INTERNSHIP PROJECT REPORT

Jan - May 2023

Elimination of unpredicted failures of robot's reducer in Maruti Suzuki India Limited Gurgaon Weld Shops

Submitted by

TUSHAR YADAV

19070123126

Under the Guidance of

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Department of Electronics and Telecommunication Engineering

SYMBIOSIS INSTITUTE OF TECHNOLOGY, PUNE

Jan - May 2023

DECLARATION

I hereby declare that the project work titled “Elimination of unpredicted failures of robot’s reducer in Weld Shops” is an authentic record of my own work carried out at Maruti Suzuki India Limited as requirements of five months internship semester for the award of degree of B.Tech. (Electronics and Telecommunication Engineering), Symbiosis Institute of Technology, Pune, under the guidance of Mr. S.Vishal and Dr. Amit Kukker, during Jan to May, 2023).

Tushar Yadav
19070123126

Date: 10/05/2023

Certified that the above statement made by the student is correct to the best of our knowledge and belief.

Dr. Amit Kukker
Assistant Professor
(Faculty Mentor)

S. Vishal
Senior Manager
(Industry Mentor)

ACKNOWLEDGEMENT

The industrial training is indeed the most important and integral part of our curriculum at the Symbiosis Institute of Technology, Pune, Maharashtra.

This industrial training gives us an ample opportunity to develop a veritable and first-hand industrial experience not only towards technical but all-round development also. Being able to see and learn about the actual implementation of the subjects we study is indeed a valuable experience.

The work culture of the leading industrial establishment of the country enhances the person's overall technical aptitude and provides a student with an ample opportunity to interact with senior engineers and learn from their experience and technical insight.

Training at **MARUTI SUZUKI INDIA LIMITED** has not only been beneficial in the technical aspects (as it has given an unprecedented opportunity to exercise and put into practice, some of the theoretical aspects of engineering), but also contributed immensely and actively towards growth in the personal capacity, as a more thinking, efficient, organized and aware individual.

My sincere and heartfelt thanks to all the people at **MARUTI SUZUKI INDIA LIMITED Gurgaon** who helped to make my training a success. I would like to convey my gratitude to **Mr. S.Vishal** and **Mr. Amanpreet Singh**. He gave me moral support and guided me in different matters regarding the topic. He had been very kind and patient while suggesting to me the outlines of this project and correcting my doubts.

INTERNSHIP COMPLETION CERTIFICATE

MARUTI SUZUKI

MSIL: PPDET: INT|2022|591

Date: 01.05.2023

TO WHOM SO EVER IT MAY CONCERN

This is to certify that **Mr. Tushar Yadav** student of **Symbiosis Institute of Technology**, has undergone Project training with MARUTI SUZUKI INDIA LIMITED as per details given below: -

PROJECT TITLE	**Elimination of unpredicted failures of robot's reducer in weld shop**
TRAINING PERIOD	**09-Jan-2023 to 03-May-2023**
DEPT/ DIVISION	**MPG2-3 / PROD**

He has completed the above project to our satisfaction and our assessment of his overall project efforts & learning is **Excellent**. During the training we found him hardworking, eager to learn and with good initiative.

We wish him very best in his future career.

With Best Wishes

Dr. Dharmendra Kumar
Department Head – GTS (HR)
Maruti Suzuki Training Academy

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TABLE OF CONTENT

INTRODUCTION OF COMPANY

Maruti Suzuki India Limited, formerly known as Maruti Udyog Limited, is an automobile manufacturer in India. It is a 56.21% owned subsidiary of the Japanese car and motorcycle manufacturer Suzuki Motor Corporation. As of January 2017, it had a market share of 51% of the Indian passenger car market. Maruti Suzuki manufactures and sells popular cars such as the Ciaz, Ertiga, Wagon R, Alto, Swift, Celerio, Swift Dzire, Baleno, Brezza, S Cross, Eeco, Ignis, S Presso, Jimny and Super Carry. The company is headquartered at New Delhi. In February 2012, the company sold its ten million vehicles in India.

Maruti Suzuki India Limited was incorporated as a Public sector company on February 24, 1981 with the following objectives:

a) Modernisation of the Indian automobile industry.
b) Production of fuel-efficient vehicles to conserve scarce resources.
c) Production of a large number of vehicles, which was necessary for economic growth.

Maruti was established in February 1981 though the actual production commenced only in 1983.

1) Maruti Suzuki India Mission

When Maruti entered the Indian car market, it sought to fill what it perceived as two very glaring needs. One, was to provide fuel efficient, low-cost vehicles, which were reliable and of high quality. Second, was to offer customers friendly sales and after sales service, total automobile value and customer satisfaction.

2) Maruti Suzuki India Vision

"The Leader in the Indian Automobile Industry,
Creating Customer delight and Shareholders wealth; A pride of India".

3) Maruti Suzuki India Culture

In Maruti Suzuki India, they give utmost importance to human safety for which we rigorously follow the Maruti Suzuki Safety Practices:

i) 5S

SEIRI	-	PROPER SELECTION
SEITON	-	ARRANGEMENT
SEISO	-	CLEANING
SEIKETSU	-	CLEANLINESS
SHITSUKE	-	DISCIPLINE

ii) 3M

In factories various problems occur which hamper production and adversely affect the quality of products. Most of these problems occur due to 3M:

MURI	-	INCONVENIENCE
MUDA	-	WASTAGE
MURA	-	INCONSISTENCY

iii) 3G

3G means that "In case of an abnormality, all concerned members should actually go to the place where the problem has occurred, see the actual thing and take realistic action to solve the problem". In the Japanese language this point is compiled in 3 words:

GENCHI	-	ACTUAL PLACE
GENBUTSU	-	ACTUAL THING
GENJITSU	-	ACTUALLY

iv) 3K

KIMERARETA KOTO GA.	-	What has been decided
KIHON DORI	-	As per the standard
KICHIN TO MAMORU	-	Must be followed

v) Kaizen

Continual improvement is the key for any company to develop the quality products and raise the quality standards of the product in order to delight our customers. Thus, in Maruti Suzuki India Limited we always motivate and support in doing kaizens for which the members are awarded.

4) Maruti Suzuki India Core Values

The Five Values identified are as follows:

i) Customer Obsession
ii) Fast, Flexible & First Mover
iii) Innovation & Creativity
iv) Networking & Partnership
v) Openness & Learning

DESCRIPTION OF ALLOTTED WORK/PROJECT UNDERTAKEN

Problem: Elimination of unpredicted failures of robot's reducer in Maruti Suzuki India Limited Gurgaon Plant Weld Shops.

Approach: Changing future of Robot maintenance by aligning with Industry 4.0 using IoT.

Robot breakdown contributes 44 % of the total downtime in Weld Shop.

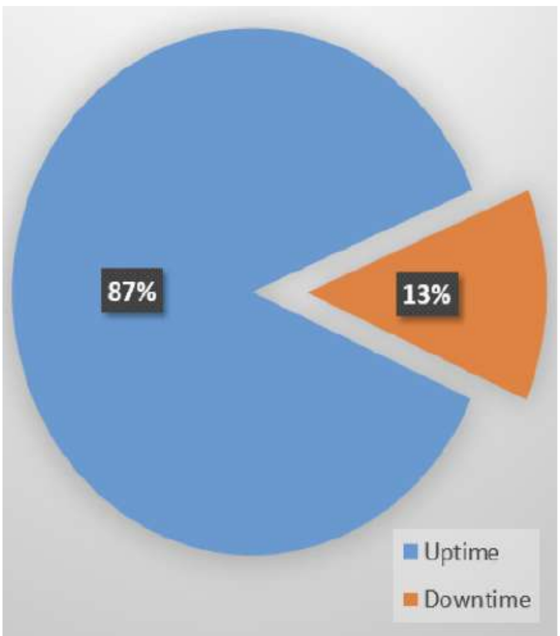


Fig.1 Line Efficiency

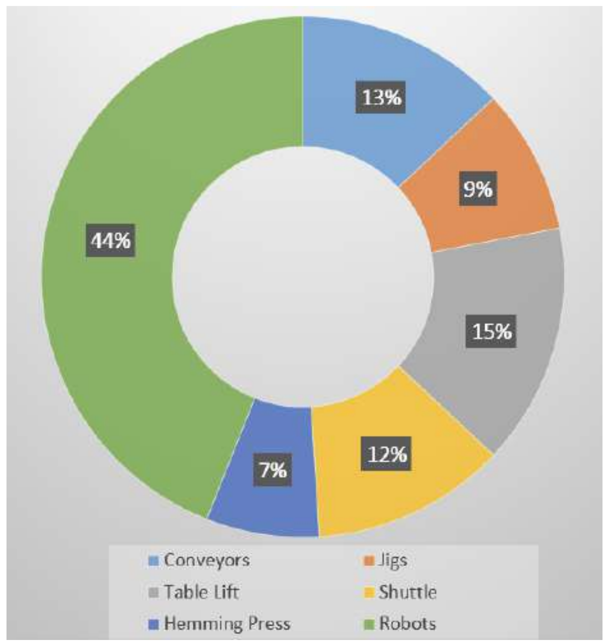


Fig.2 13% Downtime Breakup

In the line efficiency total DOWNTIME is 13% which consists of several faults like jigs, table lift. Hemming press, robots, shuttle and conveyors out of which the Robot Faults contribute the most percentage of about 44%, as shown in Fig.2.

