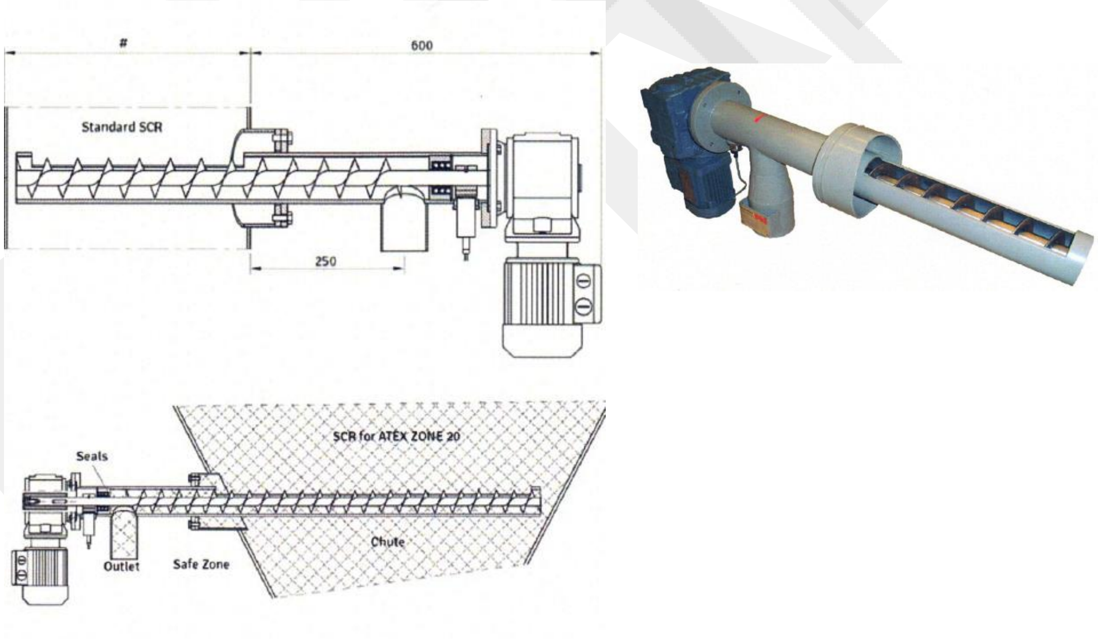


Figure 2.9: Screw sampler [8].

2.3.7 Probe Sampler

Probe samplers are used to take samples from inside transport vehicles such as trucks, ships, and wagons. The system has its own probe inside the system. To represent the material inside the vehicle, it is necessary to reach the lowest point otherwise, the representativeness of the sample will be low (Figure 2.10).

For example, the material carried in a long-haul truck will be concentrated on the bottom of the truck due to the vibrations on the road. The samples taken from the top of the truck will be drier or finer materials. It is difficult to take a sample representing the entire product [4].

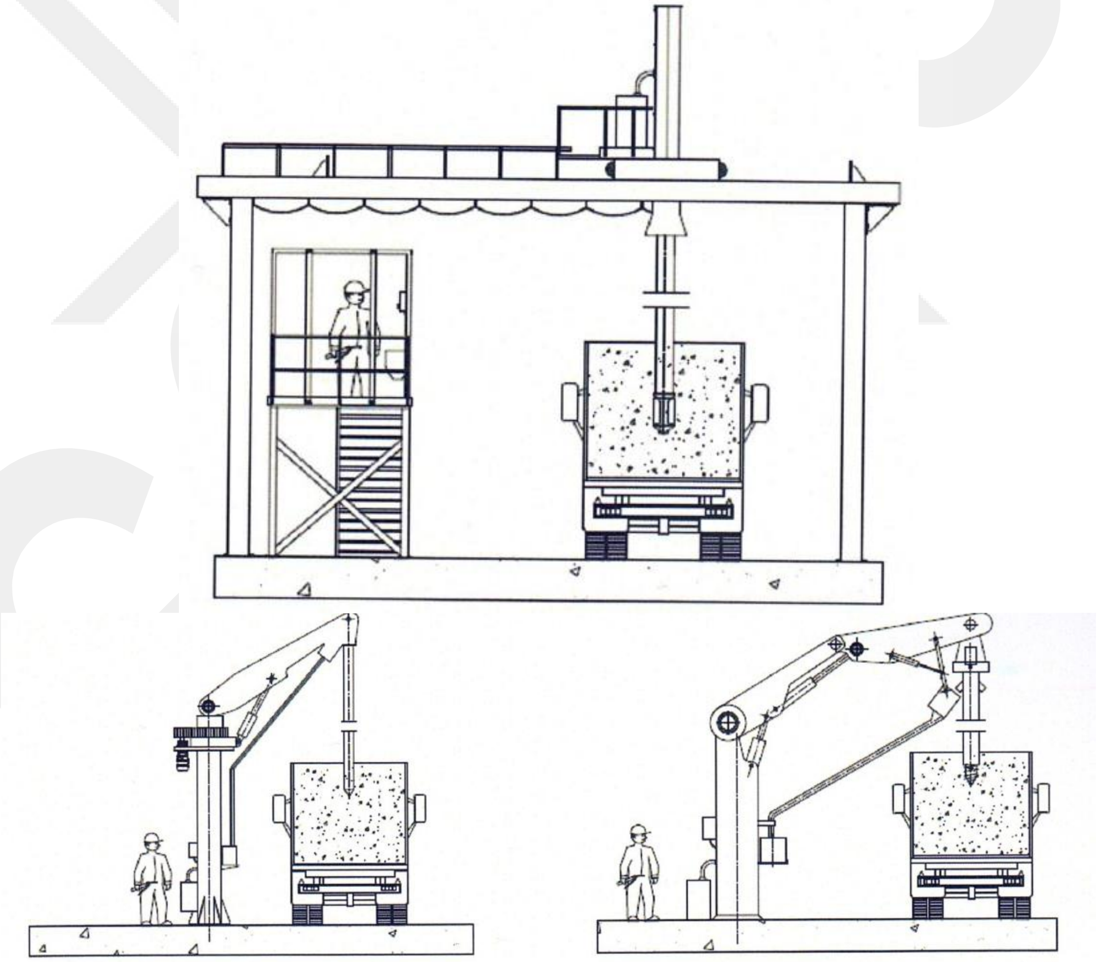


Figure 2.10: Probe sampler [8].

CHAPTER 3

DESIGN OF A SAMPLING SYSTEM

There are many sampling methods available in the industry. Each method must fulfill its own specific applicability requirements. Therefore, not every sampler can be used in every condition in the industry. These devices used in industry have been examined considering their advantages and disadvantages regardless of their suitability or unsuitability. The primary aim of a new design is to achieve fully representative sampling. In addition, easy maintenance of the machine should be considered. Under different conditions, it might be very easy to change and adjust the settings with the help of a control panel .

3.1 Sampling Systems Design Criteria

There are many things to consider while designing a sampling machine and they are clearly specified in the standards. The designs, calculations, and analyses to be made within the scope of this thesis have been performed in accordance with these standards.

3.1.1 Cutter Width

According to ISO 13909 Standard, the width of the cutter should be 3 times the width of the largest part size flowing through the conveyor belt [9]. A sampling system with a size of a maximum of 100 mm material is to be designed, so the cutter width should be at least 300 mm. The cutter is described in more detail in Section 4.1.7.

d	maximum size of the material (100 mm)
b	cutter width
b_0	critical cutter width

$$b = 3 \times d, \tag{3.1}$$

$$b = 300\ mm,$$

If $b \geq b_0$ all particles belonging to the increment eventually fall in the actual increment.

If $b < b_0$ some of the particles belonging to the increment have the risk of rebounding from the side plates of the cutter and these particles are lost by spinning over the extracting edge of the cutter [10].

3.1.2 Cutter Speed

According to standards and the literature in moving stream sampling systems, the optimum cutter speed is 0.6 m/s [9]. Calculations will continue based on this value.

3.1.3 Minimum Sampling Amount

According to the ISO 13909 standard, there is a formula that should be used to find the sampling amount. Using this formula, it will be calculated how many times and at what time intervals the sampling system will be used to be fully representative [11].

m	required mass (kg)
C	flow rate (1000 t/h)
b	cutter width (mm)
V	cutter speed (m/s)

$$m = \frac{Cb \times 10^{-3}}{3.6V} \qquad 3.2$$

$$m = \frac{1000 \times 300 \times 10^{-3}}{3.6 \times 0.6}$$

m = 138.8 kg

3.1.4 Minimum Number of Lot / Sub-lot Calculation

Table 3.1 shows the amount of reference increment mass according to the size of the material to be taken.. For 100 mm maximum material size, an approximate value of reference mass is calculated with linear interpolation.

In Table 3.1, the nominal top size of coal is 125 mm and the reference increment mass are 10 kg. Also, the nominal top size of coal is 90 mm, and the reference increment mass are 5 kg. By making a linear interpolation to find 100 mm.

d maximum size of the material (100 mm),

y reference incremental mass

$d_1 = 125$ $y_1 = 10$

$d_2 = 90$ $y_2 = 5$

$d = 100$ $y = ?$

$$y = \frac{(d-d_1)\times(y_2-y_1)}{(d_2-d_1)} + y_1 \qquad 3.3$$

$$y = \frac{(100-125)\times(5-10)}{(90-125)} + 10$$

$$y = 6.42 \text{ kg}$$

Therefore, each incremental sampling must be at least 6.42 kg. In section 3.1.3 required sample amount is found to be 138.8 kg (Equation 3.2).

$$\frac{138.8}{6.42} = 21.6 \approx 22 \qquad 3.4$$

As a result, there should be at least 22 increments.

The number of sub-lots required is determined with the help of ISO 13909 standards [11].

n	number of increments per sub-lot
V_1	primary increment variance (if no data assume 20)
V_{PT}	the preparation and testing variance (if no data assume 0.2)
P_L	the estimated overall precision of sampling (assume 1.05)
s	the number of sub-lot in the lot

$$s = \frac{4\,V_1 + 4nV_{PT}}{nP_L^2} \qquad 3.5$$

$$s = \frac{(4\times20)+(4\times22\times0.2)}{22\times1.05^2}$$

$$s = 4$$

Therefore, each lot includes 4 sub-lot, and each sub-lot includes 22 increments, each increment taking 6.42 kg sample and a total sampling amount of 138.8 kg in a sub-lot.

Table 3.1: Reference increment mass [1].

Nominal top size of coal (mm)	Reference increment mass (kg)
300	100
200	25
150	15
125	10
90	5
63	3
45	2
31.5	1
22.4	0.75
16	0.50

3.1.5 Motor Calculation

Several factors need to be calculated for the selection of the motor to be used in the system. Using the estimated value of the torque required for the system the speed at which the system operates, the motor power may be calculated and an appropriate motor will be selected.

P	power (kW)
T	torque (N/m)
ω	angular speed (rpm)
F	force (N)
d	distance measured from the axis of rotation (m)
V	cutter speed (m/s)
r	gear radius (m)
m	mass of sample receiver trolley (kg)
g	gravitational acceleration

$$V = \frac{2\pi\omega r}{60}, \tag{3.6}$$

$$F = mg, \tag{3.7}$$

$$T = Fd, \tag{3.8}$$

$$P = \frac{T\omega 2\pi}{60000}, \tag{3.9}$$

$$0.6 = \frac{2\pi\omega 0.07}{60}, \tag{3.10}$$

ω = 81.89 rpm

$$F = 95 \times 9.81 \tag{3.11}$$

F = 931.9 N

$$T = 931.9 \times 0.07 \qquad 3.12$$

$$T = 65.2\ \text{Nm}$$

$$P = \frac{65.2 \times 81.89 \times 2\pi}{60000} \qquad 3.13$$

$$P = 0.56\ kW$$

Considering a safety factor of 2, a 1.1 kW, 82 rpm gearmotor is required.

3.1.6 Correct Increment Delimitation

Another important aspect of a fully representative sampling system is the delimitation of the correct increment. It is necessary to take a line completely through the flow of incoming material. The correct increment delimitation is associated with the sampler cutter. Figures 3.1 – 3.4 show correct and incorrect increment delimitation.

Three types of cutters may be used in sampling systems.

1) Straight path cutters: Their geometry is correct if and only if the cutter edges are parallel, irrespective of their angle with the stream.
2) Circular path cutter: Their geometry is correct if and only if cutter edges are radial (intersecting on the revolution axis of the cutter), irrespective of their angle with the stream.
3) Other cutters: During their motion across the stream, a few type of mechanical samplers do actually generate a curve which is neither a straight line nor a circle. Since the correct geometry of a cutter depends on its trajectory, it can be easily shown that there is no correct cutter geometry when the cutter path is neither straight nor circular [10].

The cutter of the sampler in this study is selected to be a straight path cutter. Figure 3.1 shows a typical cutter opening. Assuming correct increment delimitation, the increment through the stream is a parallelogram. The sampling probability should be uniform for all particles, irrespective of their position in the stream cross-section.

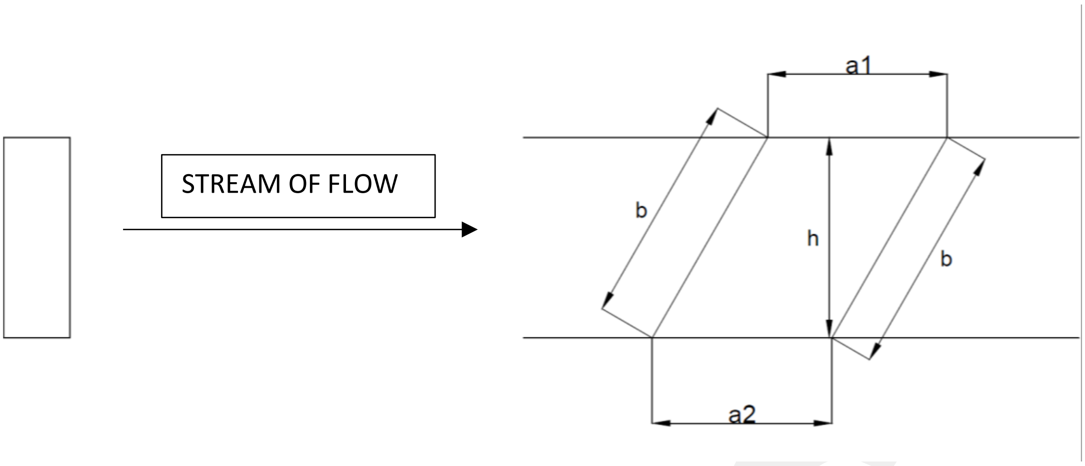


Figure 3.1: Correct increment delimitation (a1=a2) [4].

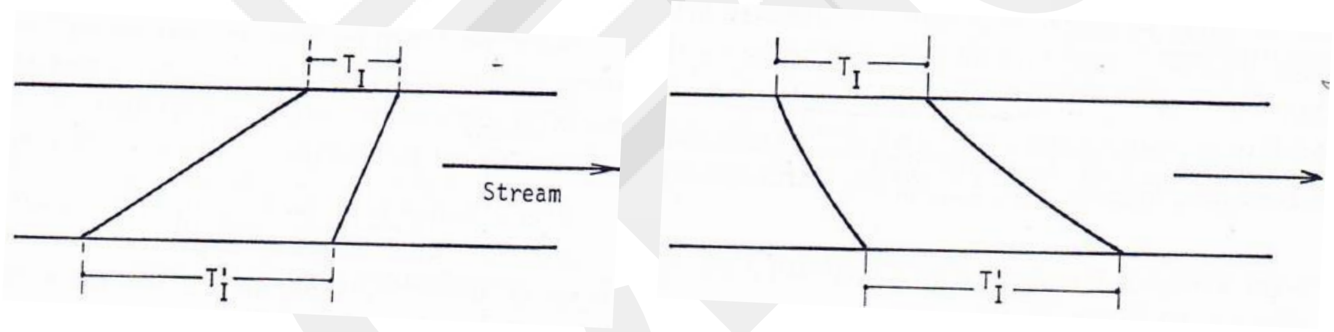


Figure 3.2: Incorrect increment delimitation [10].

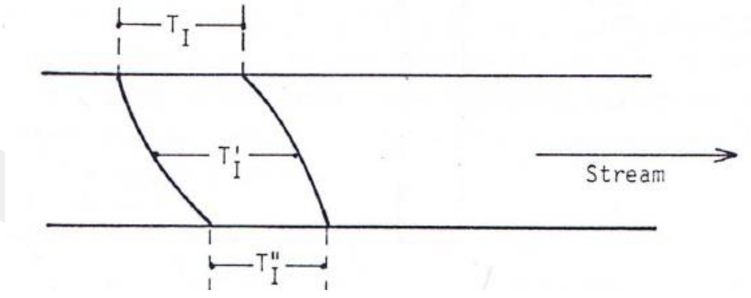


Figure 3.3: Incorrect increment delimitation [10].

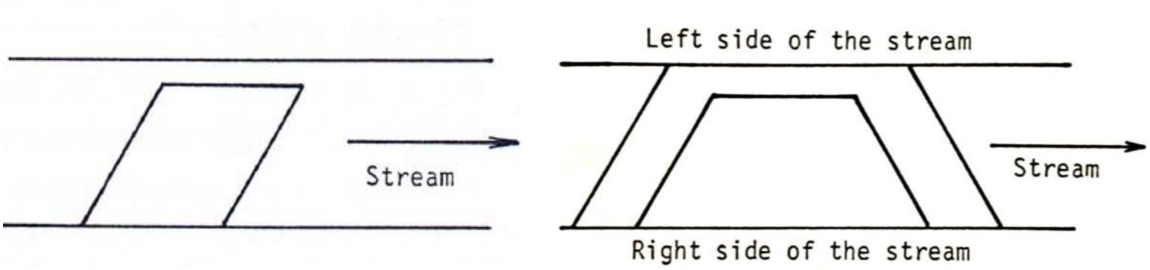


Figure 3.4: Incorrect increment delimitation [10].

3.2 Static Analysis

Before prototype production, static analyses were performed with ANSYS LS-DYNA Student Version. The sample trolley in the system was made to move from the left side to the right side at a constant speed. During this movement, an expected load was applied to the cutter. As a result of the analysis, points having maximum stress can be determined and whether the system is durable or not is found. According to the results of these analyses, prototype production was completed.

3.2.1 Von Mises Stress

As a result of the analysis, maximum Von Mises stress is 194 MPa at time 2.12 occurring in the ground connection flanges of the carrier legs (Figure 3.5). To find out whether this value is safe or not, it is necessary to calculate the safety factor. To calculate the safety factor, the yield stress value and the maximum stress value of the material to be used are needed. The material is selected to be ST37 and its yield strength is 235 MPa. According to this value, the safety factor FS can be determined. The safety factor is calculated as the ratio of yield strength to Von Mises Equivalent stress [12] (Equation 3.15).

$$FS = \frac{Yield\ Strength}{Von\ Mises\ Equivalent\ Stress} \qquad 3.15$$

$$FS = \frac{235}{194}$$

$$FS = 1.211$$

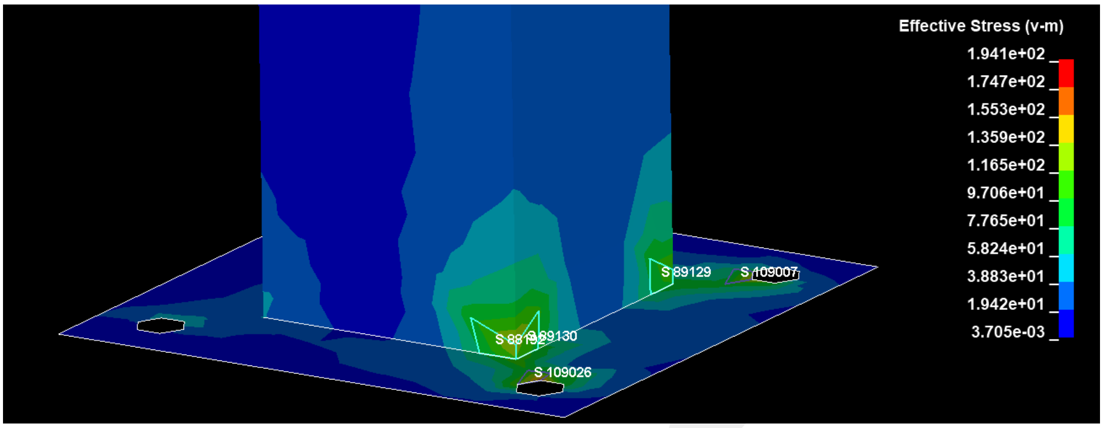


Figure 3.5: Max Von mises stress location.

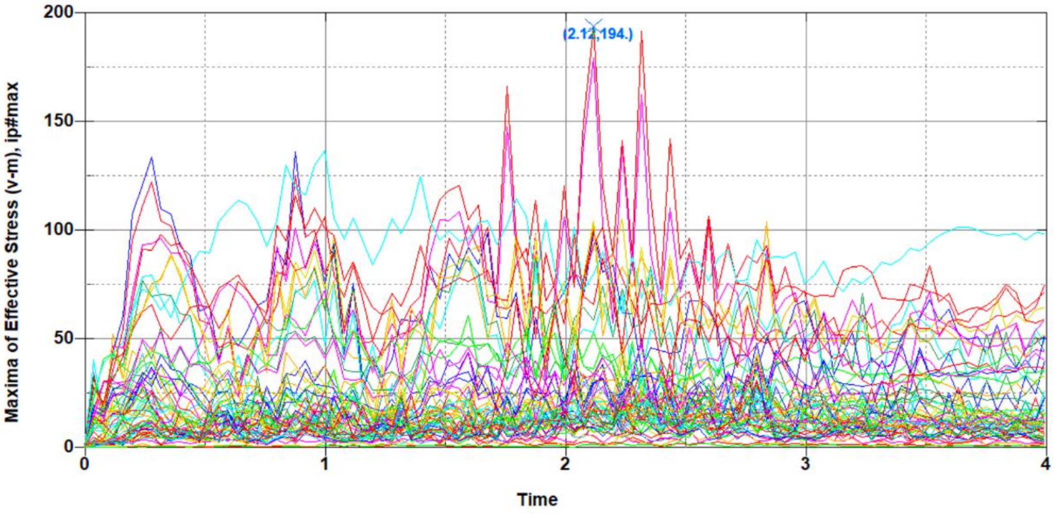


Figure 3.6: Von Mises stress analysis results.

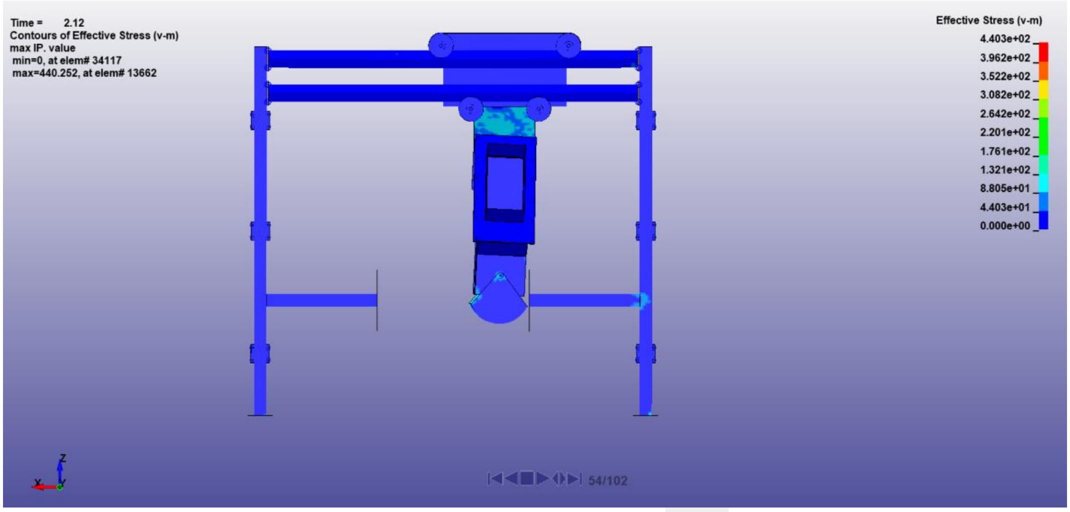


Figure 3.7: Von Mises stress analysis front view.

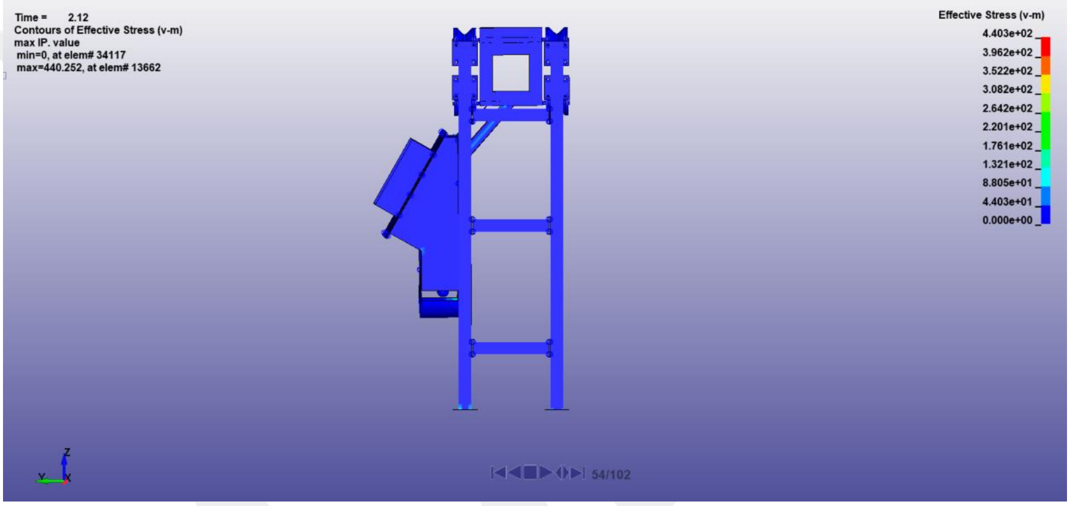


Figure 3.8: Von Mises stress analysis right view.

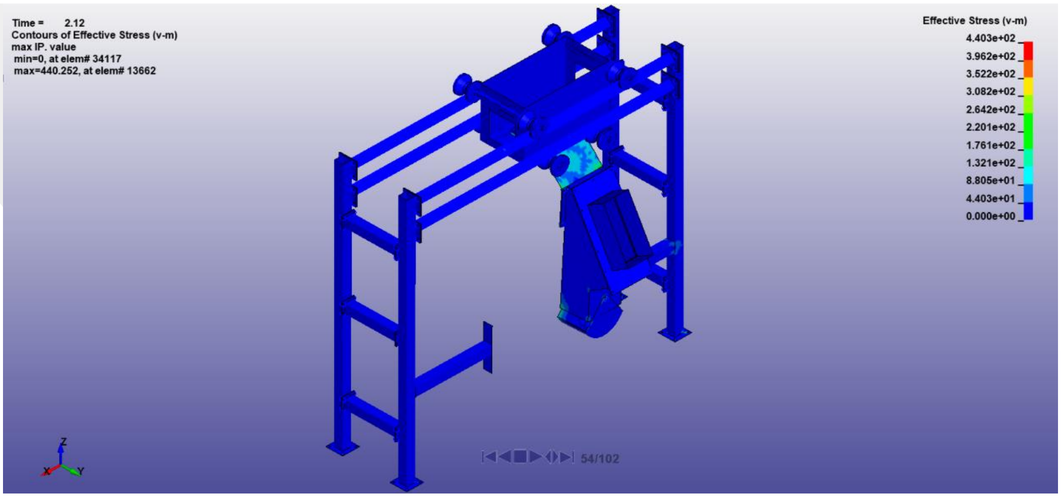


Figure 3.9: Von mises stress analysis isometric view.

CHAPTER 4

CONCEPTIONAL DESIGN

4.1 Equipment

The equipment used in the sampling machine produced (Figure 4.1) within the scope of this thesis is as follows:

- Conveyor belt
- Sample receiver trolley
- Gearmotor and chain system
- Frequency converter
- Control Panel
- Proximity sensor
- Cutter
- Chute and cover

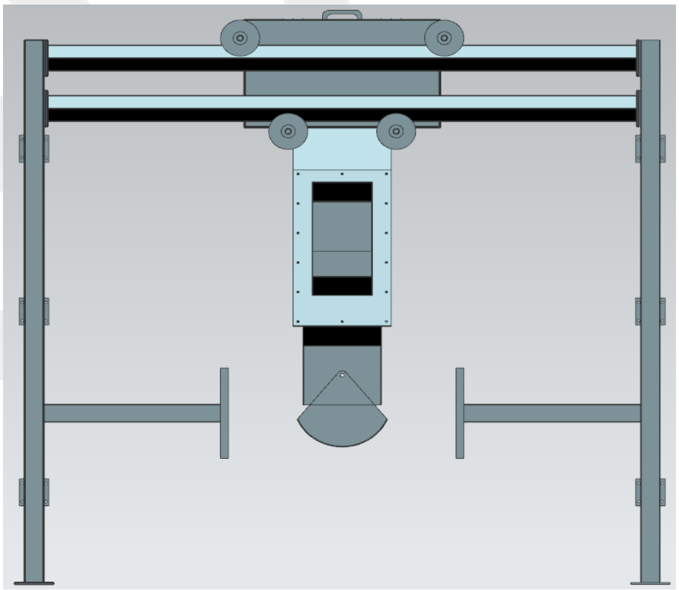


Figure 4.1: 3D design of a sampling system for a free-falling stream.

4.1.1 Conveyor Belt

The sampling system produced in this thesis is mounted in front of the drum of a conveyor belt drive. The speed of the conveyor belt, belt width, and conveyor angle must be taken into account at the design stage. When assembling the sampling system, the material poured from the conveyor belt should be perpendicular to the cutter surface [13].

4.1.2 Sample Receiver Trolley

The sampler trolley is a system carried by a chain system on steel structures and it moves in one direction. There are 4 wheels at the top and 4 wheels at the bottom. These wheels are designed to move on 100 x 100 mm profiles that are rotated 45 degrees (Figures 4.1 and 4.2).

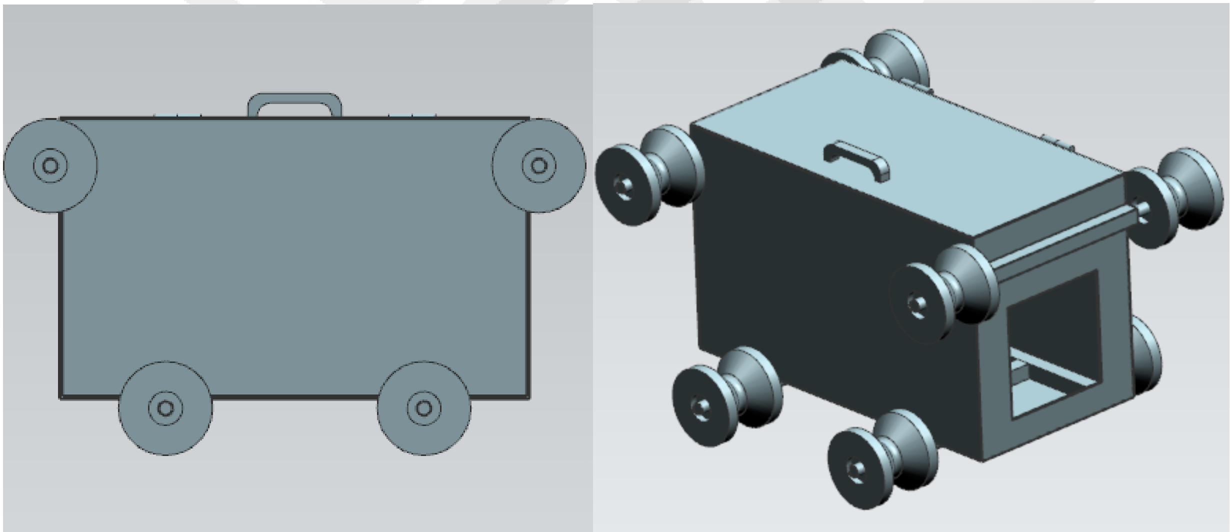


Figure 4.2: Sample receiver trolley 3D design.

4.1.3 Gearmotor and Chain system

A gearmotor connected to a sprocket system moves the sampler trolley. As calculated in Section 3.1.5, a geared motor operating with 1.1 kW, 82 rpm is selected . As described in Section 3.1.2, the cutter speed is set to 0.6 m/s. With the help of the chain system, the sample receiver trolley moves right to left and left to right.

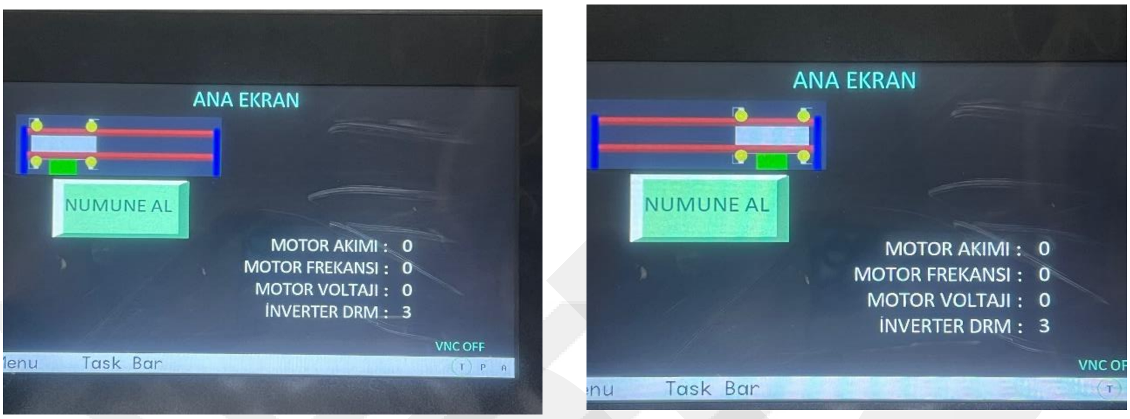
4.1.4 Frequency Converter

The selected motor operates with 82 rpm at 50Hz. By using a frequency converter, the rotation speed of the motor may be adjusted with different frequency values. Changing the frequency may be used to increase or decrease the speed of the conveyor belt. The working range of the frequency converter is 0-400Hz. (Figure 4.3)

Figure 4.3: Frequency convertor.

4.1.5 Control Panel

There is a control panel for automatic or manual control of the sampler system (Figures 4.4). There are buttons on this panel to operate and control the system. The frequency converter is inside the control panel (Figure 4.5).