The robot in whole might not be at fault. There are several parts present inside a robot like sensors, reducer, solenoid, motor etc.

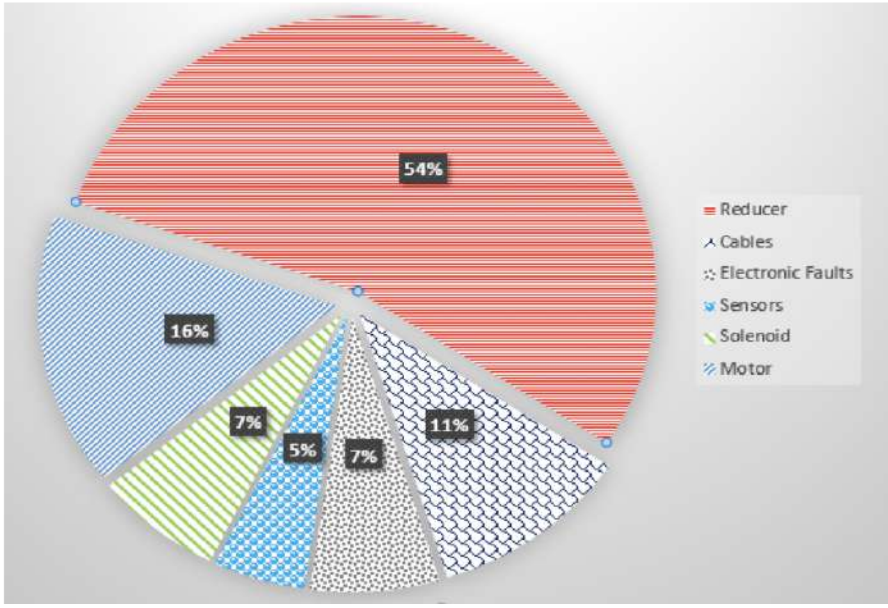


Fig.3 44% Robot Downtime Breakup

From the above pie chart Fig.3, it is clear that maximum downtime in robots is due to Reducer Failure which is about 54%.

Impact of Reducer Breakdown:

Loss of 1000+ Vehicles Annually

There are a total of 7-10 breakdowns of Reducer Failure which took around an average of 5 hours for each breakdown resolution. i.e. 35-50 hrs. annually, resulting in the loss of 1000-1250 Vehicles Annually.

To work on this problem it had to be performed in following steps:

1. Understanding Existing Methodology
2. Choosing Data Collection Software
3. Data Analysis Methodology
4. Analysis Execution

WORK DONE DURING THE INTERNSHIP PERIOD

Existing Methodology

Grease Analysis

For a robot's reducer to operate smoothly, grease is used as lubricant. The company's method calculates the ferrous content in the grease sample that will be analyzed in parts per million (ppm) (parts per million).

Ferrous Content (x) (IN PPM)	Status
0<x<450	Normal
450<x<1000	Under Observation
1000<x	Alarm (Reducer Replacement)

Table 1 Grease Conditional Analysis for Ferrous Content

The ppm concentration of ferrous impurities in the grease sample rises as the reducer ages over time. When the ferrous impurities threshold value is exceeded, this can result in a "Collision Fault," which occurs when a robot needs to apply more force than what is required to move a particular axis.

At Maruti Suzuki India Ltd. Grease samples were collected from all of the robots that were placed in the line of work and analyzed six months later. This posed a number of difficulties, including:

1) Labor-intensive:
   The operator must visit each robot, gather each of its six axis worth of grease samples in a different collection bottle, and then send the samples to the lab for analysis.
2) Skilled Operation:
   Being a skilled operation, it requires skilled labor which means that variation between samples is possible if not taken in the correct way.

3) Transportation & Handling:

The handling of the oil sample poses unique difficulties.

4) It is not feasible to keep an eye on the Robot's Reducer's condition in real time.

5) Recurring Failures:

The efficiency of this technique for predicting breakdowns is only up to 90%, which is crucial. The remaining 10% of cases result in significant breakdowns that cost the business a significant sum of money. These reducer failures go unnoticed twice a month, which is a very high failure frequency.

It was determined to reverse-engineer the issue in order to forecast reducer failure.

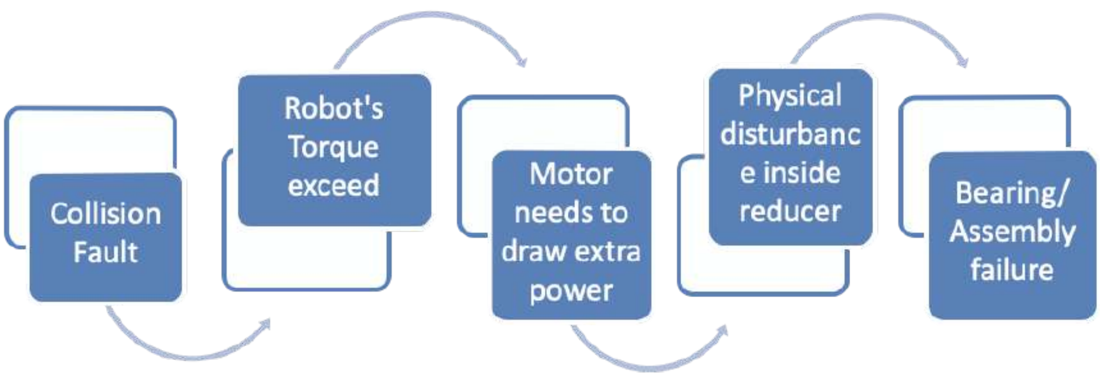


Fig. 4

Based on analysis, it was determined to keep an eye on the Robot's Torque parameter, which, when exceeded, causes a collision fault.

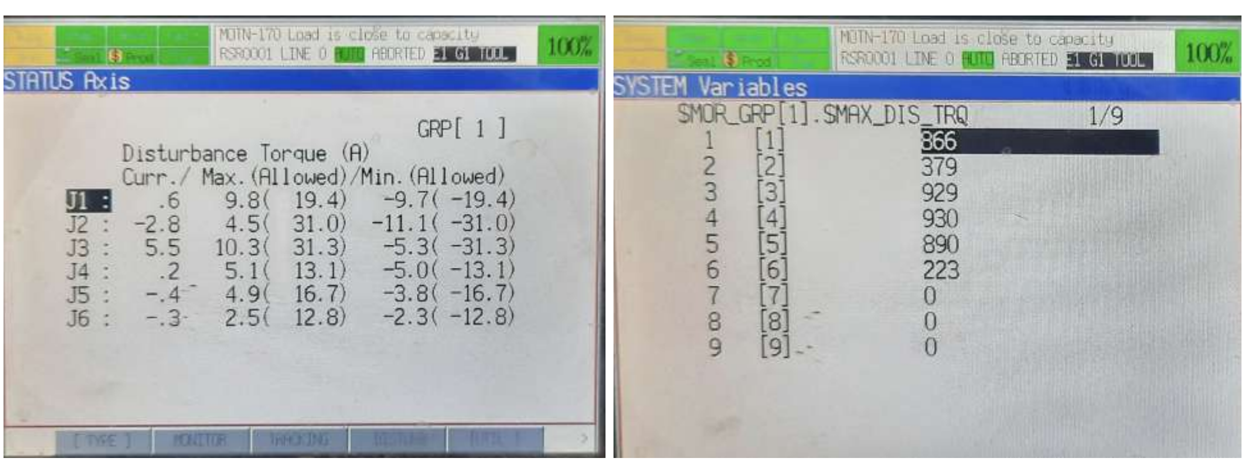


Fig. 5 disturbance torque reading

Data Collection

To collect Robot data, following sources were contacted for data logging.