MOTOR AKIMI : 0
MOTOR FREKANSI : 0
MOTOR VOLTAJI : 0
İNVERTER DRM : 3

MOTOR AKIMI : 0
MOTOR FREKANSI : 0
MOTOR VOLTAJI : 0
İNVERTER DRM : 3

Figure 4.4: Control panel.

Figure 4.5: Control panel outside and inside view.

4.1.6 Proximity Sensors

Two proximity sensors are used to ensure that the sample receiver trolley stops at the predetermined points at each end of the machine without hitting the frame (Figure 4.6).

Figure 4.6: Proximity sensor inside the prototype sampling system.

4.1.7 Cutter

The cutter is designed according to ISO 13909 standards and the cutter width is described in Section 3.1.1. The cutter is a part that takes the sample from the conveyor belt. The ISO 13909 standard states that the poured material comes perpendicularly into the cutter. It is necessary to pay attention to this arrangement during the assembling of the machine. The cutter is designed to be replaceable. If different sizes of material pass through the conveyor belt, the cutter can be replaced for a representative sampling (Figure 4.7).

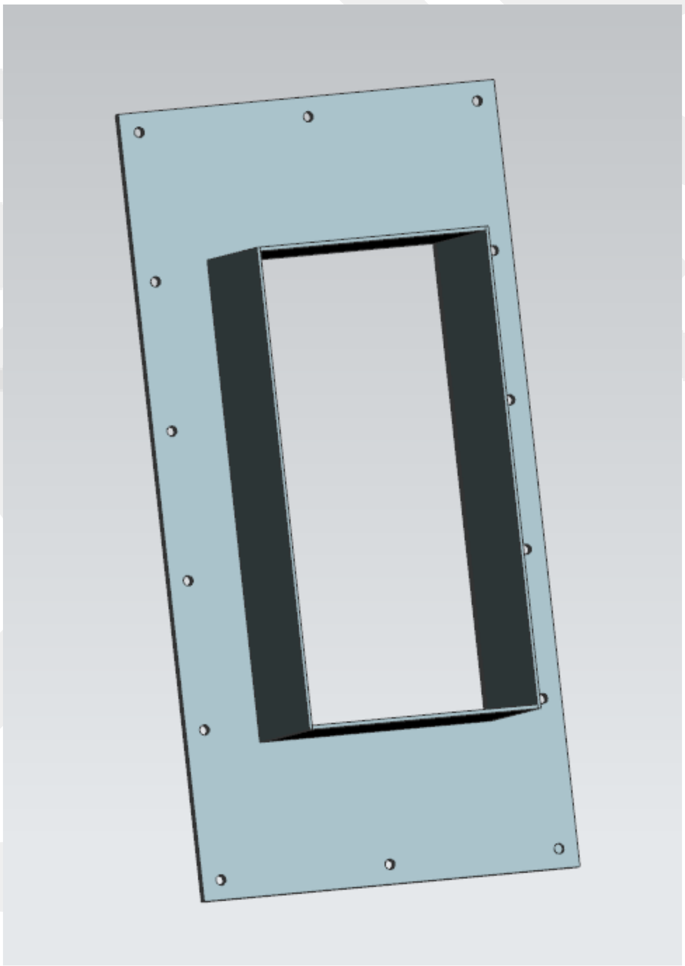


Figure 4.7: 3D design of the cutter.

4.1.8 Chute and Cover

The samples taken by the cutter are transported with the help of a chute (Figure 4.8). Samples passing through the chute are collected in a cover. When the sampling process is finished, the cover is opened and the collected samples are guided into a bucket. Finally, they are transferred for analysis.

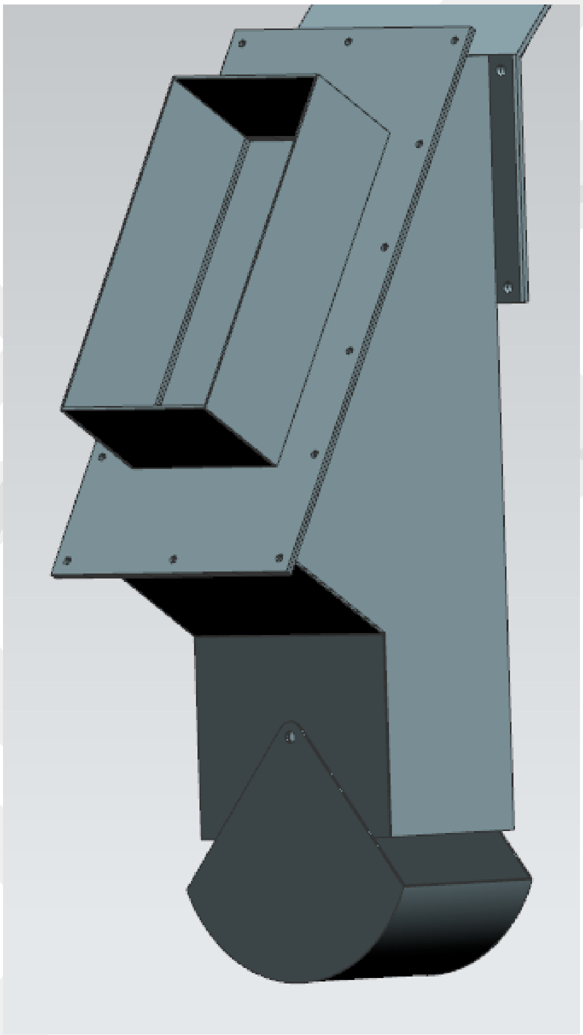


Figure 4.8: 3D design of the chute and cover.

4.2 Method

The sampling machine is designed in accordance with the standards and all calculations have been made accordingly. The machine will be mounted at the end of a conveyor belt. As shown in Sections 3.1.3 and 3.1.4, sampling amounts and number of increments are calculated according to the standards.

When the conveyor belt is pouring material, the cutter moves from the first point on one end of the machine, takes a sample from the flow, and stops at the second point on the other end of the machine. There are sampling buckets at both points. The movement of the cutter from one point to the other is defined as a sampling. It stops at the correct positions thanks to the proximity sensors. The positioning of these sensors is related to the place where the machine will be installed.

Materials falling from the conveyor belt must fall perpendicular to the cutter surface. This is necessary for a representative sampling. Otherwise, there is a possibility that the materials hitting the surface at a wrong angle may be dispersed by hitting the outside and the sample may not be taken properly.

The sampler is operated with a control panel. With this control panel, it is possible to operate the system automatically. This automation process should be set to take samples at the quantity specified in Section 3.1.3 and in time intervals specified in Section 3.1.4. If desired, the machine may be operated manually at any time.

In addition, this machine can be integrated with some other machines used in the industry. For example, there are belt scales that continuously measure the weight of the material passing over the conveyor belts. According to the data received from these scales, the sampling machine can start working. An automation program can be written to take samples every time a particular amount of material passes through the conveyor belt.

4.2.1 Parameters

There are some parameters that may affect the results of the tests to be performed on the prototype produced. These parameters are conveyor belt speed and the cutter speed.

4.2.1.1 Conveyor Belt Speed

Five different belt speeds were tested. The belt speed can change with the frequency converter. The gearmotor works with 50 Hz and that frequency provides a 3m/s speed for the conveyor belt. If the frequency of the motor is adjusted using a frequency converter, the operating speed of the motor will decrease or increase in the same proportion. The frequency values and the corresponding conveyor belt speeds are presented in Table 4.1.

Table 4.1: Conveyor belt speed with the change of frequency

Frequency (Hz)	Conveyor Belt speed (m/s)
16.1	1
25	1.5
33.3	2
41.6	2.5
50	3

4.2.1.2 Cutter Speed

As mentioned in Section 3.1.2 the cutter speed is specified as 0.6 m/s in the standards. However, five different cutter speeds were tested to analyze the effect of the cutter speed. The gearmotor works with 50 Hz and that frequency provides 0.6 m/s cutter speed. The frequency values and the corresponding cutter speeds are presented in Table 4.2.

Table 4.2: Cutter speed with the change of frequency

Frequency (Hz)	Cutter speed (m/s)
33.3	0.4
41.6	0.5
50	0.6
58	0.7
66.6	0.8

4.3 Prototype Manufacturing

In line with the theoretical calculations and analyses, 3D solid modelling of the design was made with the Siemens NX12 program. To proceed to the production stage, the necessary technical drawings were produced (Figure 4.9).

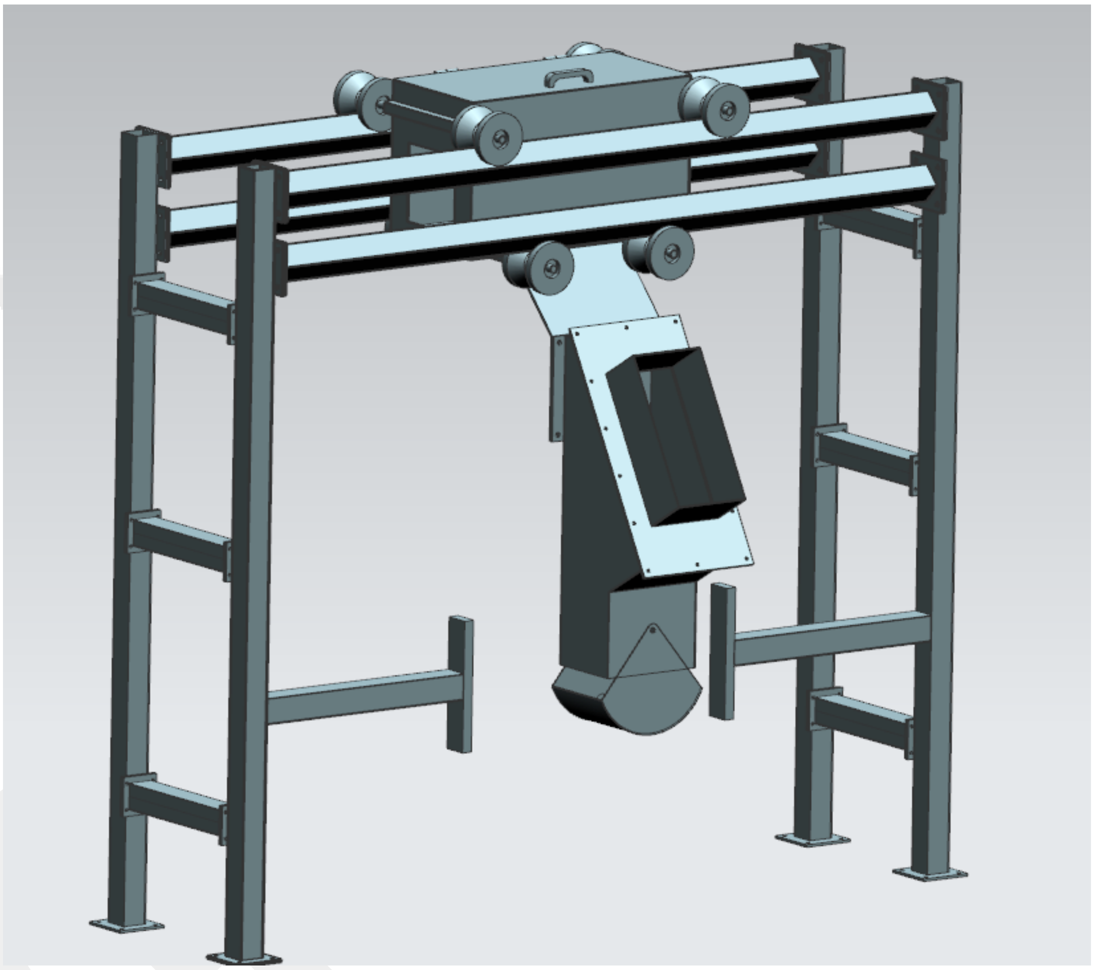


Figure 4.9: Finished design.

The first part produced was the cutter (Figure 4.10).

Figure 4.10: Cutter manufacturing process.

Then, the production of the sample receiver trolley was started. The V-type wheels to be used in this section were also produced (Figure 4.11).

Figure 4.11: Manufacturing process of the wheels.

Figure 4.12: Manufacturing process of sample receiver trolley.

Then, the produced parts so far were assembled together (Figure 4.13).

Figure 4.13: Assembling process of the sample receiver trolley, cutter, and chute.

Afterwards, the steel structure to carry the trolley and cutter was manufactured. 100x100x4 mm square box profiles were rotated 45 degrees and placed between the wheels (Figures 4.14 and 4.15).

Figure 4.14: Assembling process of cutter, sample receiver trolley, chute, and steel structure.

Figure 4.15: Another view of assembling process of cutter, sample receiver trolley, chute, and steel structure.

Finally, gearmotor and chain assembly were made (Figure 4.16 and 4.17).

Figure 4.16: Assembling process of gearmotor and chain system.

Figure 4.17: Fixing process of the chain.

A few improvements were made at the design stage for ease of use and ease of maintenance in the future. For that purpose, the positions of the wheels were changed and a cover was made on the upper side (Figure 4.18).

Figure 4.18: Changing the position of the wheels.

After the control panel, sensors, and necessary cable connections were completed, a conveyor belt was installed to proceed to the experimental phase. A chute was produced on the conveyor belt (Figure 4.19). The purpose of this chute is to ensure that the flow of the material is synchronized and regular.

Figure 4.19: Manufacturing of the Chute on the conveyor belt.

Figure 4.20: The system is e ready for experiments.

4.4 Material

Some of the parameters used within the scope of this thesis are specified in Section 1.2. The prototype is designed for smaller material.

A total of 100 kg of materials of different sizes and weights were prepared. These materials were separated by painting them in different colors in certain proportions (Figure 4.21). Of the 100 kg of material prepared, 15 % was painted yellow, 20 % was painted blue, 25 % was painted black, and 40 % was painted white. All materials that have been painted were mixed homogeneously. The expectation in the tests is that the ratio of each color in the sample taken is the same with the ratio in the total amount of the material. In addition, the size of this material varies between 20-30 mm.

Figure 4.21: Painted materials for testing.

CHAPTER 5

EXPERIMENTAL RESULTS

25 different test setups were prepared. For these tests, 4 different colors of material with sizes between 10-30 mm were prepared. The prepared material is 100 kg in total. Of this 100 kg material, 40 kg was painted white, 25 kg was black, 20 kg was blue and 15 kg was yellow. These materials were mixed homogeneously before the test (Figure 5.1). For each test, the prototype sampler takes 5 samples from these mixed material and the results are compared. The sample taken is divided into color groups and it is checked whether the color ratios of the whole material and the sampled material are the same.

Figure 5.1: Homogeneously mixed materials.

TEST 1

In Test 1, the speed of the conveyor belt was 1 m/s at 16.1 Hz, and the cutter speed was 0.4 m/s at 33.3 Hz.

Table 5.1: Type decomposition of Test 1.

	WHITE (kg)	BLACK (kg)	BLUE (kg)	YELLOW (kg)	TOTAL
1ST SAMPLE	2.5	2.5	2.1	1.2	8.3
2ND SAMPLE	2.7	2.4	1.9	1.4	8.4
3RD SAMPLE	3	2.2	1.8	1.6	8.6
4TH SAMPLE	2.2	2.1	1.9	1.5	7.7
5TH SAMPLE	2.7	2.2	1.9	1.2	8
AVERAGE	2.62	2.28	1.92	1.38	8.2

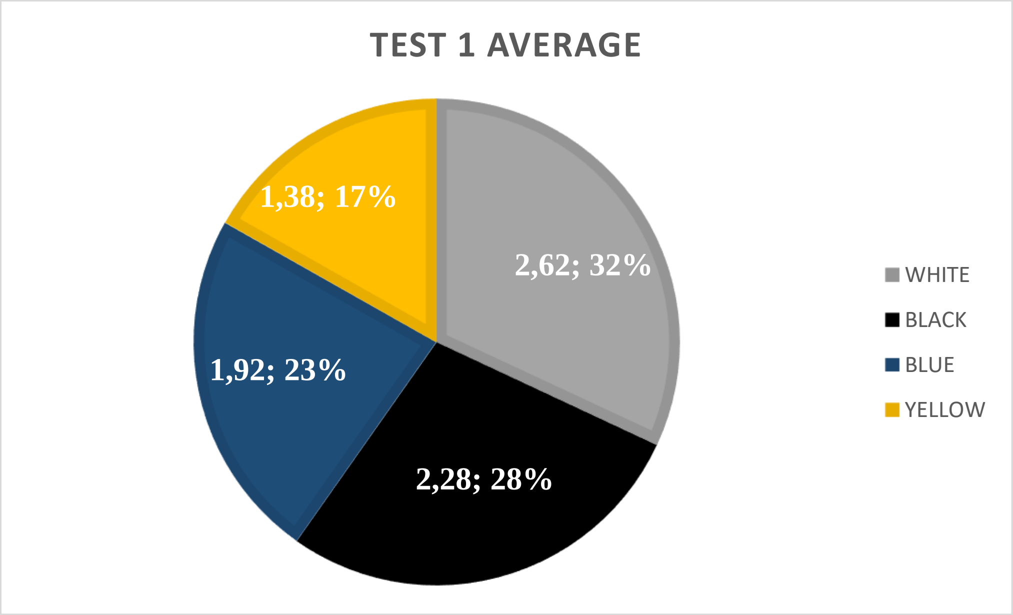


Figure 5.2: Piechart of Test 1 Average.

TEST 2

In Test 2, the speed of the conveyor belt was 1.5 m/s at 25 Hz, and the cutter speed was 0.4 m/s at 33.3 Hz.

Table 5.2: Type decomposition of Test 2.

	WHITE (kg)	BLACK (kg)	BLUE (kg)	YELLOW (kg)	TOTAL
1ST SAMPLE	3.2	2.6	1.8	1.2	8.8
2ND SAMPLE	3.6	2.3	1.9	1.9	9.7
3RD SAMPLE	3.5	2.5	1.8	1.4	9.2
4TH SAMPLE	3.1	2.9	1.5	1.5	9
5TH SAMPLE	2.9	2.4	1.5	1.4	8.2
AVERAGE	3.26	2.56	1.82	1.48	9.12

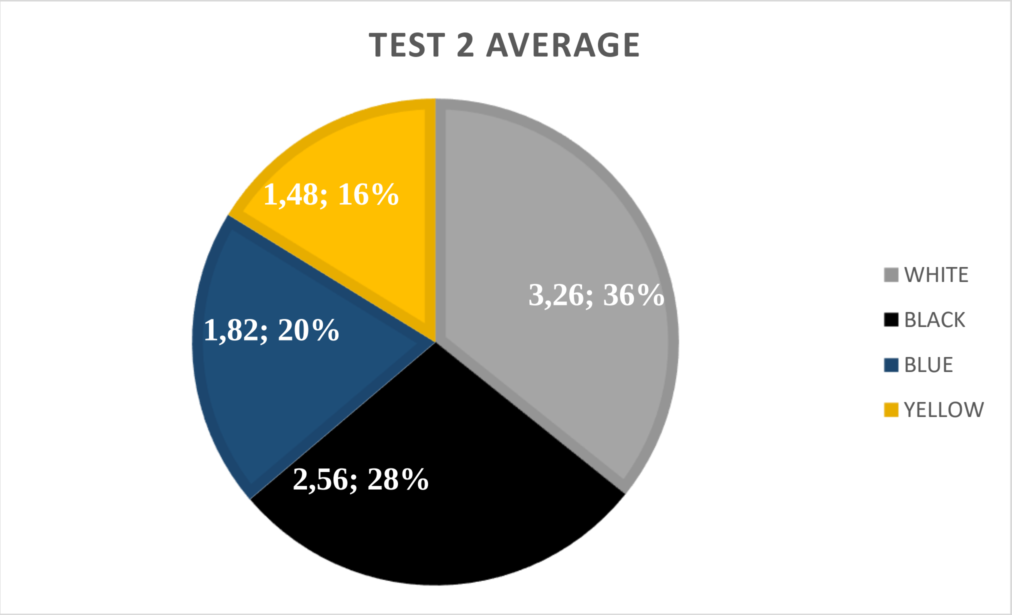


Figure 5.3: Piechart of Test 2 Average.

TEST 3

In Test 3, the speed of the conveyor belt was 2 m/s at 33.3 Hz, and the cutter speed was 0.4 m/s at 33.3 Hz.

Table 5.3: Type decomposition of Test 3.

	WHITE (kg)	BLACK (kg)	BLUE (kg)	YELLOW (kg)	TOTAL
1ST SAMPLE	3.9	2.4	2	1.5	9.8
2ND SAMPLE	3.5	2.6	2.2	1.7	10
3RD SAMPLE	3.6	2.5	2.3	1.7	10.1
4TH SAMPLE	3.3	2.8	2.5	1.9	10.5
5TH SAMPLE	4.1	2.4	2.1	1.1	9.7
AVERAGE	3.68	2.54	2.22	1.58	10.02

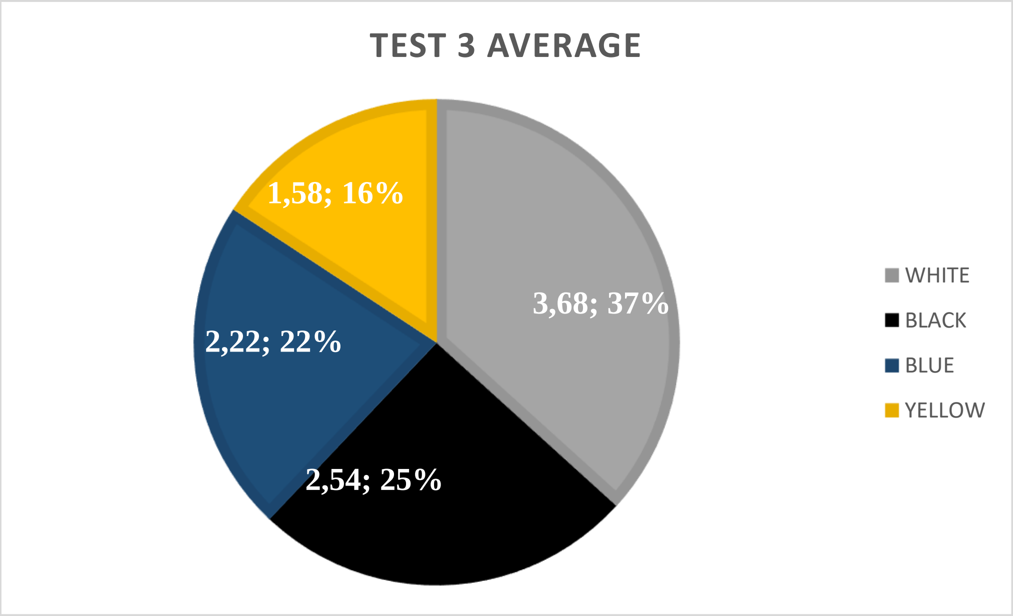


Figure 5.4: Piechart of Test 3 Average.

TEST 4

In Test 4, the speed of the conveyor belt was 2.5 m/s at 41.6 Hz, and the cutter speed was 0.4 m/s at 33.3 Hz.

Table 5.4: Type decomposition of Test 4.

	WHITE (kg)	BLACK (kg)	BLUE (kg)	YELLOW (kg)	TOTAL
1ST SAMPLE	4.1	2.5	2.2	1.5	10.3
2ND SAMPLE	4	2.7	2.4	1.7	10.8
3RD SAMPLE	3.7	2.8	2.8	2.2	11.5
4TH SAMPLE	4.3	2.9	1.8	1.7	10.7
5TH SAMPLE	4.2	2.6	2.1	1.6	10.5
AVERAGE	4.06	2.7	2.26	1.74	10.76

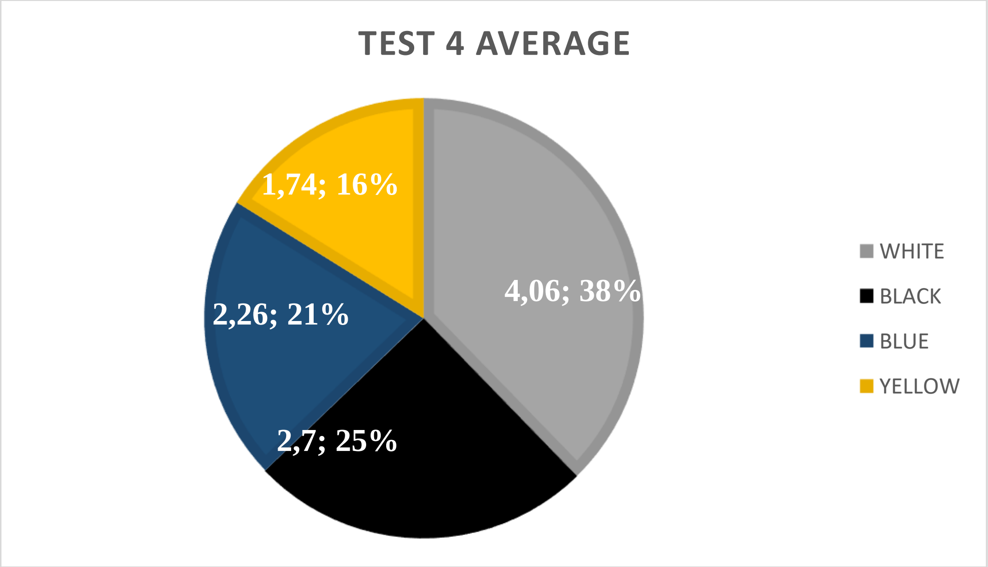


Figure 5.5: Piechart of Test 4 Average.

TEST 5

In Test 5, the speed of the conveyor belt was 3 m/s at 50 Hz, and the cutter speed was 0.4 m/s at 33.3 Hz.

Table 5.5: Type decomposition of Test 5.

	WHITE (kg)	BLACK (kg)	BLUE (kg)	YELLOW (kg)	TOTAL
1ST SAMPLE	4.4	2.7	2.3	1.6	11
2ND SAMPLE	4.2	2.6	2.4	1.8	11
3RD SAMPLE	4.1	2.8	2.5	1.7	11.1
4TH SAMPLE	4.5	3	2.1	1.5	11.1
5TH SAMPLE	4.3	2.8	2.3	1.5	10.9
AVERAGE	4.3	2.78	2.32	1.62	11.02

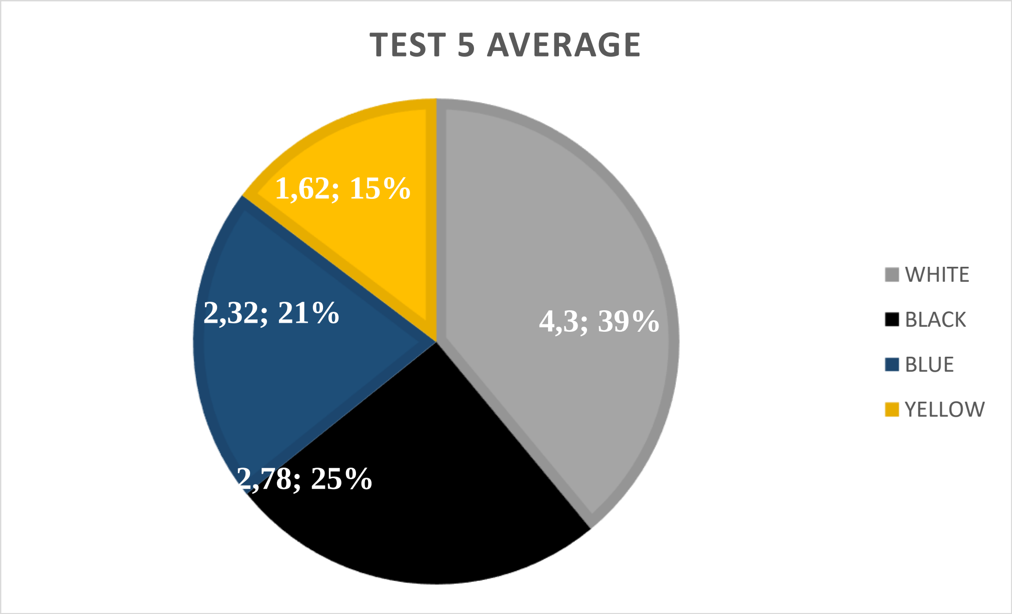


Figure 5.6: Piechart of Test 5 Average.

TEST 6

In Test 6, the speed of the conveyor belt was 1 m/s at 16.1 Hz, and the cutter speed was 0.5 m/s at 41.6 Hz.

Table 5.6: Type decomposition of Test 6.

	WHITE (kg)	BLACK (kg)	BLUE (kg)	YELLOW (kg)	TOTAL
1ST SAMPLE	2.8	1.7	1.4	1	6.9
2ND SAMPLE	2.4	1.9	1.3	0.8	6.4
3RD SAMPLE	2.9	1.9	1.1	1.1	7
4TH SAMPLE	2.7	1.7	0.8	1.2	6.4
5TH SAMPLE	3.1	1.4	1.2	0.9	6.6
AVERAGE	2.78	1.72	1.16	1	6.66

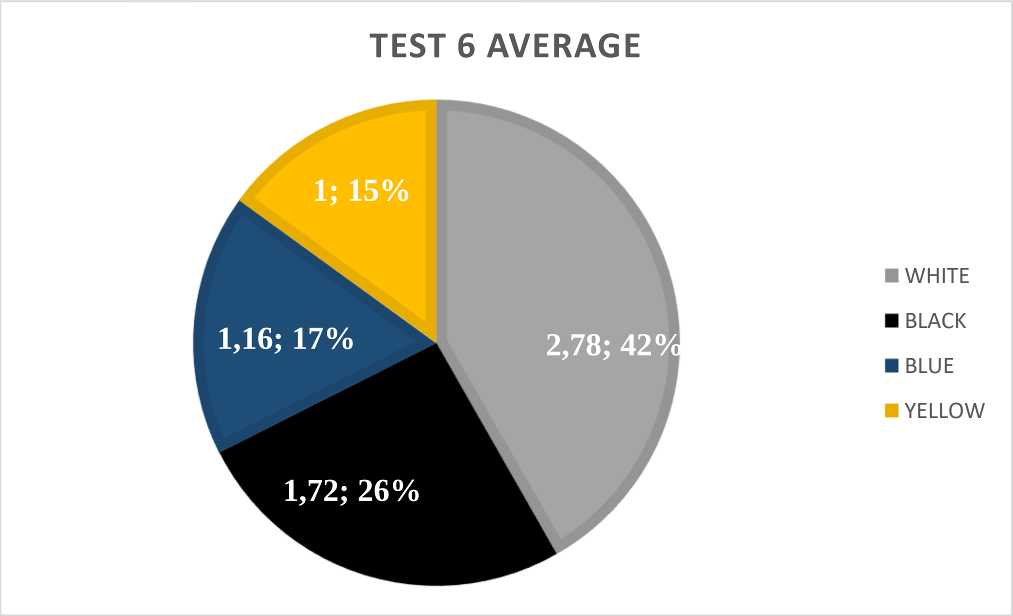


Figure 5.7: Piechart of Test 6 Average.

TEST 7

In Test 7, the speed of the conveyor belt was 1.5 m/s at 25 Hz, and the cutter speed was 0.5 m/s at 41.6 Hz.

Table 5.7: Type decomposition of Test 7.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1^{ST} SAMPLE	3	1.8	1.3	1.1	7.2
2^{ND} SAMPLE	2.6	2	1.2	0.8	6.6
3^{RD} SAMPLE	3	1.9	1.2	1.1	7.2
4^{TH} SAMPLE	2.8	1.9	1.5	1.1	7.3
5^{TH} SAMPLE	3.8	1.2	1.6	1	7.6
AVERAGE	3.04	1.76	1.36	1.02	7.18

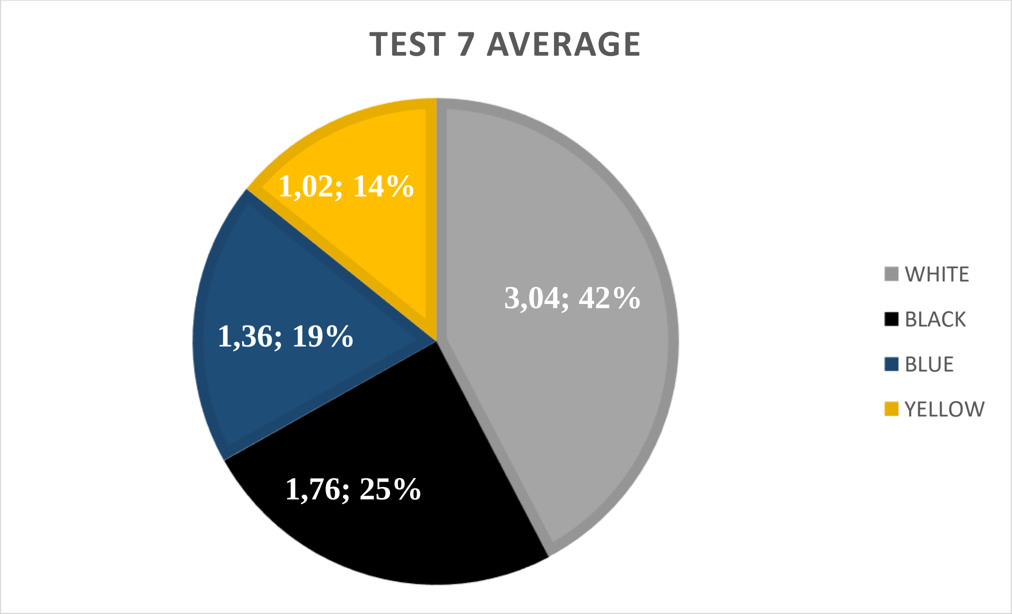


Figure 5.8: Piechart of Test 7 Average.

TEST 8

In Test 8, the speed of the conveyor belt was 2 m/s at 33.3 Hz, and the cutter speed was 0.5 m/s at 41.6 Hz.