Discussion with OEM (Fanuc Robotics India Pvt Ltd.) along with Maruti Maintenance Team

1. Various Robotic forums
2. RobotPLCforum.com
3. Robot-Forum.com
4. Control.com

After exploring these platforms, following solutions were found which could help in logging Torque data onto the server by using

- ZDT System (Fanuc's licensed software)

ZDT (Zero Down Time) is the preventive and diagnostic function. ZDT creates a centralized control system of Mechanical Condition Check, Process Status Check, Preventive Maintenance, and System Health Check by connecting robots with Ethernet.

Fig. 6 ZDT

A greater operating ratio is influenced by the preventative and diagnostic function.

The preventive and diagnosis feature sends maintenance notifications and information about troubleshooting to reduce unplanned downtime.

Servers can centralize data, and smartphones or other devices can also watch it.

Fig. 7 ZDT System Overview

- KepserverEX

KEPServerEX is the connectivity platform that provides a single source of industrial automation data to all applications. The platform design allows users to connect, manage, monitor, and control diverse automation devices and software applications through one intuitive user interface. KEPServerEX leverages OPC (the automation industry's standard for interoperability) and IT-centric communication protocols to provide users with a single source for industrial data.

Following are KepserverEX' s salient features -

1. IoT-Ready: Connecting Operations with IT and enabling Business Intelligence and Operational Excellence across the enterprise

2. Security: Advanced application security features to meet site security requirements

3. Control: Sophisticated access control to the server, data source, and data values

4. Scalability: Scalable unified architecture, providing the flexibility to combine drivers and consume multiple protocols in a single server

5. User Interface: Streamlined interface for simple installation, configuration, maintenance, and troubleshooting

6. Accessibility: Data stored via KepserverEX is easily accessible and data can be stored in multiple file formats

7. Optimization: KEPServerEX optimizes communications and reduces network and device load via data conditioning and reduction, customized load balancing, and protocol-specific optimization.

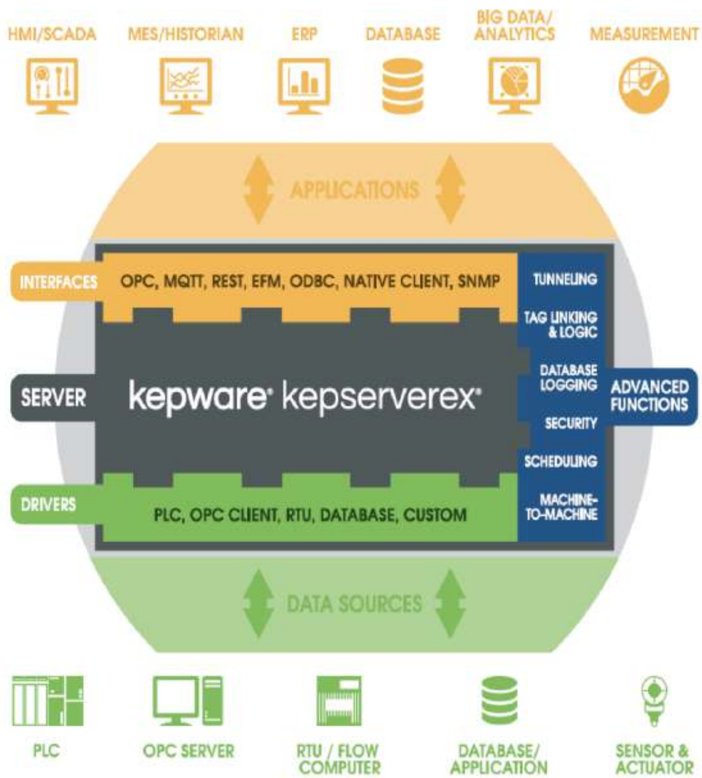


Fig. 8 KepserverEX' s Architecture

Out of these two platforms available, it was decided to go ahead with KepserverEX software due to the following benefit of KepserverEX instead of ZDT.

<u>Cost</u>: Following is the cost comparison analysis of both softwares

S. No.	Cost Head	ZDT Software (Fanuc)	KepserverEX (Kepware)
1	Software Cost	Rs 15,35,00,000 (Rs 2.5 Lakh/Robot x 614 Robots)	Rs 1,30,320 (Perpetual License cost $1629)
2	Development Cost	Nil (Ready to use)	Rs 2,50,000
3	**Total Cost**	**Rs 153.5 Million**	**Rs. 0.38 Million**

Table 2

Data Analysis Methodology

Brainstorming was done to propose the following possible methods to analyze the data -

- Maxima-Minima:

Idea: Monitoring the maximum and minimum values of torque being produced at the reducer.

Challenges: Multiple alarms being generated daily due to the torque value exceeding the limit set multiple times during the course of operation leading to setting the increased value as new threshold value, hence defeating the purpose.

- Torque Gradient:

Idea: Monitoring the gradient of the torque values with respect to time to calculate the rate of change of torque and set a limit on this derivative.

Challenges: As the value may increase suddenly during a cycle of operation
the limit that is set on the derivative will inadvertently be crossed multiple times during a single cycle. This method gives us an instantaneous torque gradient rather than giving us a complete picture of the whole cycle.

- Area Under the Curve:

Idea: Calculating and monitoring the area under the torque time graph during each cycle of operation. Analyzing the area by calculating the average area under a number of cycles and comparing the percentage deviation with the ideal base case.

Challenges: To calculate area under the curve based upon raw data was a challenge, especially since we didn't know the point at which torque curve crossed from +ve to –ve or vice versa.

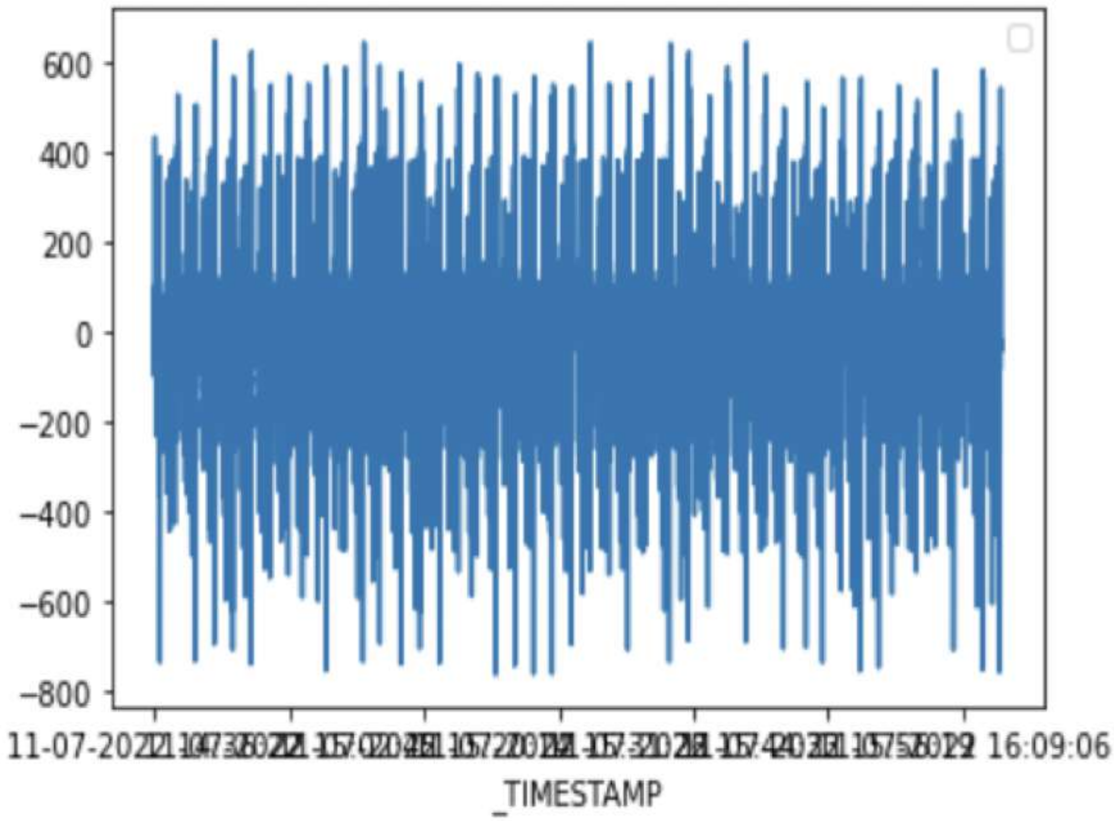


Fig. 9 Torque - Time graph for one axis of the robot over multiple operation cycles

Considering the different methodologies and their drawbacks it was finally decided that we should proceed with the Area Under the Curve methodology as it offered us a wholesome result for the whole cycle rather than giving us instantaneous points of fault values.

Analysis Execution

In order to complete the project successfully, the project was divided into 4 major stages.