Table 5.8: Type decomposition of Test 8.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	3.2	2	1.7	1	7.9
2ND SAMPLE	2.9	1.8	1.3	1.1	7.1
3RD SAMPLE	3.6	2.2	1.8	1.4	9
4TH SAMPLE	2.6	2.1	1.6	1.3	7.6
5TH SAMPLE	3.1	1.4	1.8	1	7.3
AVERAGE	3.08	1.9	1.64	1.16	7.78

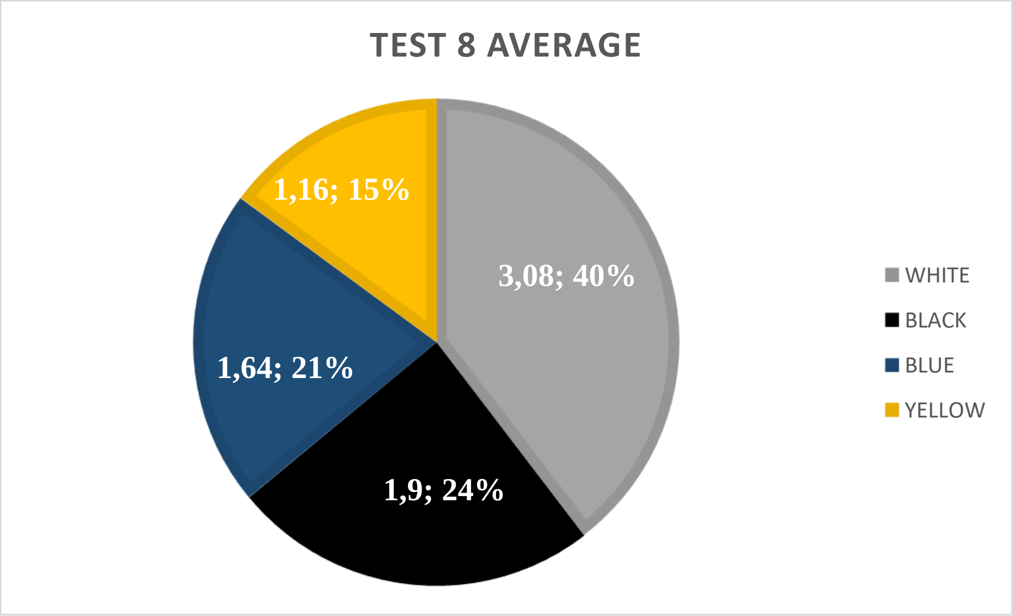


Figure 5.9: Piechart of Test 8 Average.

TEST 9

In Test 9, the speed of the conveyor belt was 2.5 m/s at 41.6 Hz, and the cutter speed was 0.5 m/s at 41.6 Hz.

Table 5.9: Type decomposition of Test 9.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	3.4	2.1	1.9	1.5	8.9
2ND SAMPLE	3	1.8	1.3	1.1	7.2
3RD SAMPLE	3.9	2.3	1.8	1.3	9.3
4TH SAMPLE	2.8	2	1.9	1.1	7.8
5TH SAMPLE	3.4	1.7	1.8	1.2	8.1
AVERAGE	3.3	1.98	1.74	1.24	8.26

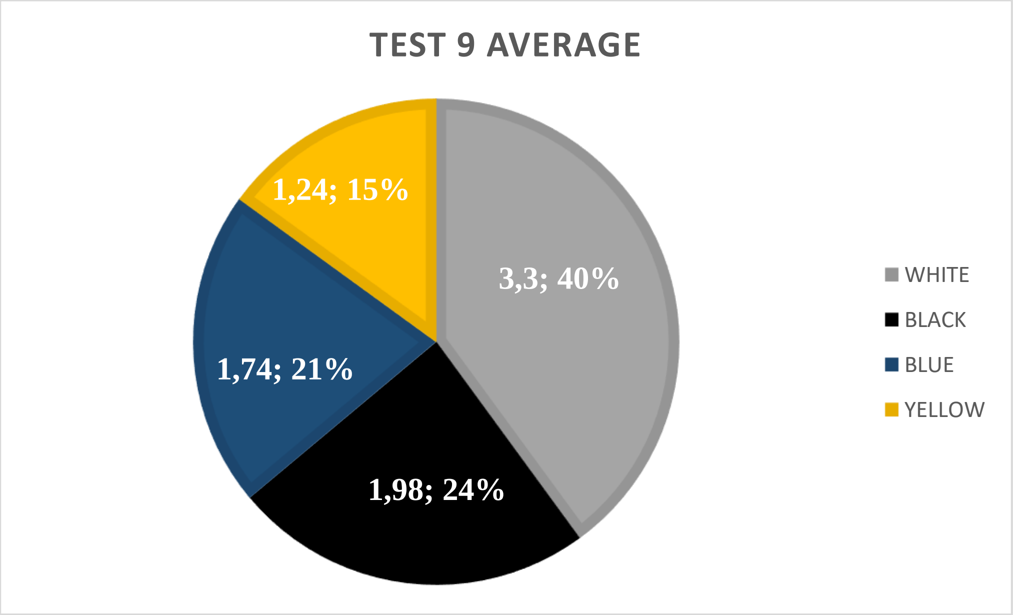


Figure 5.10: Piechart of Test 9 Average.

TEST 10

In Test 10, the speed of the conveyor belt was 3 m/s at 50 Hz, and the cutter speed was 0.5 m/s at 41.6 Hz.

Table 5.10: Type decomposition of Test 10.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	3.8	2.4	2.1	1.7	10
2ND SAMPLE	3.1	1.8	1.4	0.8	7.1
3RD SAMPLE	4	2.1	2	1.8	9.9
4TH SAMPLE	3.5	2.8	2.2	1.6	10.1
5TH SAMPLE	3.4	1.3	1.8	1.8	8.3
AVERAGE	3.56	2.08	1.9	1.54	9.08

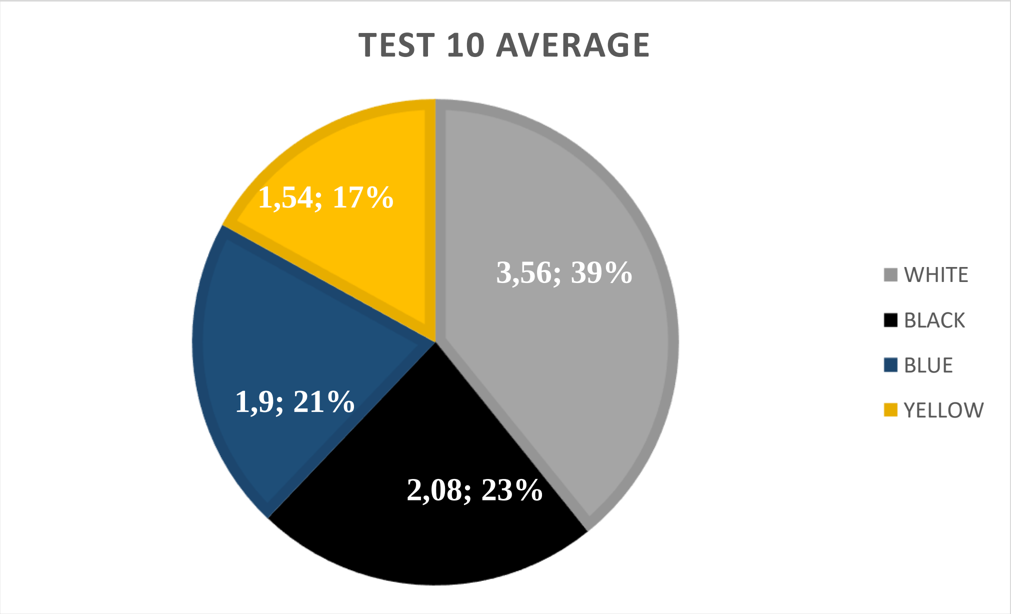


Figure 5.11: Piechart of Test 10 Average.

TEST 11

In Test 11, the speed of the conveyor belt was 1 m/s at 16.1 Hz, and the cutter speed was 0.6 m/s at 50 Hz.

Table 5.11: Type decomposition of Test 11.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	1.4	0.9	0.7	0.5	3.5
2ND SAMPLE	1.5	1	0.75	0.6	3.85
3RD SAMPLE	1.3	0.8	0.65	0.5	3.25
4TH SAMPLE	1.5	0.95	0.75	0.55	3.75
5TH SAMPLE	1.35	0.9	0.7	0.7	3.65
AVERAGE	1.41	0.91	0.71	0.57	3.6

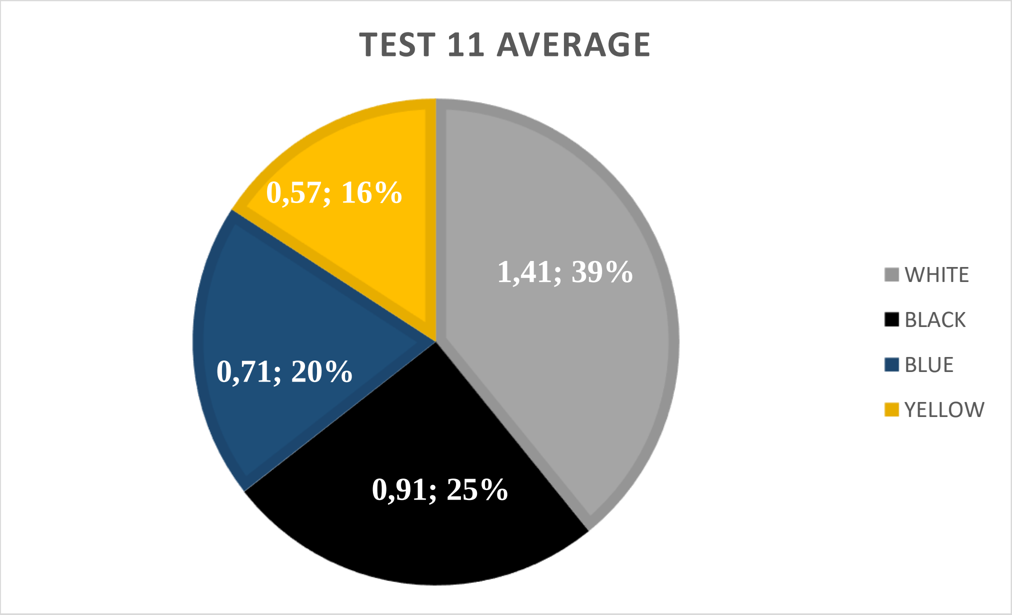


Figure 5.12: Piechart of Test 11 Average.

TEST 12

In Test 12, the speed of the conveyor belt was 1.5 m/s at 25 Hz, and the cutter speed was 0.6 m/s at 50 Hz.

Table 5.12: Type decomposition of Test 12.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	1.65	1	0.65	0.6	3.9
2ND SAMPLE	1.8	1.05	0.95	0.7	4.5
3RD SAMPLE	1.75	0.9	0.85	0.55	4.05
4TH SAMPLE	1.5	1.2	0.85	0.65	4.2
5TH SAMPLE	2	1.15	0.95	0.6	4.7
AVERAGE	1.74	1.06	0.85	0.62	4.27

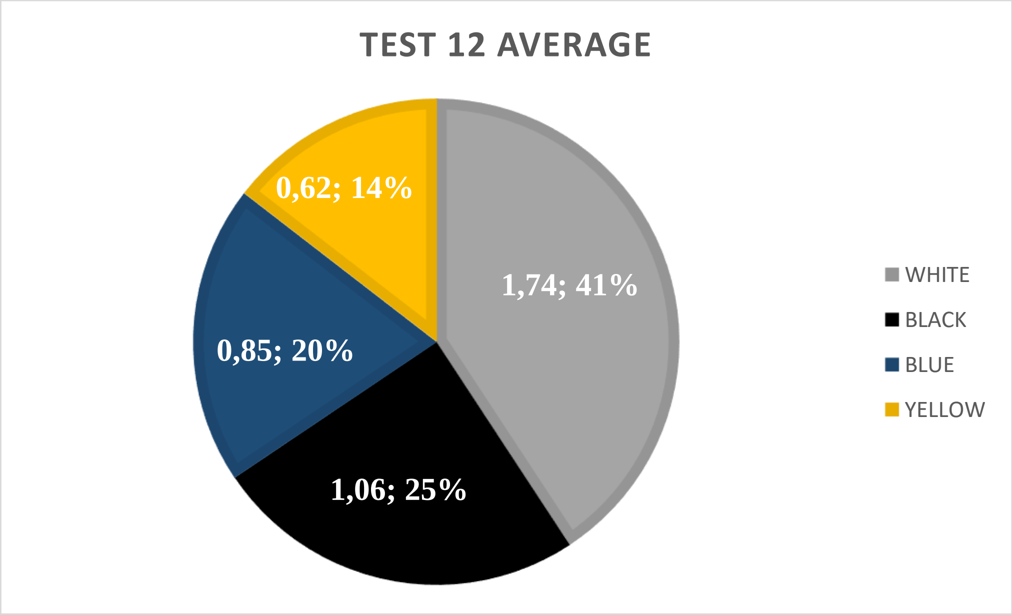


Figure 5.13: Piechart of Test 12 Average.

TEST 13

In Test 13, the speed of the conveyor belt was 2 m/s at 33.3 Hz, and the cutter speed was 0.6 m/s at 50 Hz.

Table 5.13: Type decomposition of Test 13.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	2.25	1.4	1.1	0.85	5.6
2ND SAMPLE	2.1	1.3	1.05	0.8	5.25
3RD SAMPLE	1.9	1.2	0.95	0.7	4.75
4TH SAMPLE	2.05	1.25	1	0.75	5.05
5TH SAMPLE	1.94	1.2	0.95	0.7	4.79
AVERAGE	2.048	1.27	1.01	0.76	5.088

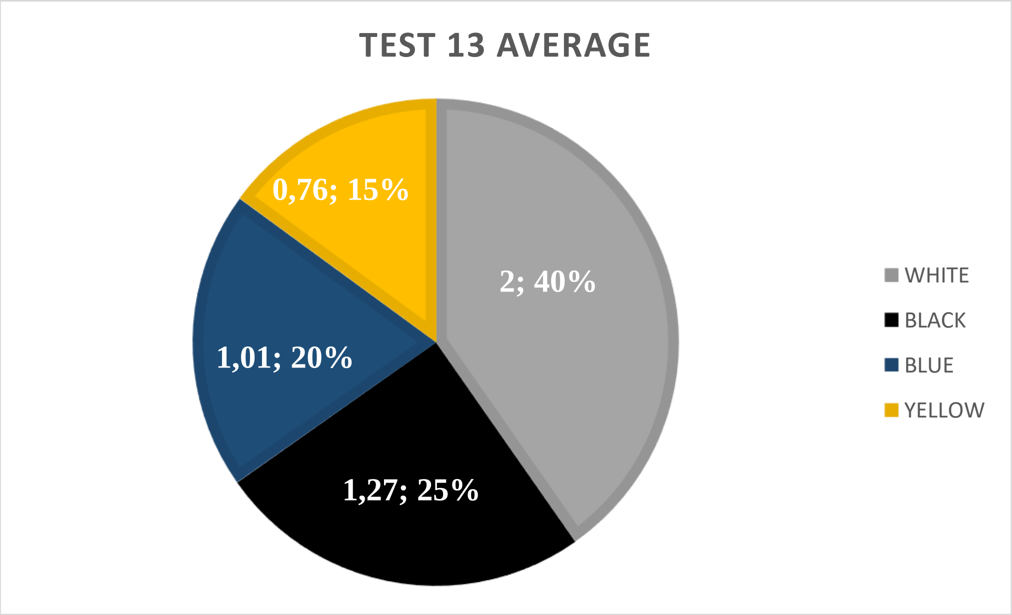


Figure 5.14: Piechart of Test 13 Average.

TEST 14

In Test 14, the speed of the conveyor belt was 2.5 m/s at 41.6 Hz, and the cutter speed was 0.6 m/s at 50 Hz.

Table 5.14: Type decomposition of Test 14.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	2.5	1.6	1.4	0.8	6.3
2ND SAMPLE	2.4	1.4	1	0.85	5.65
3RD SAMPLE	2.2	1.1	0.9	0.9	5.1
4TH SAMPLE	2.7	1.5	1.15	0.75	6.1
5TH SAMPLE	2	1.4	1.4	1	5.8
AVERAGE	2.36	1.4	1.17	0.86	5.79

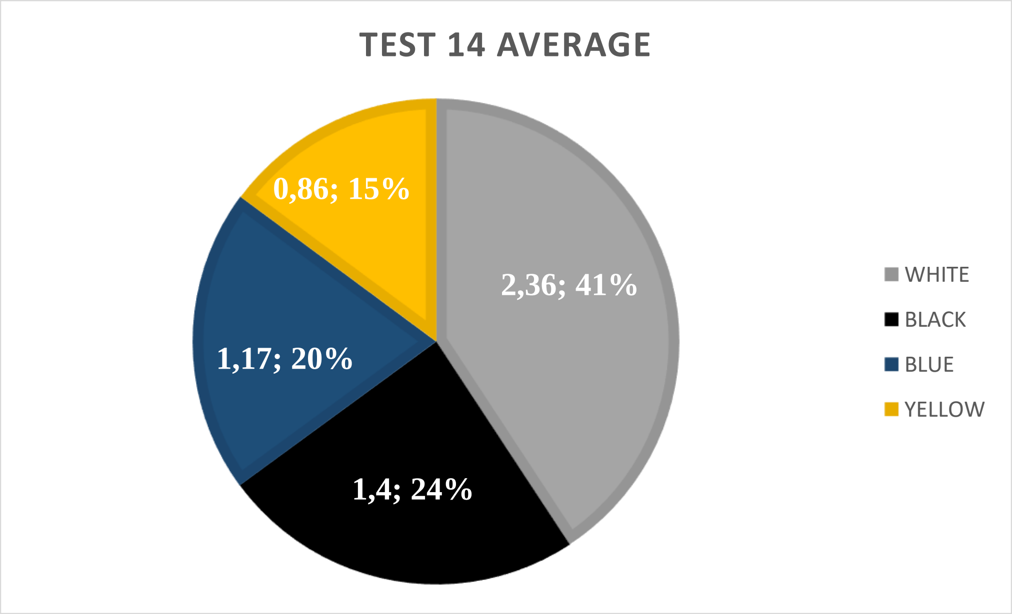


Figure 5.15: Piechart of Test 14 Average.