Stage 1: Collection and logging of Raw Data

Stage 2: Filtering of Data collected

Stage 3: Developing the required algorithm

Stage 4: Validation of Results

Stage 1: Collection of Raw Data

Data collection started via KepserverEX software by connecting software to Robot via Ethernet protocol. IP address was assigned to Robot's CPU and after successfully connecting Robot CPU with Server, Robot's data register's real-time data was monitored.

After successful live data monitoring, in Robot, a separate programme was created which would continuously update Robot Torque data onto those data registers.

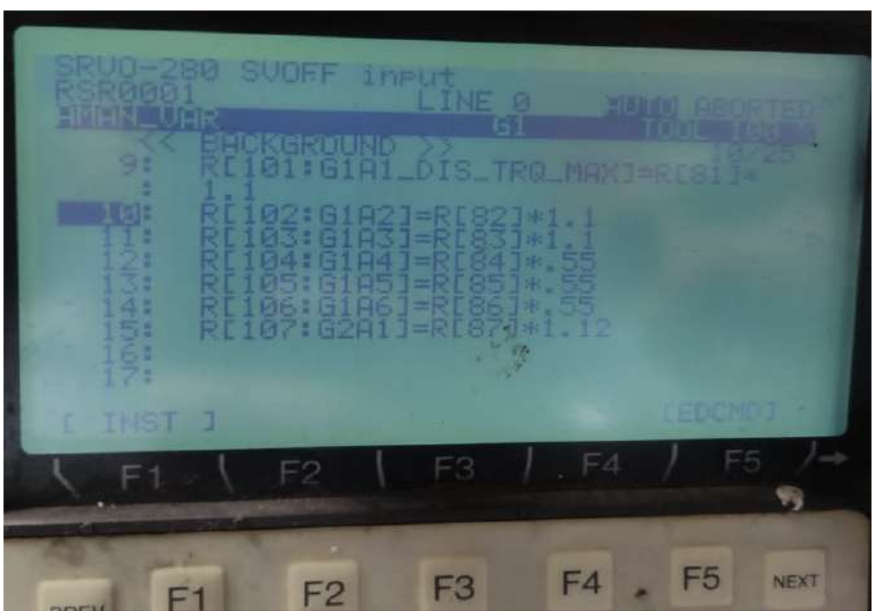


Fig. 10

Following is the Torque Data from KepserverEX:

Id	_NAME	_NUMERICID	_VALUE	_QUALITY
1	YE3 LSB.561A ROBOT.CUR_TORQUEJ1	0	153	192
2	YE3 LSB.561A ROBOT.CUR_TORQUEJ2	0	511	192
3	YE3 LSB.561A ROBOT.CUR_TORQUEJ3	0	487	192
4	YE3 LSB.561A ROBOT.CUR_TORQUEJ4	0	566	192
5	YE3 LSB.561A ROBOT.CUR_TORQUEJ5	0	71	192
6	YE3 LSB.561A ROBOT.CUR_TORQUEJ6	0	241	192
7	YE3 LSB.561A ROBOT.Programme No	0	0	192
8	YE3 LSB.561A ROBOT.CUR_TORQUEJ1	0	453	192
9	YE3 LSB.561A ROBOT.CUR_TORQUEJ2	0	-714	192
10	YE3 LSB.561A ROBOT.CUR_TORQUEJ3	0	1042	192
11	YE3 LSB.561A ROBOT.CUR_TORQUEJ4	0	54	192
12	YE3 LSB.561A ROBOT.CUR_TORQUEJ5	0	35	192
13	YE3 LSB.561A ROBOT.CUR_TORQUEJ6	0	48	192
14	YE3 LSB.561A ROBOT.CUR_TORQUEJ1	0	-62	192
15	YE3 LSB.561A ROBOT.CUR_TORQUEJ2	0	-244	192
16	YE3 LSB.561A ROBOT.CUR_TORQUEJ3	0	-173	192
17	YE3 LSB.561A ROBOT.CUR_TORQUEJ4	0	20	192
18	YE3 LSB.561A ROBOT.CUR_TORQUEJ5	0	12	192
19	YE3 LSB.561A ROBOT.CUR_TORQUEJ6	0	14	192
20	YE3 LSB.561A ROBOT.CUR_TORQUEJ1	0	-97	192
21	YE3 LSB.561A ROBOT.CUR_TORQUEJ2	0	-184	192
22	YE3 LSB.561A ROBOT.CUR_TORQUEJ3	0	-257	192
23	YE3 LSB.561A ROBOT.CUR_TORQUEJ4	0	37	192
24	YE3 LSB.561A ROBOT.CUR_TORQUEJ5	0	22	192
25	YE3 LSB.561A ROBOT.CUR_TORQUEJ6	0	22	192
26	YE3 LSB.561A ROBOT.CUR_TORQUEJ1	0	25	192
27	YE3 LSB.561A ROBOT.CUR_TORQUEJ2	0	-473	192
28	YE3 LSB.561A ROBOT.CUR_TORQUEJ3	0	272	192
29	YE3 LSB.561A ROBOT.CUR_TORQUEJ4	0	104	192

Table 3 Torque Excel Data

Id	_NAME	_NUMERICID	_VALUE	_QUALITY
98	YE3 LSB.561A ROBOT.CUR_TORQUEJ1	0	-42	192
99	YE3 LSB.561A ROBOT.CUR_TORQUEJ2	0	140	192
100	YE3 LSB.561A ROBOT.CUR_TORQUEJ3	0	95	192
101	YE3 LSB.561A ROBOT.CUR_TORQUEJ4	0	-10	192
102	YE3 LSB.561A ROBOT.CUR_TORQUEJ5	0	-90	192
103	YE3 LSB.561A ROBOT.CUR_TORQUEJ6	0	-107	192
104	YE3 LSB.561A ROBOT.CUR_TORQUEJ1	0	92	192
105	YE3 LSB.561A ROBOT.CUR_TORQUEJ2	0	104	192
106	YE3 LSB.561A ROBOT.CUR_TORQUEJ3	0	-26	192
107	YE3 LSB.561A ROBOT.CUR_TORQUEJ4	0	-156	192
108	YE3 LSB.561A ROBOT.CUR_TORQUEJ5	0	194	192
109	YE3 LSB.561A ROBOT.CUR_TORQUEJ6	0	42	192
110	YE3 LSB.561A ROBOT.CUR_TORQUEJ6	0	-1053	192
111	YE3 LSB.561A ROBOT.CUR_TORQUEJ1	0	654	192
112	YE3 LSB.561A ROBOT.CUR_TORQUEJ2	0	-380	192
113	YE3 LSB.561A ROBOT.CUR_TORQUEJ3	0	339	192
114	YE3 LSB.561A ROBOT.CUR_TORQUEJ4	0	-65	192
115	YE3 LSB.561A ROBOT.CUR_TORQUEJ5	0	107	192
116	YE3 LSB.561A ROBOT.CUR_TORQUEJ6	0	-918	192
117	YE3 LSB.561A ROBOT.CUR_TORQUEJ1	0	514	192
118	YE3 LSB.561A ROBOT.CUR_TORQUEJ2	0	-866	192
119	YE3 LSB.561A ROBOT.CUR_TORQUEJ3	0	625	192
120	YE3 LSB.561A ROBOT.CUR_TORQUEJ4	0	-33	192
121	YE3 LSB.561A ROBOT.CUR_TORQUEJ5	0	173	192
123	YE3 LSB.561A ROBOT.CUR_TORQUEJ6	0	-891	192
124	YE3 LSB.561A ROBOT.CUR_TORQUEJ1	0	539	192
125	YE3 LSB.561A ROBOT.CUR_TORQUEJ2	0	-1012	192
126	YE3 LSB.561A ROBOT.CUR_TORQUEJ3	0	643	192
127	YE3 LSB.561A ROBOT.CUR_TORQUEJ4	0	45	192
128	YE3 LSB.561A ROBOT.CUR_TORQUEJ5	0	414	192

Table 4 Torque Excel Data

Stage 2: Filtering of Data collected

In the First stage for 80 robot cycles a total of 4,10,068 values were collected, so filtration of redundant data was necessary.

In the filtration process, each cycle's cycle time (time taken to complete one cycle) was calculated; then calculated cycle time was compared with standard cycle time of 53 seconds.

id	_NAME	_NUMERICID	_VALUE	_QUALITY	Cycle Time
7	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
2365	YE3 LSB.561A ROBOT.Programme No	0	21	192	54
5222	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
6406	YE3 LSB.561A ROBOT.Programme No	0	21	192	53
9271	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
6406	YE3 LSB.561A ROBOT.Programme No	0	21	192	54
9271	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
10464	YE3 LSB.561A ROBOT.Programme No	0	21	192	53
13317	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
14473	YE3 LSB.561A ROBOT.Programme No	0	21	192	53
17338	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
18445	YE3 LSB.561A ROBOT.Programme No	0	21	192	54
21299	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
22470	YE3 LSB.561A ROBOT.Programme No	0	21	192	54
24523	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
26520	YE3 LSB.561A ROBOT.Programme No	0	21	192	54
29376	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
30567	YE3 LSB.561A ROBOT.Programme No	0	21	192	54
33444	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
34615	YE3 LSB.561A ROBOT.Programme No	0	21	192	54
41534	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
42688	YE3 LSB.561A ROBOT.Programme No	0	21	192	53
45529	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
46318	YE3 LSB.561A ROBOT.Programme No	0	21	192	18
50176	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
50907	YE3 LSB.561A ROBOT.Programme No	0	21	192	53
53765	YE3 LSB.561A ROBOT.Programme No	0	0	192	0
54959	YE3 LSB.561A ROBOT.Programme No	0	21	192	54
57834	YE3 LSB.561A ROBOT.Programme No	0	0	192	0

Table 5 Torque Excel Filtered Data

After comparison with standard 53 second cycle time, out of 80 cycles, 43 cycles matched with standard time.

Stage 3: Developing the required algorithm

Step 1: Reading the data from the excel file and storing it in a data frame.

```
import pandas as pd
df=pd.read_csv(r"C:\Users\admin\Desktop\TORQUEDATA.csv")
```

```
          id                            _NAME  _NUMERICID  _VALUE  \
0          1  YE3 LSB.561A ROBOT.CUR_TORQUE_J1           0       0
1          2  YE3 LSB.561A ROBOT.CUR_TORQUE_J2           0       0
2          3  YE3 LSB.561A ROBOT.CUR_TORQUE_J3           0       0
3          4  YE3 LSB.561A ROBOT.CUR_TORQUE_J4           0       0
4          5  YE3 LSB.561A ROBOT.CUR_TORQUE_J5           0       0
5          6  YE3 LSB.561A ROBOT.CUR_TORQUE_J6           0       0
6          7   YE3 LSB.561A ROBOT.Programme No           0       0
7          8  YE3 LSB.561A ROBOT.CUR_TORQUE_J1           0       4
8          9  YE3 LSB.561A ROBOT.CUR_TORQUE_J2           0    -714
9         10  YE3 LSB.561A ROBOT.CUR_TORQUE_J3           0    1042
10        11  YE3 LSB.561A ROBOT.CUR_TORQUE_J4           0      54
11        12  YE3 LSB.561A ROBOT.CUR_TORQUE_J5           0      35
12        13  YE3 LSB.561A ROBOT.CUR_TORQUE_J6           0      48
13        14  YE3 LSB.561A ROBOT.CUR_TORQUE_J1           0     -62
14        15  YE3 LSB.561A ROBOT.CUR_TORQUE_J2           0    -244
15        16  YE3 LSB.561A ROBOT.CUR_TORQUE_J3           0    -173
16        17  YE3 LSB.561A ROBOT.CUR_TORQUE_J4           0      20
17        18  YE3 LSB.561A ROBOT.CUR_TORQUE_J5           0      12
```

Step 2: Dropping the redundant columns from the data frame.

```
df=df.drop(columns="_NUMERICID")
df=df.drop(columns="_QUALITY")
df=df.drop(columns="id")
```

```
                               _NAME  _VALUE
0   YE3 LSB.561A ROBOT.CUR_TORQUE_J1       0
1   YE3 LSB.561A ROBOT.CUR_TORQUE_J2       0
2   YE3 LSB.561A ROBOT.CUR_TORQUE_J3       0
3   YE3 LSB.561A ROBOT.CUR_TORQUE_J4       0
4   YE3 LSB.561A ROBOT.CUR_TORQUE_J5       0
5   YE3 LSB.561A ROBOT.CUR_TORQUE_J6       0
6    YE3 LSB.561A ROBOT.Programme No       0
7   YE3 LSB.561A ROBOT.CUR_TORQUE_J1       4
8   YE3 LSB.561A ROBOT.CUR_TORQUE_J2    -714
9   YE3 LSB.561A ROBOT.CUR_TORQUE_J3    1042
10  YE3 LSB.561A ROBOT.CUR_TORQUE_J4      54
11  YE3 LSB.561A ROBOT.CUR_TORQUE_J5      35
12  YE3 LSB.561A ROBOT.CUR_TORQUE_J6      48
13  YE3 LSB.561A ROBOT.CUR_TORQUE_J1     -62
14  YE3 LSB.561A ROBOT.CUR_TORQUE_J2    -244
15  YE3 LSB.561A ROBOT.CUR_TORQUE_J3    -173
16  YE3 LSB.561A ROBOT.CUR_TORQUE_J4      20
17  YE3 LSB.561A ROBOT.CUR_TORQUE_J5      12
18  YE3 LSB.561A ROBOT.CUR_TORQUE_J6      14
19  YE3 LSB.561A ROBOT.CUR_TORQUE_J1     -97
20  YE3 LSB.561A ROBOT.CUR_TORQUE_J2    -184
21  YE3 LSB.561A ROBOT.CUR_TORQUE_J3    -259
22  YE3 LSB.561A ROBOT.CUR_TORQUE_J4      37
23  YE3 LSB.561A ROBOT.CUR_TORQUE_J5      22
24  YE3 LSB.561A ROBOT.CUR_TORQUE_J6      22
25  YE3 LSB.561A ROBOT.CUR_TORQUE_J1      25
```

Step 3: Creating a new data frame in which only that data is stored which is taken while the manufacturing cycle is in process. Rest of the data is redundant and can be ignored. This data frame is created by using a function on the original data frame defined as:

```
def identifystartstopalto(df):
    temp=pd.DataFrame()
    i=0
    x=0
    for i in range (len(df)):
        if(df.loc[i]["_NAME"]==("YE3 LSB.561A ROBOT.Programme No")):
            if(df.loc[i]["_VALUE"]==21):
                x=1
            if(df.loc[i]["_VALUE"]==0):
                x=0
        if (x==1):
            temp=temp.append(df.iloc[i])
        i=i+1
    return temp
```

	_NAME	_VALUE
2520	YE3 LSB.561A ROBOT.Programme No	21.0
2521	YE3 LSB.561A ROBOT.CUR_TORQUE_J1	-94.0
2522	YE3 LSB.561A ROBOT.CUR_TORQUE_J2	104.0
2523	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	-283.0
2524	YE3 LSB.561A ROBOT.CUR_TORQUE_J4	-101.0
2525	YE3 LSB.561A ROBOT.CUR_TORQUE_J5	-79.0
2526	YE3 LSB.561A ROBOT.CUR_TORQUE_J6	-172.0
2527	YE3 LSB.561A ROBOT.CUR_TORQUE_J1	-211.0
2528	YE3 LSB.561A ROBOT.CUR_TORQUE_J2	-853.0
2529	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	491.0
2530	YE3 LSB.561A ROBOT.CUR_TORQUE_J4	-38.0
2531	YE3 LSB.561A ROBOT.CUR_TORQUE_J5	-229.0
2532	YE3 LSB.561A ROBOT.CUR_TORQUE_J6	-148.0
2533	YE3 LSB.561A ROBOT.CUR_TORQUE_J1	-33.0
2534	YE3 LSB.561A ROBOT.CUR_TORQUE_J2	-519.0
2535	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	713.0
2536	YE3 LSB.561A ROBOT.CUR_TORQUE_J4	155.0
2537	YE3 LSB.561A ROBOT.CUR_TORQUE_J5	-222.0
2538	YE3 LSB.561A ROBOT.CUR_TORQUE_J6	196.0
2539	YE3 LSB.561A ROBOT.CUR_TORQUE_J1	-37.0
2540	YE3 LSB.561A ROBOT.CUR_TORQUE_J2	-125.0
2541	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	732.0
2542	YE3 LSB.561A ROBOT.CUR_TORQUE_J4	130.0
2543	YE3 LSB.561A ROBOT.CUR_TORQUE_J5	-245.0
2544	YE3 LSB.561A ROBOT.CUR_TORQUE_J6	77.0
2545	YE3 LSB.561A ROBOT.CUR_TORQUE_J1	-21.0
2546	YE3 LSB.561A ROBOT.CUR_TORQUE_J2	-453.0
[illegible]	[illegible]	[illegible]