TEST 15

In Test 15, the speed of the conveyor belt was 3 m/s at 50 Hz, and the cutter speed was 0.6 m/s at 50 Hz.

Table 5.15: Type decomposition of Test 15.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	2.5	1.7	1.3	0.85	6.35
2ND SAMPLE	2.35	1.4	1	0.95	5.7
3RD SAMPLE	2.8	1.65	1.5	0.95	6.9
4TH SAMPLE	2.6	1.8	1.5	1	6.9
5TH SAMPLE	2.8	1.6	1.3	1.05	6.9
AVERAGE	2.61	1.63	1.32	0.96	6.75

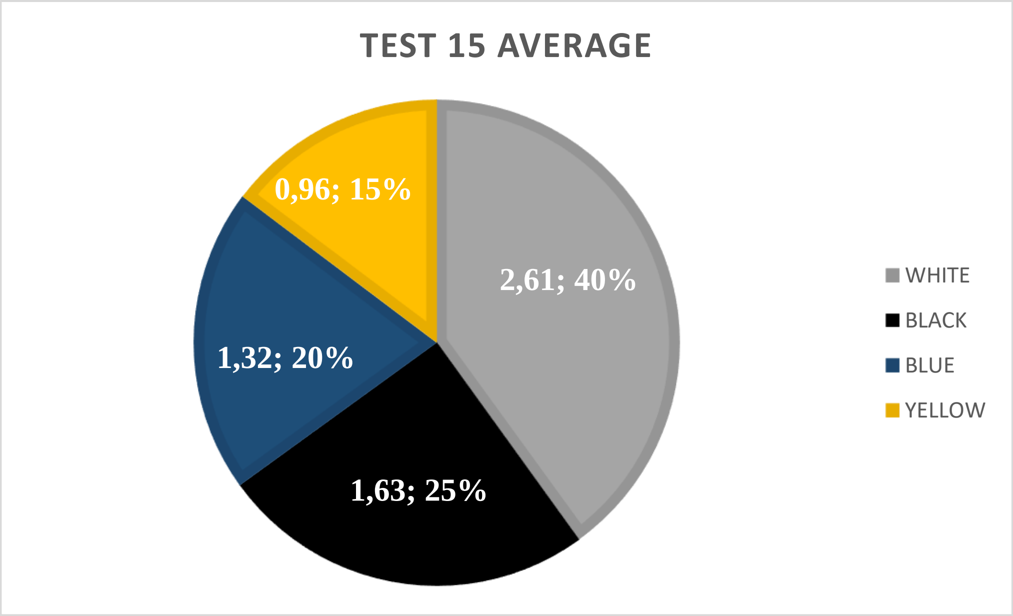


Figure 5.16: Piechart of Test 15 Average.

TEST 16

In Test 16, the speed of the conveyor belt was 1 m/s at 16.1 Hz, and the cutter speed was 0.7 m/s at 58 Hz.

Table 5.16: Type decomposition of Test 16.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	1.4	0.9	0.5	0.6	3.4
2ND SAMPLE	1.5	0.8	0.65	0.55	3.5
3RD SAMPLE	1.55	0.95	0.8	0.4	3.7
4TH SAMPLE	1.8	1.1	0.75	0.65	4.3
5TH SAMPLE	1.6	1	0.85	0.55	4
AVERAGE	1.57	0.95	0.71	0.55	3.78

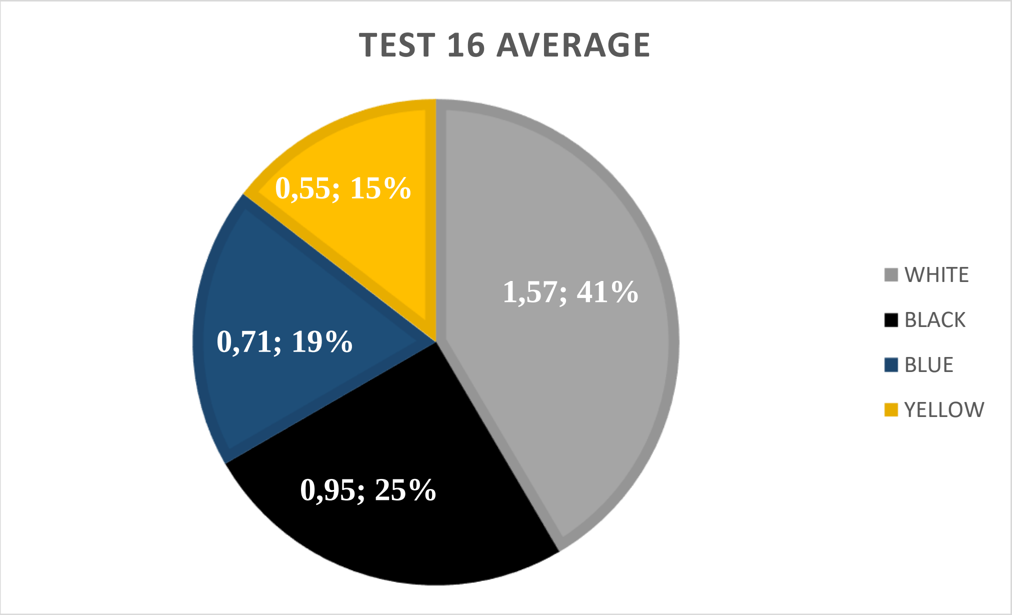


Figure 5.17: Piechart of Test 16 Average.

TEST 17

In Test 17, the speed of the conveyor belt was 1.5 m/s at 25 Hz, and the cutter speed was 0.7 m/s at 58 Hz.

Table 5.17: Type decomposition of Test 17.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	1.6	1	0.8	0.6	4
2ND SAMPLE	1.45	1.2	0.75	0.8	4.2
3RD SAMPLE	1.8	1.3	0.7	0.55	4.35
4TH SAMPLE	1.5	1.15	0.9	0.6	4.15
5TH SAMPLE	1.6	1.05	1.1	0.8	4.55
AVERAGE	1.59	1.14	0.85	0.67	4.25

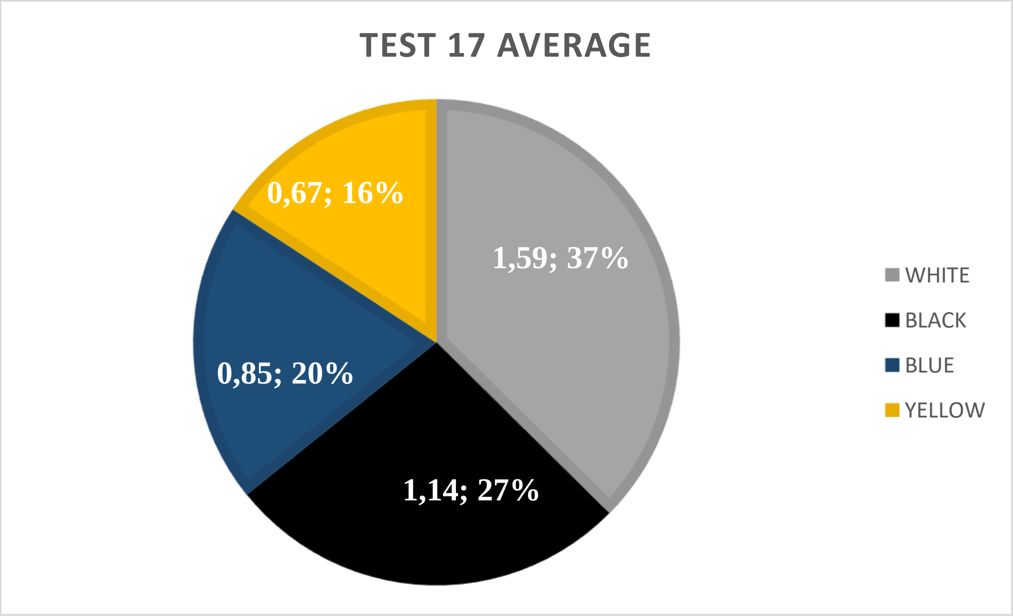


Figure 5.18: Piechart of Test 17 Average.

TEST 18

In Test 18, the speed of the conveyor belt was 2 m/s at 33.3 Hz, and the cutter speed was 0.7 m/s at 58 Hz.

Table 5.18: Type decomposition of Test 18.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	1.9	1.2	0.95	0.75	4.8
2ND SAMPLE	2	1.1	0.5	0.7	4.3
3RD SAMPLE	2.4	1.4	0.85	0.5	5.15
4TH SAMPLE	2.1	1.05	1.1	0.8	5.05
5TH SAMPLE	1.6	1.5	1.3	0.95	5.35
AVERAGE	2	1.25	0.94	0.74	4.93

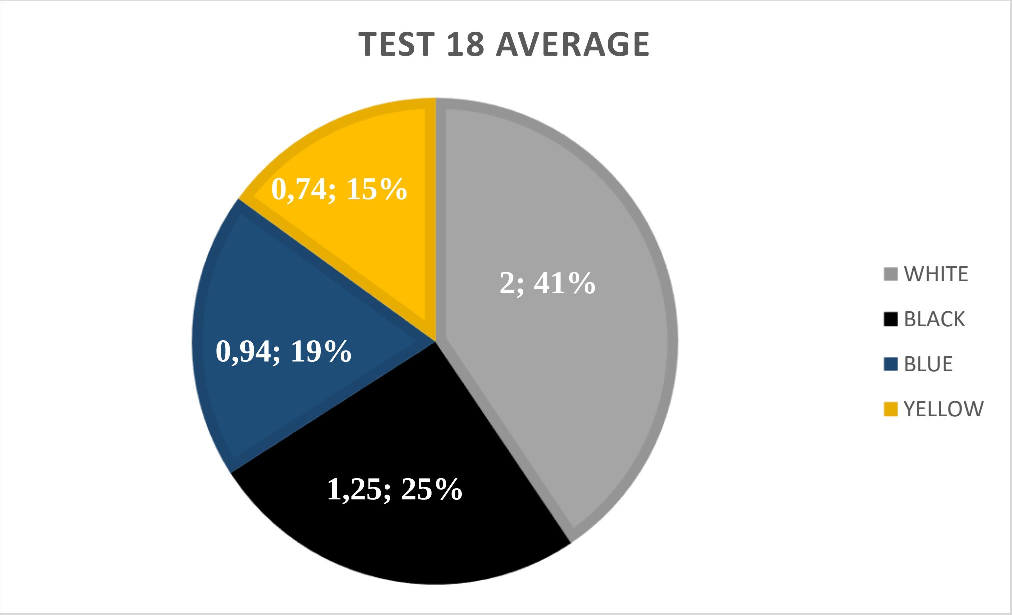


Figure 5.19: Piechart of Test 18 Average.

TEST 19

In Test 19, the speed of the conveyor belt was 2.5 m/s at 41.6 Hz, and the cutter speed was 0.7 m/s at 58 Hz.

Table 5.19: Type decomposition of Test 19.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	2.05	1.3	1.05	0.8	5.2
2ND SAMPLE	2.4	1.8	0.95	0.4	5.55
3RD SAMPLE	2.1	1.55	0.95	0.75	5.35
4TH SAMPLE	2.2	1.4	1.25	0.65	5.5
5TH SAMPLE	1.9	1.25	1.1	0.7	4.95
AVERAGE	2.13	1.46	1.06	0.66	5.31

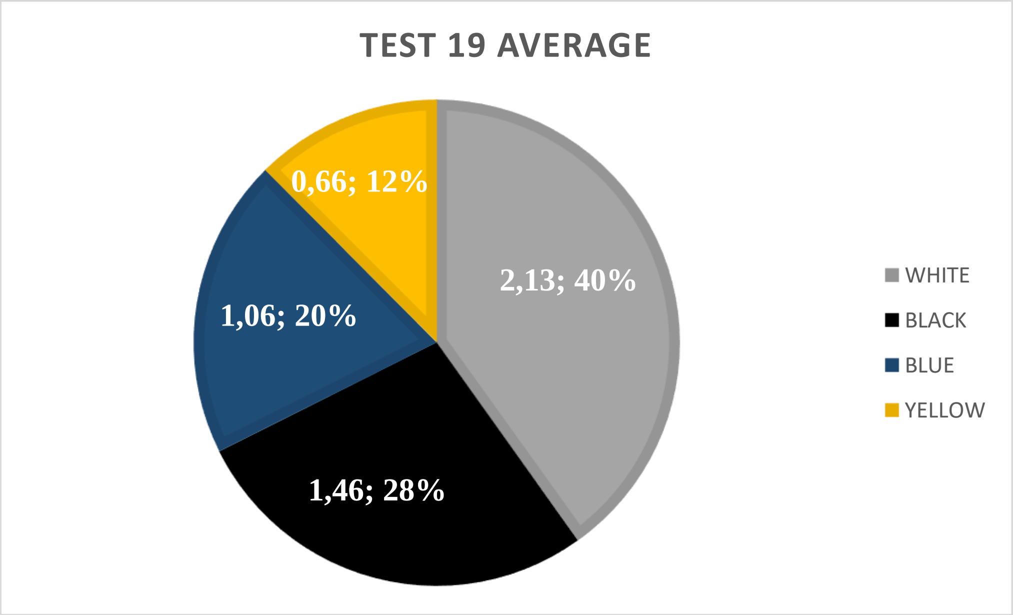


Figure 5.20: Piechart of Test 19 Average.

TEST 20

In Test 20, the speed of the conveyor belt was 3 m/s at 50 Hz, and the cutter speed was 0.7 m/s at 58 Hz.

Table 5.20: Type decomposition of Test 20.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	2.3	1.45	1.15	0.85	5.75
2ND SAMPLE	2.5	1.4	1.4	1	6.3
3RD SAMPLE	2	1.8	1.9	1.15	6.85
4TH SAMPLE	1.8	1.1	1.3	1.05	5.25
5TH SAMPLE	1.95	1.5	1.75	0.8	6
AVERAGE	2.11	1.45	1.5	0.97	6.03

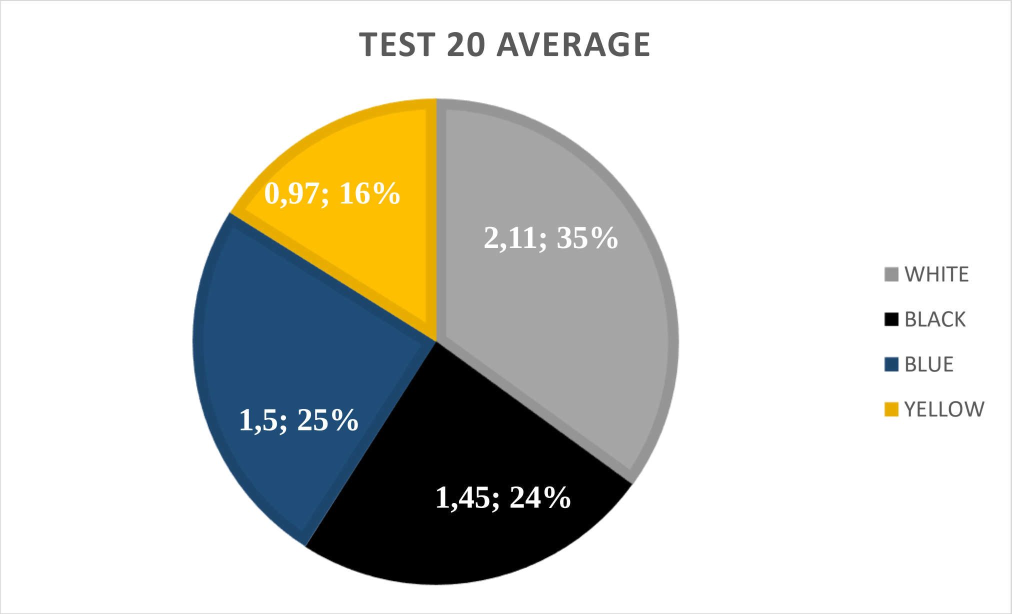


Figure 5.21: Piechart of Test 20 Average.

TEST 21

In Test 21, the speed of the conveyor belt was 1 m/s at 16.1 Hz, and the cutter speed was 0.8 m/s at 66.6 Hz.