Step 4: Creating six new data frames for separating the data for all six axes of the robot which will further be analyzed individually. The data is extracted by using basic "if" constructs.

```
dfj1alto=pd.DataFrame()
dfj1alto=dfnewalto[dfnewalto['_NAME'].str.contains("J1|Programme No")]

dfj2alto=pd.DataFrame()
dfj2alto=dfnewalto[dfnewalto['_NAME'].str.contains("J2|Programme No")]

dfj3alto=pd.DataFrame()
dfj3alto=dfnewalto[dfnewalto['_NAME'].str.contains("J3|Programme No")]

dfj4alto=pd.DataFrame()
dfj4alto=dfnewalto[dfnewalto['_NAME'].str.contains("J4|Programme No")]

dfj5alto=pd.DataFrame()
dfj5alto=dfnewalto[dfnewalto['_NAME'].str.contains("J5|Programme No")]

dfj6alto=pd.DataFrame()
dfj6alto=dfnewalto[dfnewalto['_NAME'].str.contains("J6|Programme No")]
```

	_NAME	_VALUE
2520	YE3 LSB.561A ROBOT.Programme No	21.0
2523	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	-283.0
2529	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	491.0
2535	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	713.0
2541	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	732.0
2547	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	921.0
2553	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	857.0
2560	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	653.0
2566	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	851.0
2572	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	859.0
2578	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1052.0
2584	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1085.0
2590	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1059.0
2596	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1053.0
2602	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1057.0
2612	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1053.0
2616	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1055.0
2620	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1054.0
2625	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1055.0
2631	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1052.0
2637	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	-260.0
2643	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	893.0
2649	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1073.0
2655	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1165.0
2661	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	844.0
2667	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	628.0
2673	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1006.0
2679	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1107.0
2685	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	738.0

Step 5: For each axis we separate the positive and negative values of torque followed by re-indexing the newly made data frames and dropping the old indices.

```
dfj1altopositive=pd.DataFrame()
dfj2altopositive=pd.DataFrame()
dfj3altopositive=pd.DataFrame()
dfj4altopositive=pd.DataFrame()
dfj5altopositive=pd.DataFrame()
dfj6altopositive=pd.DataFrame()

dfj1altonegative=pd.DataFrame()
dfj2altonegative=pd.DataFrame()
dfj3altonegative=pd.DataFrame()
dfj4altonegative=pd.DataFrame()
dfj5altonegative=pd.DataFrame()
dfj6altonegative=pd.DataFrame()
```

```
dfj1altopositive=dfj1alto.loc[dfj1alto['_VALUE']>=0]
dfj2altopositive=dfj2alto.loc[dfj2alto['_VALUE']>=0]
dfj3altopositive=dfj3alto.loc[dfj3alto['_VALUE']>=0]
dfj4altopositive=dfj4alto.loc[dfj4alto['_VALUE']>=0]
dfj5altopositive=dfj5alto.loc[dfj5alto['_VALUE']>=0]
dfj6altopositive=dfj6alto.loc[dfj6alto['_VALUE']>=0]

dfj1altopositive.reset_index(drop=True,inplace=True)
dfj2altopositive.reset_index(drop=True,inplace=True)
dfj3altopositive.reset_index(drop=True,inplace=True)
dfj4altopositive.reset_index(drop=True,inplace=True)
dfj5altopositive.reset_index(drop=True,inplace=True)
dfj6altopositive.reset_index(drop=True,inplace=True)
```

```
dfj1altonegative=dfj1alto.loc[(dfj1alto['_VALUE']<=0) | (dfj1alto['_VALUE']==21)]
dfj2altonegative=dfj1alto.loc[(dfj1alto['_VALUE']<=0) | (dfj1alto['_VALUE']==21)]
dfj3altonegative=dfj1alto.loc[(dfj1alto['_VALUE']<=0) | (dfj1alto['_VALUE']==21)]
dfj4altonegative=dfj1alto.loc[(dfj1alto['_VALUE']<=0) | (dfj1alto['_VALUE']==21)]
dfj5altonegative=dfj1alto.loc[(dfj1alto['_VALUE']<=0) | (dfj1alto['_VALUE']==21)]
dfj6altonegative=dfj1alto.loc[(dfj1alto['_VALUE']<=0) | (dfj1alto['_VALUE']==21)]

dfj1altonegative.reset_index(drop=True,inplace=True)
dfj2altonegative.reset_index(drop=True,inplace=True)
dfj3altonegative.reset_index(drop=True,inplace=True)
dfj4altonegative.reset_index(drop=True,inplace=True)
dfj5altonegative.reset_index(drop=True,inplace=True)
dfj6altonegative.reset_index(drop=True,inplace=True)
```