Table 5.21: Type decomposition of Test 21.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1^{ST} SAMPLE	1.2	0.75	0.6	0.45	3
2^{ND} SAMPLE	1	0.7	0.75	0.5	2.95
3^{RD} SAMPLE	0.95	0.8	0.65	0.2	2.6
4^{TH} SAMPLE	1.05	0.85	0.8	0.45	3.15
5^{TH} SAMPLE	1.1	0.95	0.75	0.4	3.2
AVERAGE	1.06	0.81	0.82	0.4	2.98

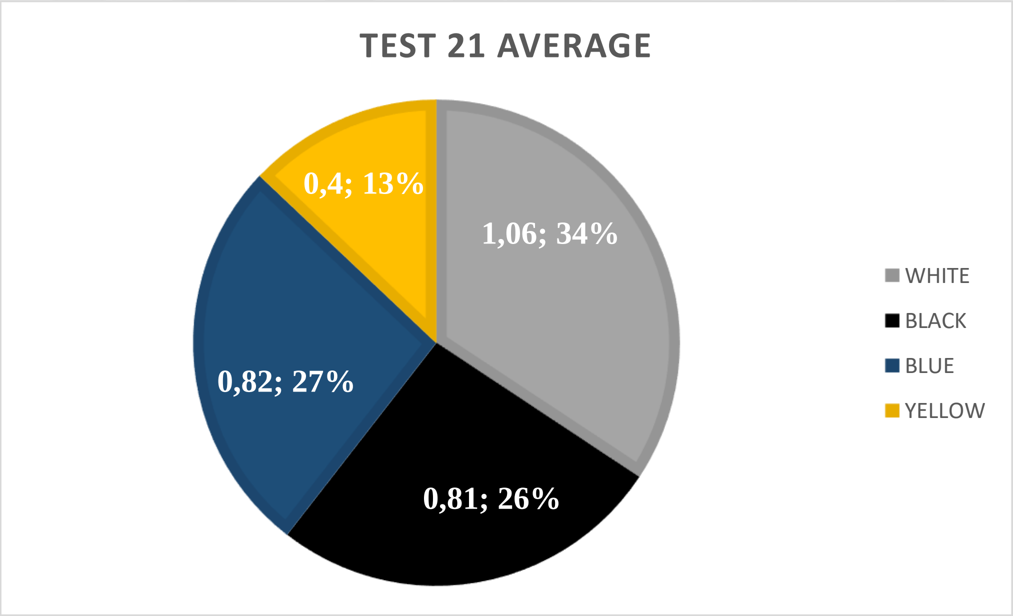


Figure 5.22: Piechart of Test 21 Average.

TEST 22

In Test 22, the speed of the conveyor belt was 1.5 m/s at 25 Hz, and the cutter speed was 0.8 m/s at 66.6 Hz.

Table 5.22: Type decomposition of Test 22.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	1.4	0.9	0.75	0.55	3.6
2ND SAMPLE	1.36	0.95	0.7	0.45	3.4
3RD SAMPLE	1.4	1.4	0.6	0.3	3.7
4TH SAMPLE	1.2	1.1	0.7	0.75	3.75
5TH SAMPLE	1	0.7	0.9	0.4	3
AVERAGE	1.26	1.01	0.73	0.49	3.49

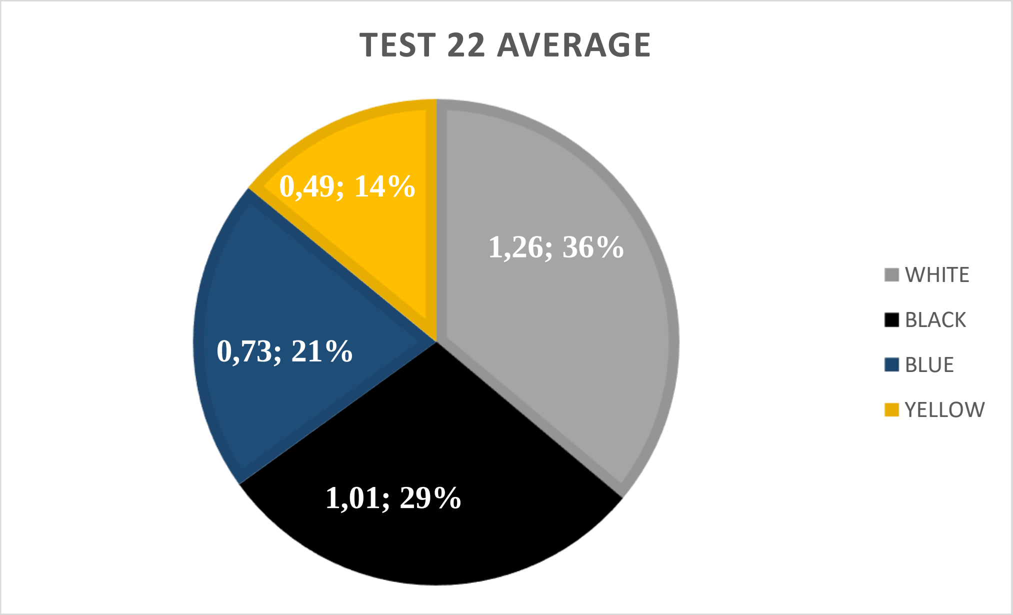


Figure 5.23: Piechart of Test 22 Average.

TEST 23

In Test 23, the speed of the conveyor belt was 2 m/s at 33.3 Hz, and the cutter speed was 0.8 m/s at 66.6 Hz.

Table 5.23: Type decomposition of Test 23.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	1.8	1.15	0.9	0.65	4.5
2ND SAMPLE	1.6	1.35	0.8	0.7	4.45
3RD SAMPLE	1.4	1.3	0.65	0.65	4
4TH SAMPLE	1.55	1.1	0.95	0.8	4.4
5TH SAMPLE	1.7	0.95	1.1	0.9	4.65
AVERAGE	1.61	1.17	0.88	0.74	4.4

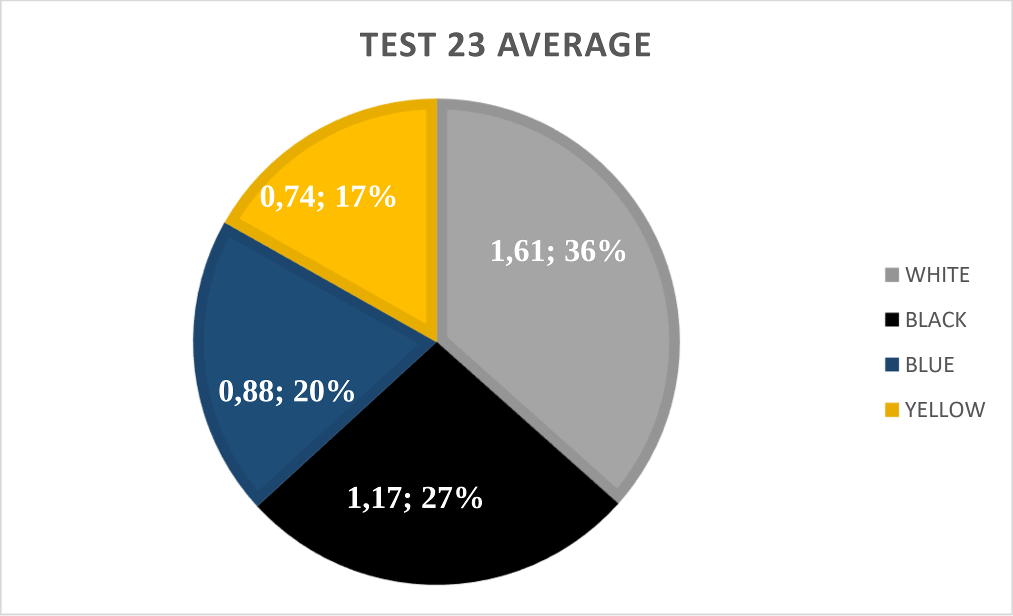


Figure 5.24: Piechart of Test 23 Average.

TEST 24

In Test 24, the speed of the conveyor belt was 2.5 m/s at 41.6 Hz, and the cutter speed was 0.8 m/s at 66.6 Hz.

Table 5.24: Type decomposition of Test 24.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	2.2	1.35	1.1	0.85	5.5
2ND SAMPLE	2.05	1.45	1.3	0.5	5.3
3RD SAMPLE	2.4	1.3	1.2	0.3	5.2
4TH SAMPLE	2.15	1.8	1	0.5	5.45
5TH SAMPLE	1.95	1.1	1.8	0.7	5.55
AVERAGE	2.15	1.4	1.28	0.57	5.4

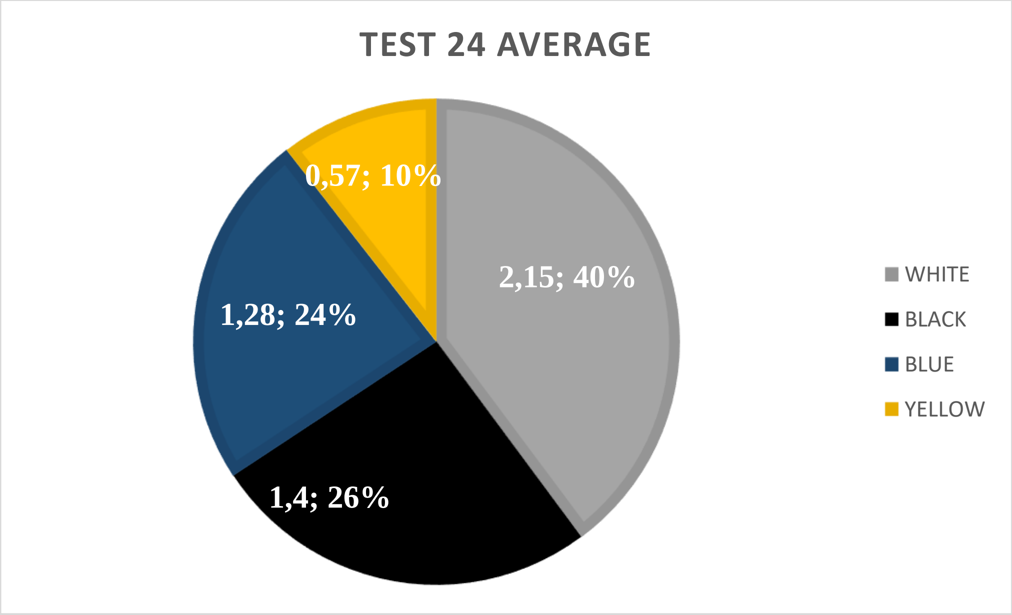


Figure 5.25: Piechart of Test 24 Average.

TEST 25

In Test 25, the speed of the conveyor belt was 3 m/s at 50 Hz, and the cutter speed was 0.8 m/s at 66.6 Hz.

Table 5.25: Type decomposition of Test 25.

	WHITE (% 40)	BLACK (% 25)	BLUE (% 20)	YELLOW (% 15)	TOTAL
1ST SAMPLE	2.4	1.5	1.2	0.9	6
2ND SAMPLE	2.8	1.1	1.4	0.5	5.8
3RD SAMPLE	2.1	1.6	1.5	0.8	6
4TH SAMPLE	2.5	1.45	1.55	0.85	6.35
5TH SAMPLE	1.9	1.75	1.25	1.2	6.1
AVERAGE	2.34	1.48	1.38	0.85	6.05

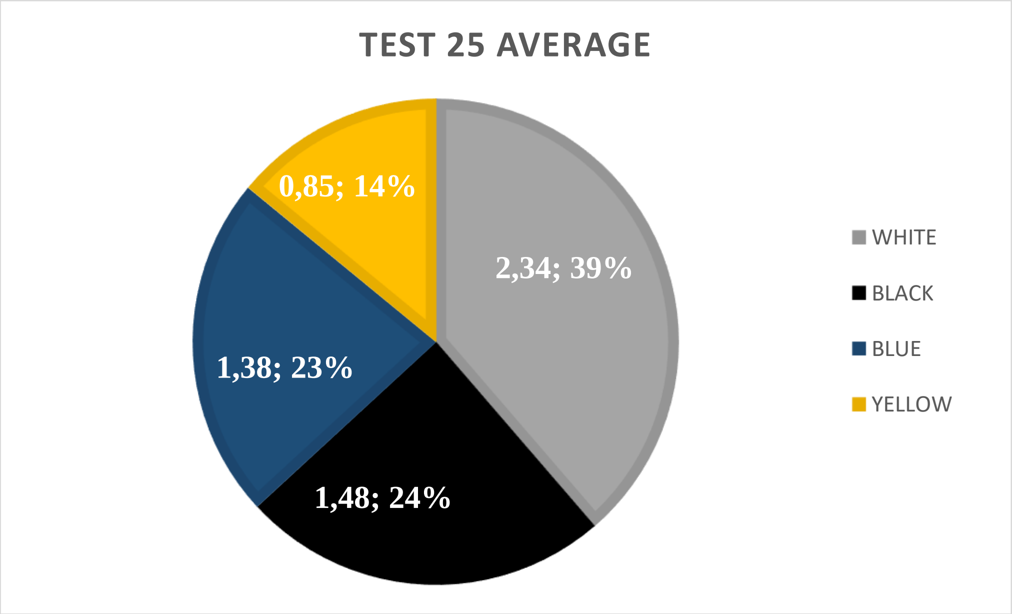


Figure 5.26: Piechart of Test 25 Average.

Averages of each of the 25 different tests were calculated and all results are shown in Table 5.26.

Table 5.26: Results of All Tests.

	Cutter Speed (m/s)	Conveyor Belt Speed (m/s)	White %40	Black %25	Blue %20	Yellow %15
Test 1	0.4	1	32	28	23	17
Test 2	0.4	1.5	36	28	20	16
Test 3	0.4	2	37	25	22	16
Test 4	0.4	2.5	38	25	21	16
Test 5	0.4	3	39	25	21	15
Test 6	0.5	1	42	26	17	15
Test 7	0.5	1.5	42	25	19	14
Test 8	0.5	2	40	24	21	15
Test 9	0.5	2.5	40	24	21	15
Test 10	0.5	3	39	23	21	17
Test 11	0.6	1	39	25	20	16
Test 12	0.6	1.5	41	25	20	14
Test 13	0.6	2	40	25	20	15
Test 14	0.6	2.5	41	24	20	15
Test 15	0.6	3	40	25	20	15
Test 16	0.7	1	41	25	19	15
Test 17	0.7	1.5	37	27	20	16
Test 18	0.7	2	41	25	19	15
Test 19	0.7	2.5	40	28	20	12
Test 20	0.7	3	35	24	25	16
Test 21	0.8	1	34	26	27	13
Test 22	0.8	1.5	36	29	21	14
Test 23	0.8	2	36	27	20	17
Test 24	0.8	2.5	40	26	24	10
Test 25	0.8	3	39	24	23	14

The conditions of the experiment and the separation of the sample results are shown in Figures 5.27 – 5.29.

Figure 5.27: A photo during the experiment.

Figure 5.28: Homogeneously mixed materials flowing regularly.

Figure 5.29: The samples are separated by colour.

CHAPTER 6

DISCUSSION AND CONCLUSIONS

The results of the research, theoretical calculations, analyses, and experiments conducted within the scope of this thesis will be discussed in this chapter.

One of the most successful types of sampling systems are those that take samples during free fall. Free fall sampling systems have been produced in line with the previous sampling systems, standards, research, tests, and analyses conducted in the past.

Sampling is a key stage in many important points such as producing the right product, selling the right product, and reducing the production costs, provided that the sample is taken under the right conditions in accordance with the standards. To test these conditions, 25 different tests were set up and 5 samples were taken in each test. The average of 5 samples at each test was calculated and this data was tabulated. To generate test conditions, the cutter speed and conveyor belt speed were varied using a frequency converter.

According to the standards, there is no calculation for cutter speed calculation in free-flow sampling systems and it is specified as 0.6 m/s. To confirm this value, in this thesis, different current speeds such as 0.4, 0.5, 0.6, 0.7, and 0.8 m/s were used in the experiments.

Conveyor belts used in factories can be at very different speeds. For this reason, 5 different conveyor belt speeds were used in the experiments. These speeds are 1, 1.5, 2, 2.5, 3 m/s.

Samples were taken at all conveyor belt speeds with each cutter speed.

When the test results are analyzed, the most representative samples are in Test 15, and Test 13. In Test 15, 0.6 m/s cutter speed and 3 m/s conveyor belt speed were used. In Test 13, 0.6 m/s cutter speed and 2 m/s conveyor belt speed were used.

In addition to the above tests, 7 more test results have very good representativeness. These experiments are 8, 9, 11, 12, 14, 16, and 18. The common feature in these results is that the cutter speed is 0.6 m/s.

When the results of all experiments are analyzed, it is understood that the first common feature of the most representative and good-representative samples is the cutter speed of 0.6 m/s. The second common feature is the conveyor belt speed of 2 m/s.

As a result of the experiments, it was concluded that a fully representative sampling machine using free-falling sampling method is produced. In parallel with the standards, the most representative tests were operated with a cutter speed of 0.6 m/s. In addition, a conveyor belt speed of 2 m/s is suggested to have representative samples. Because among all conveyor belt speeds that speed had most representative results.

Following the methods used in the design and the experimental stages of this study, new sampling systems may be produced for different materials with different capacities.