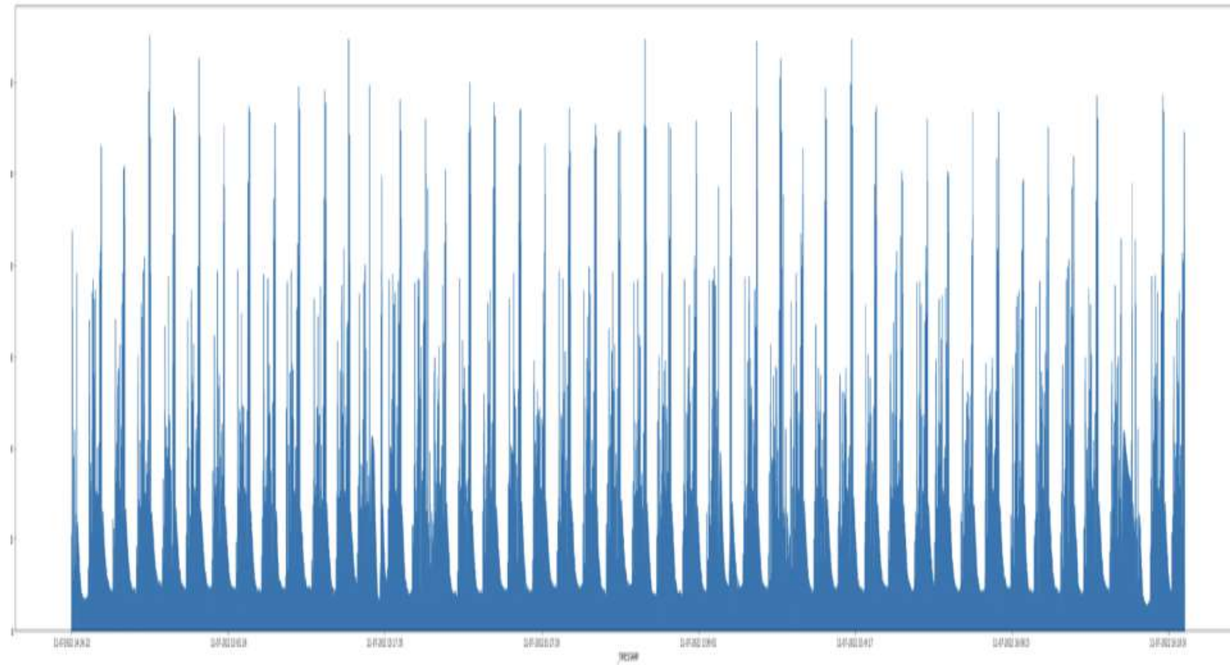


Fig. 11 Positive torque versus time graph for one axis

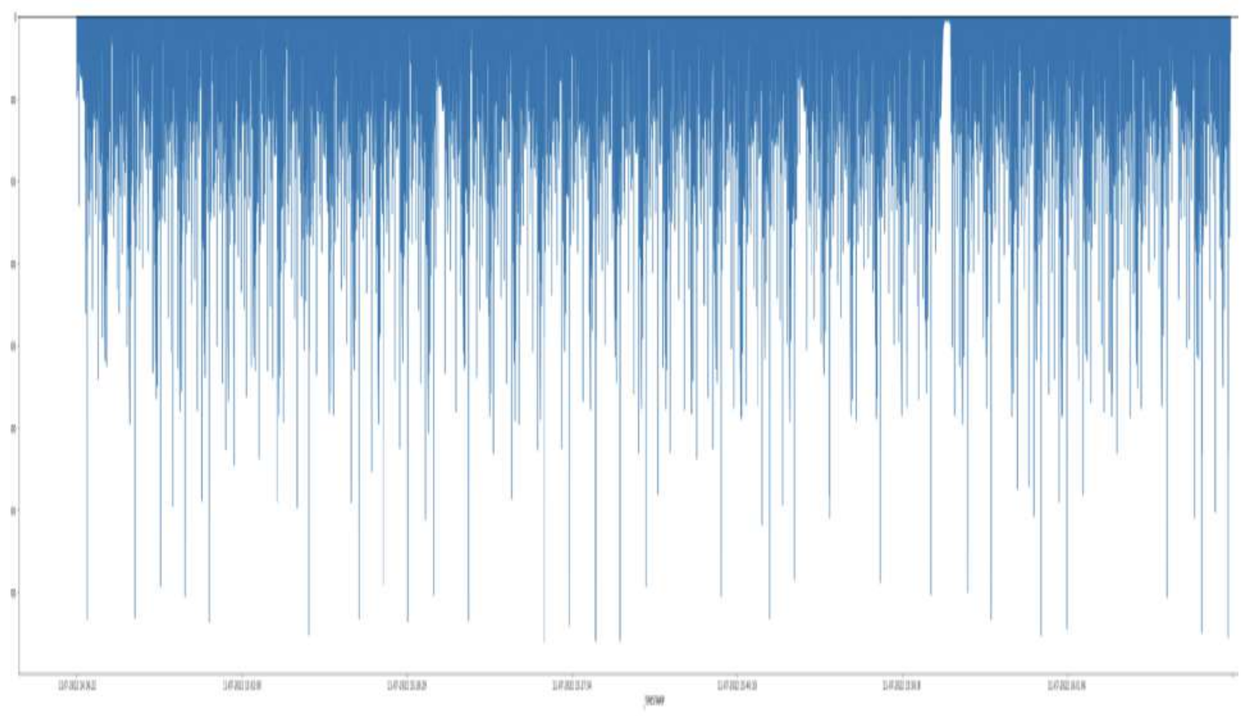


Fig. 12 Negative torque vs time graph for one axis

	_NAME	_VALUE
0	YE3 LSB.561A ROBOT.Programme No	21.0
1	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	491.0
2	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	713.0
3	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	732.0
4	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	921.0
5	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	857.0
6	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	653.0
7	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	851.0
8	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	859.0
9	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1052.0
10	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1085.0
11	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1059.0
12	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1053.0
13	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1057.0
14	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1053.0
15	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1055.0
16	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1054.0
17	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1055.0
18	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1052.0
19	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	893.0
20	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1073.0
21	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	1165.0
22	YE3 LSB.561A ROBOT.CUR_TORQUE_J3	844.0

Step 6: Creating new data frames for storing the area of each cycle of operation. Six such data frames are created for six different axes. Each data frame has a column 'AREA'.

```
dfAJ1alto=pd.DataFrame(columns=['AREA'])
dfAJ2alto=pd.DataFrame(columns=['AREA'])
dfAJ3alto=pd.DataFrame(columns=['AREA'])
dfAJ4alto=pd.DataFrame(columns=['AREA'])
dfAJ5alto=pd.DataFrame(columns=['AREA'])
dfAJ6alto=pd.DataFrame(columns=['AREA'])
```

Step 7: Appending a row of data at the end of the data frame containing positive torque values. This ensures that the cycle terminates and the program does not run an infinite loop.

```
z={ '_NAME':'YE3 LSB.561A ROBOT.Programme No','_VALUE':0}
dfj1altopositive=dfj1altopositive.append(z, ignore_index=True)
```

Step 8: Writing the code for calculating the area of each cycle of operation and simultaneously storing these values in a separate data frame to be used for further analysis.

```
import numpy as np
from scipy.integrate import simps
from numpy import trapz
#z={ '_NAME':'YE3 LSB.561A ROBOT.Programme No','_VALUE':0}
#w={'_VALUE':0}
#dfj1altopositive=dfj1altopositive.append(z, ignore_index=True)
#dfj1altopositive=dfj1altopositive.append(w, ignore_index=True)
x=0
c=0
temp=pd.DataFrame()
for i in range (0, len(dfj3altopositive)-1):
    if(dfj1altopositive.loc[i]["_NAME"]=="YE3 LSB.561A ROBOT.Programme No" ):
        if ( dfj1altopositive.loc[i]["_VALUE"]==21):
            x=0
            c=1

            while(c!=0):

                temp=temp.append(dfj1altopositive.iloc[i])
                #y=np.array([temp['_VALUE']])
                #x=x+trapz(y,dx=0.1)
                #dfaj1alto={'AREA':x}
                #dfAJ1alto=dfAJ1alto.append(dfaj1alto , ignore_index=True)
                if(dfj1altopositive.loc[i]["_NAME"]=="YE3 LSB.561A ROBOT.Programme No" ):
                    if ( dfj1altopositive.loc[i]["_VALUE"]==0):
```

```
        y=np.array([temp['_VALUE']])
        x=x+trapz(y,dx=0.1)
        dfaj1alto={'AREA':x}
        dfAJ1alto=dfAJ1alto.append(dfaj1alto , ignore_index=True)

        temp=temp.iloc[0:0]
        c=0

 i=i+1
```

	AREA
0	[1109042.4500000002]
1	[1086065.8499999999]
2	[1060474.9500000002]
3	[1036412.9500000002]
4	[1011749.15]
5	[987842.55]
6	[962656.45]
7	[938240.8500000001]
8	[913045.8500000001]
9	[888937.8500000001]
10	[863585.25]
11	[839462.85]
12	[804583.65]
13	[780025.35]
14	[754683.95]
15	[730589.75]
16	[705187.25]
17	[681158.15]
18	[656159.4500000001]
19	[632097.15]
20	[607222.9500000001]

Step 9: Similar codes in Step 8 are written for all the remaining 5 axes.

Step 10: The values of area of each cycle of operation is stored outside the program for future analysis.

```
import xlsxwriter
with pd.ExcelWriter('PrasenjitOut.xlsx') as writer:
    file_name='PrasenjitOut.xlsx'
    dfAJ1alto.to_excel(writer,sheet_name='J1')
    dfAJ2alto.to_excel(writer,sheet_name='J2')
    dfAJ3alto.to_excel(writer,sheet_name='J3')
    dfAJ4alto.to_excel(writer,sheet_name='J4')
    dfAJ5alto.to_excel(writer,sheet_name='J5')
    dfAJ6alto.to_excel(writer,sheet_name='J6')
```

Stage 4: Validation of Results

For validation of results, a Weld Robot was selected to find the relation between the standard Grease Analysis method and Torque Analysis Programme developed.

Torque Area 561A Robot J3 Axis

	1	2	3	4	5	6
25 March Torque Area	24447.8999999999	25440.6000000001	26766.5	26958	26767.8999999999	24835.900
10 April Torque Area	28724.8	27621.3999999999	26705.1000000001	27048.7000000001	27450.9	26850.799

Table 6 Torque Area 561A-J3

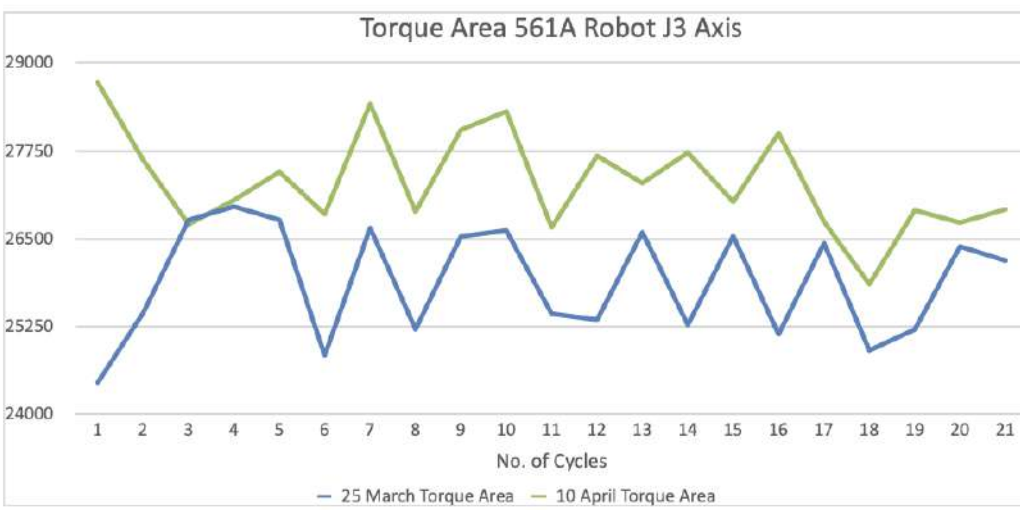


Fig. 13 Torque Area 561A-J3

From the above graph we were able to see a significant difference in Torque Area between 25th March 2023 & 10th April 2023.