Table 6.1: Comparison of most representative samples

	1	1.5	2	2.5	3
0.4					
0.5			Test 8	Test 9	
0.6	Test 11	Test 12	Test 13	Test 14	Test 15
0.7	Test 16		Test 18		
0.8					

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APPENDICES

APPENDIX A

ELECTRICAL PROJECT

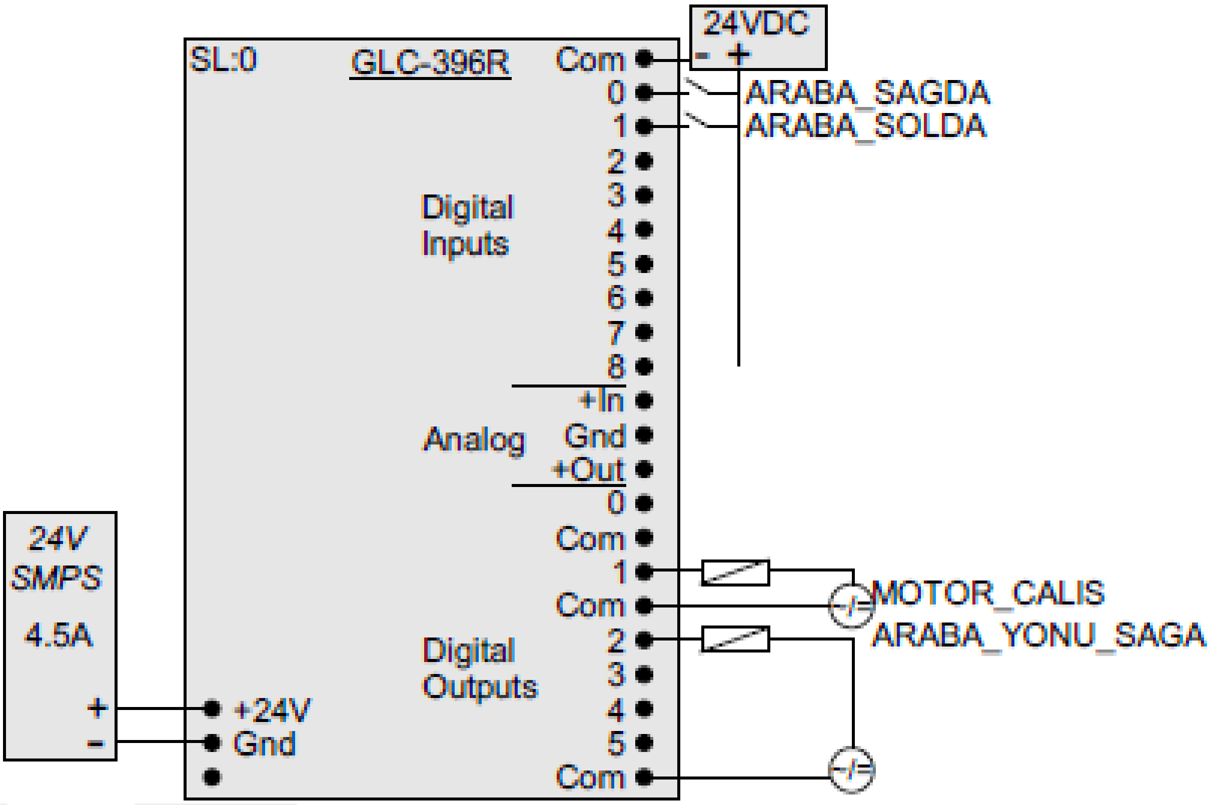

Figure A.1: PLC connections

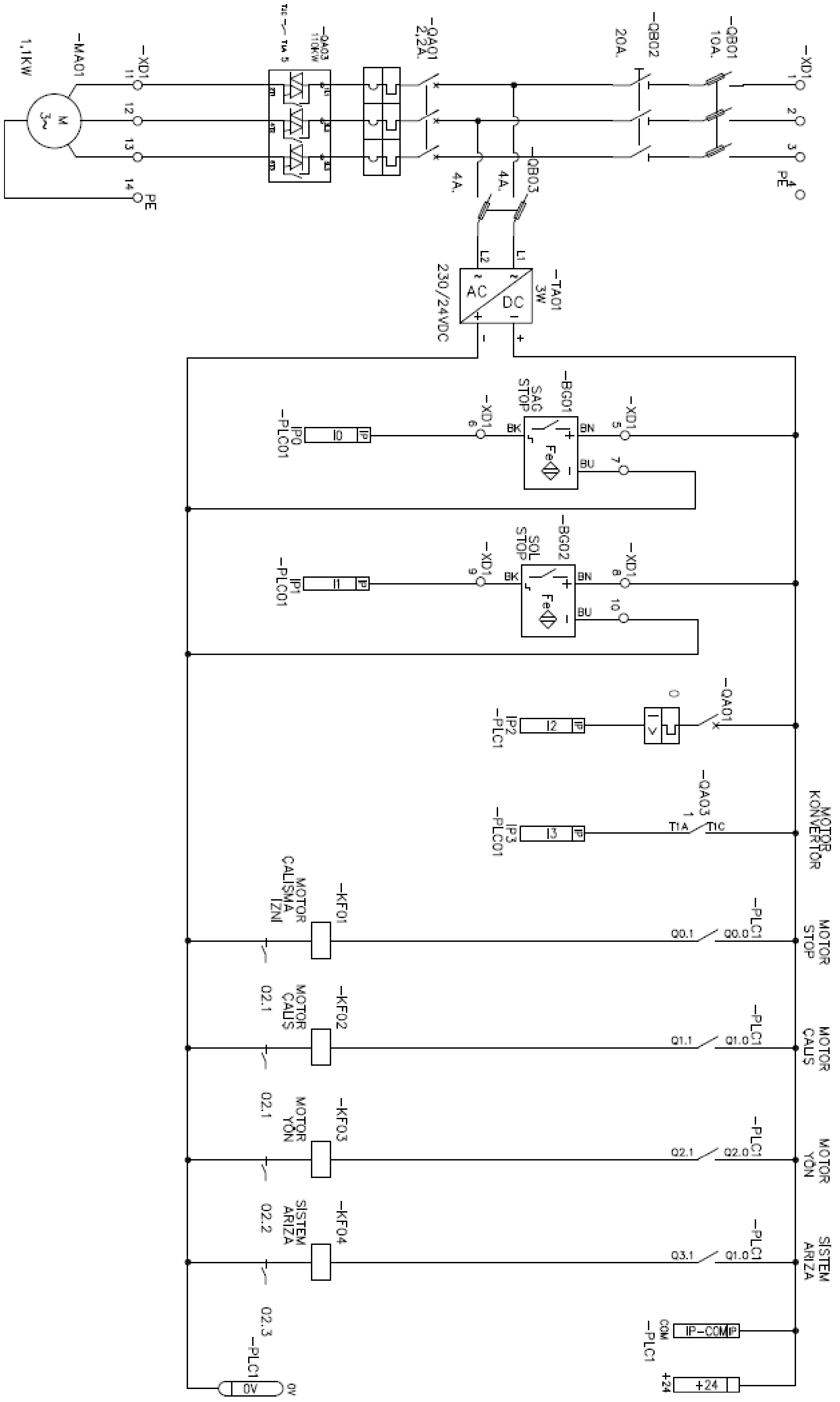

Figure A.2: Power and control circuit

APPENDIX B

3D DESIGN

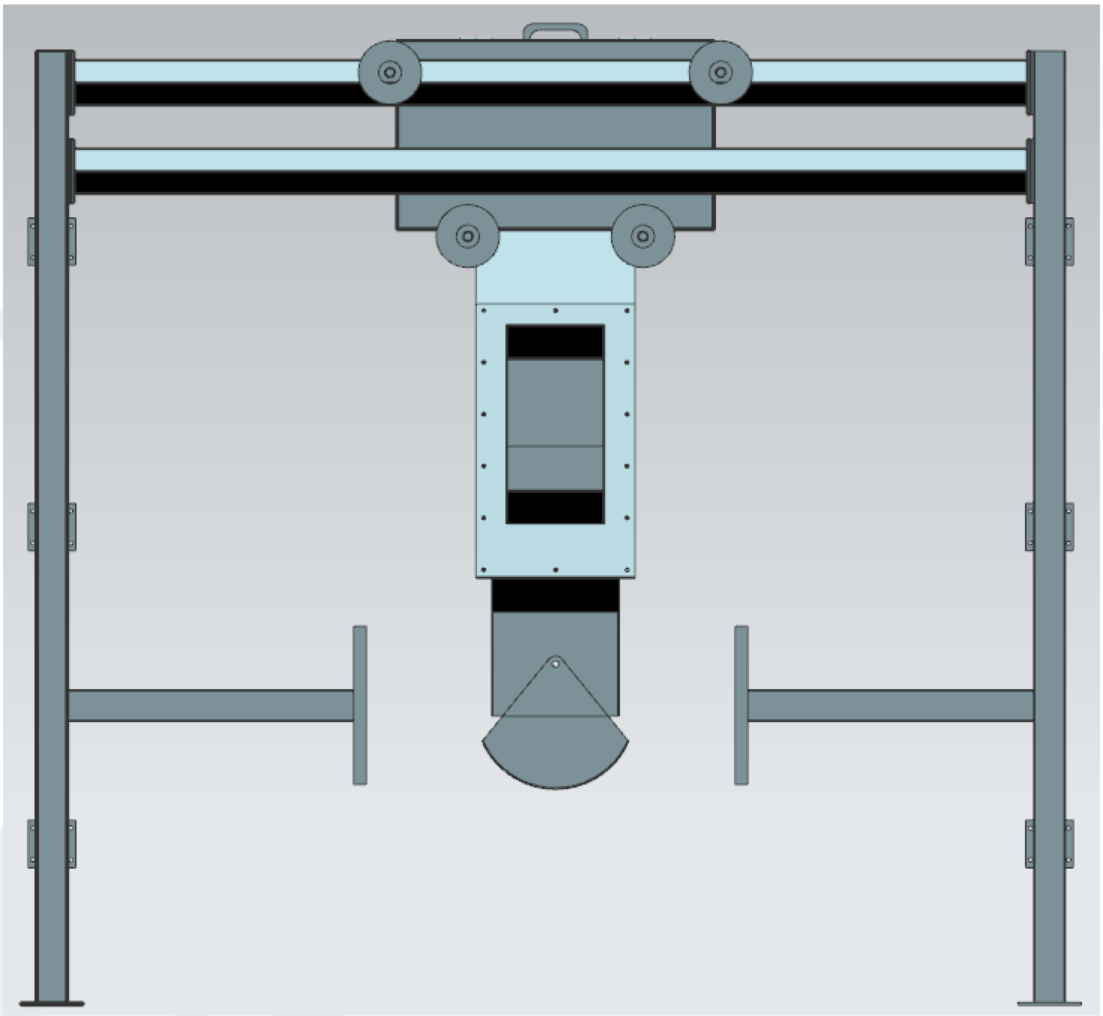

Figure B.1: Middle view of sampling machine

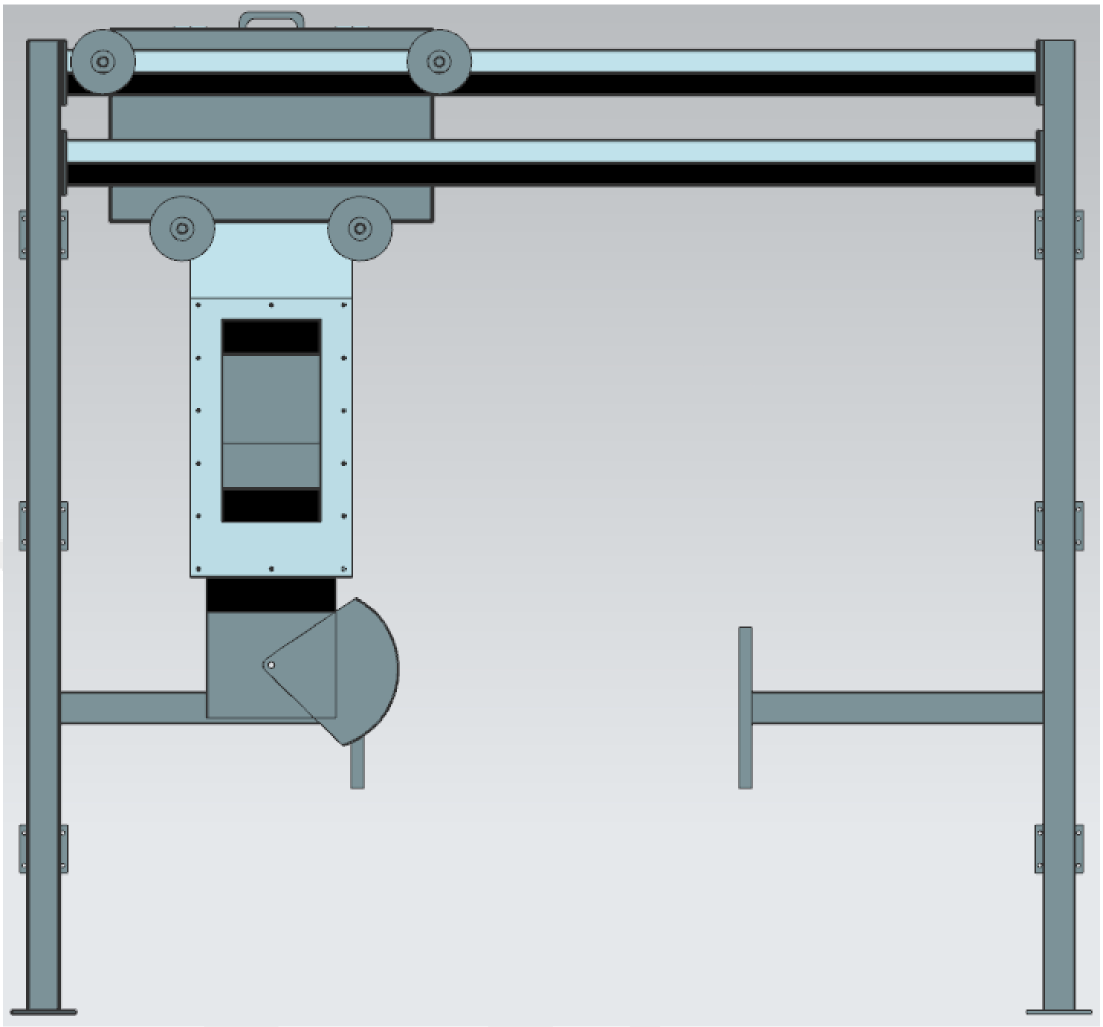

Figure B.2: Left view of sampling machine

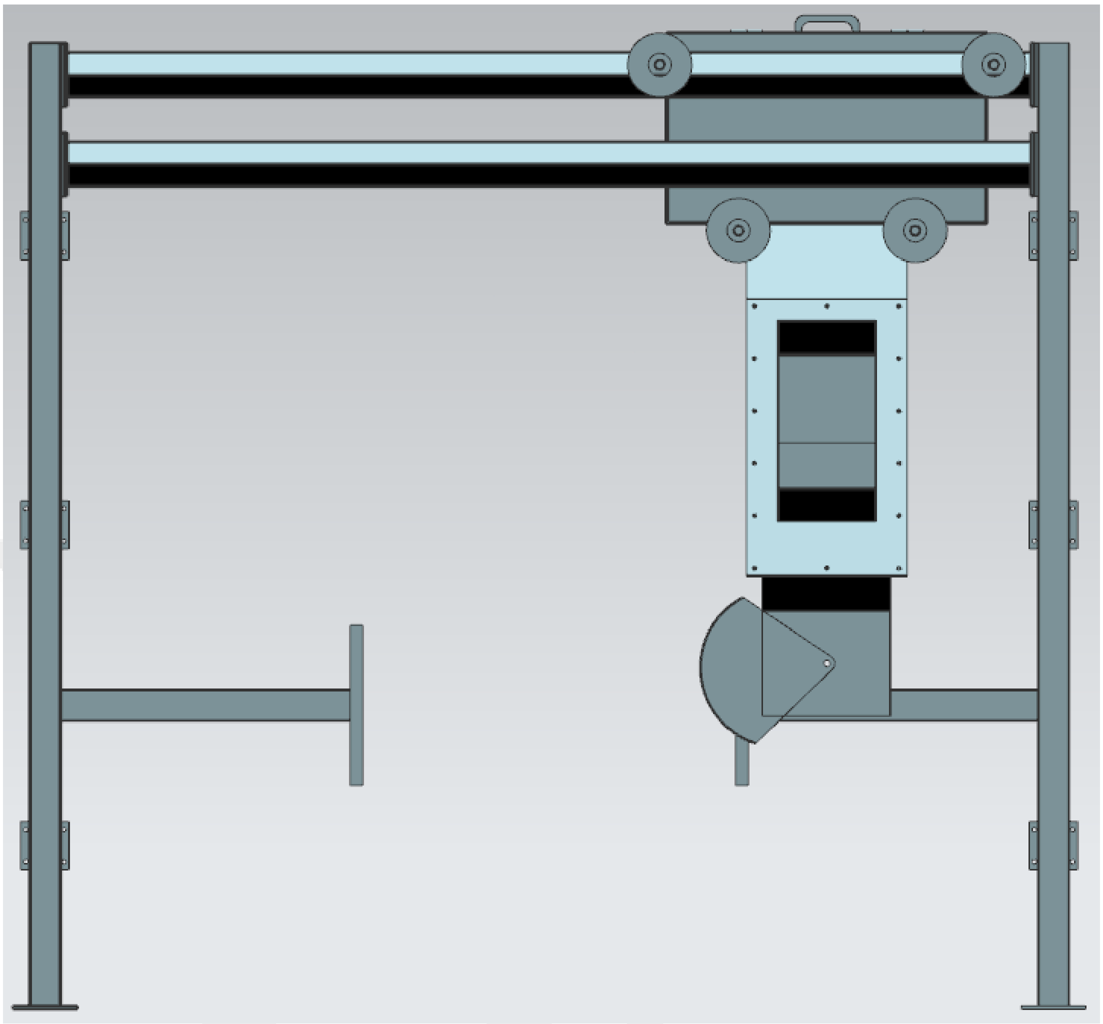

Figure B.3: Right view of sampling machine