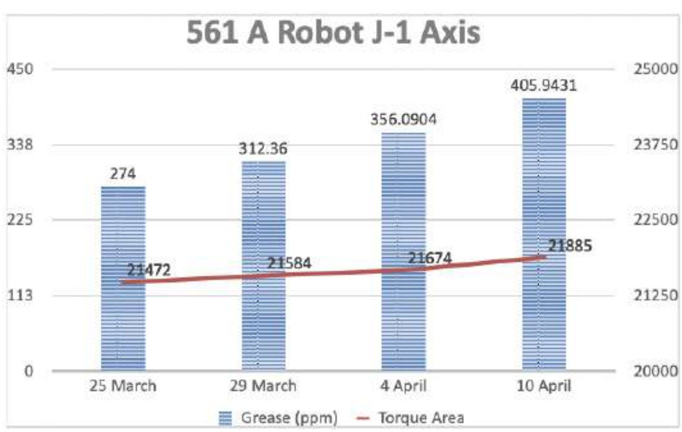
Robot Torque Area vs Grease Ferrous Content											
S. No.	Robot Application	Robot Name	Axis	Grease Sample (in ppm)				Torque Data (Area under Curve)			
				25 March	29 March	4 April	10 April	25 March	29 March	4 April	10 April
1	Weld	561A	J1	274	312	356	406	21472	21584	21674	21985
2	Weld	561A	J2	118	146	181	225	21178	21276	21314	21482
3	Weld	561A	J3	580	675	760	963	25874	26417	27051	27978
4	Weld	561A	J4	48	97	105	118	14521	14589	14674	14714
5	Weld	561A	J5	87	124	129	147	17254	17312	17387	17432
6	Weld	561A	J6	121	168	192	207	9824	9978	10026	10096

Table 7 Robot Torque Area vs Grease Ferrous Content

Graphical relationship between Torque area and Robot's axis Grease ferrous content (in ppm):

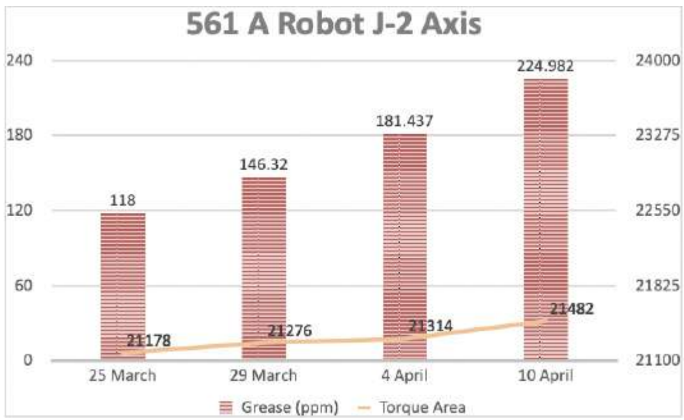
561 A Robot J-1 Axis

	25 March	29 March	4 April	10 April
Grease (ppm)	274	312.36	356.0904	405.943056
Torque Area	21472	21584	21674	21885



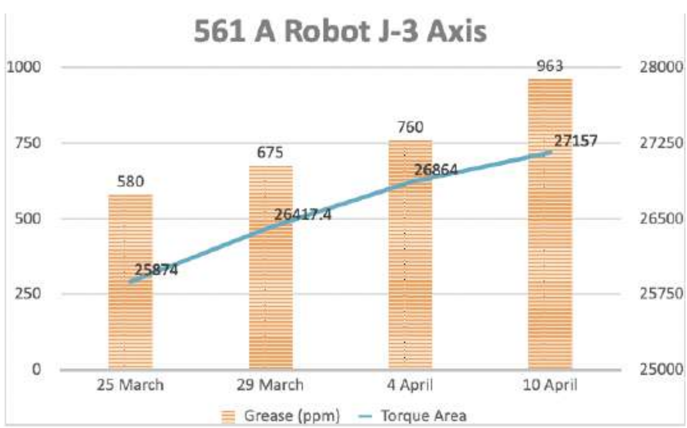
561 A Robot J-2 Axis

	25 March	29 March	4 April	10 April
Grease (ppm)	118	146.32	181.4368	224.981632
Torque Area	21178	21276	21314	21482



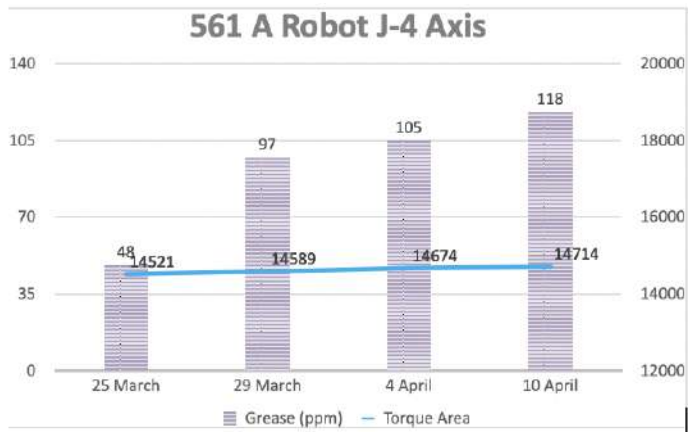
561 A Robot J-3 Axis

	25 March	29 March	4 April	10 April
Grease (ppm)	580	675	760	963
Torque Area	25874	26417.354	26864	27157



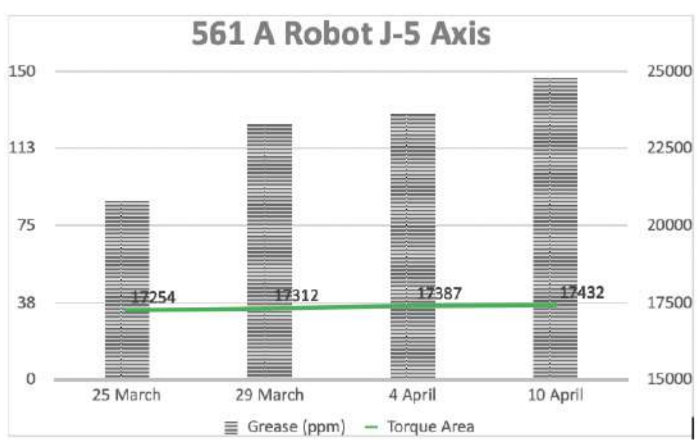
561 A Robot J-4 Axis

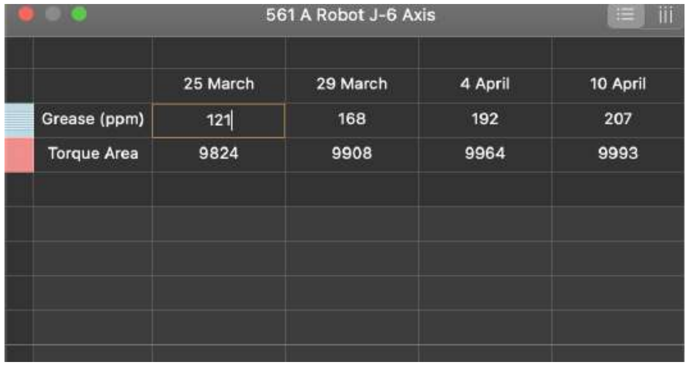
	25 March	29 March	4 April	10 April
Grease (ppm)	48	97	105	118
Torque Area	14521	14589	14674	14714



561 A Robot J-5 Axis

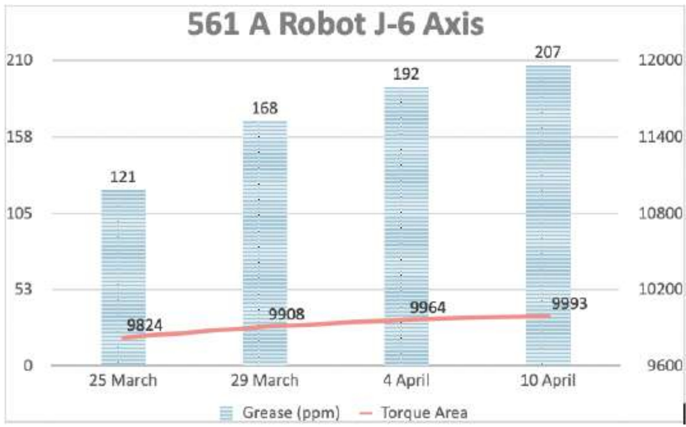
	25 March	29 March	4 April	10 April
Grease (ppm)	87	124	129	147
Torque Area	17254	17312	17387	17432





561 A Robot J-6 Axis

	25 March	29 March	4 April	10 April
Grease (ppm)	121	168	192	207
Torque Area	9824	9908	9964	9993



Based upon the above data collected between Torque area and Robot's axis Grease ferrous content (in ppm), a direct correlation can be observed. If Grease ppm value exceeds ≈ 400-450 ppm, then a sharp increase in Torque Area is observed exactly as in 561A Robot J3 Axis.

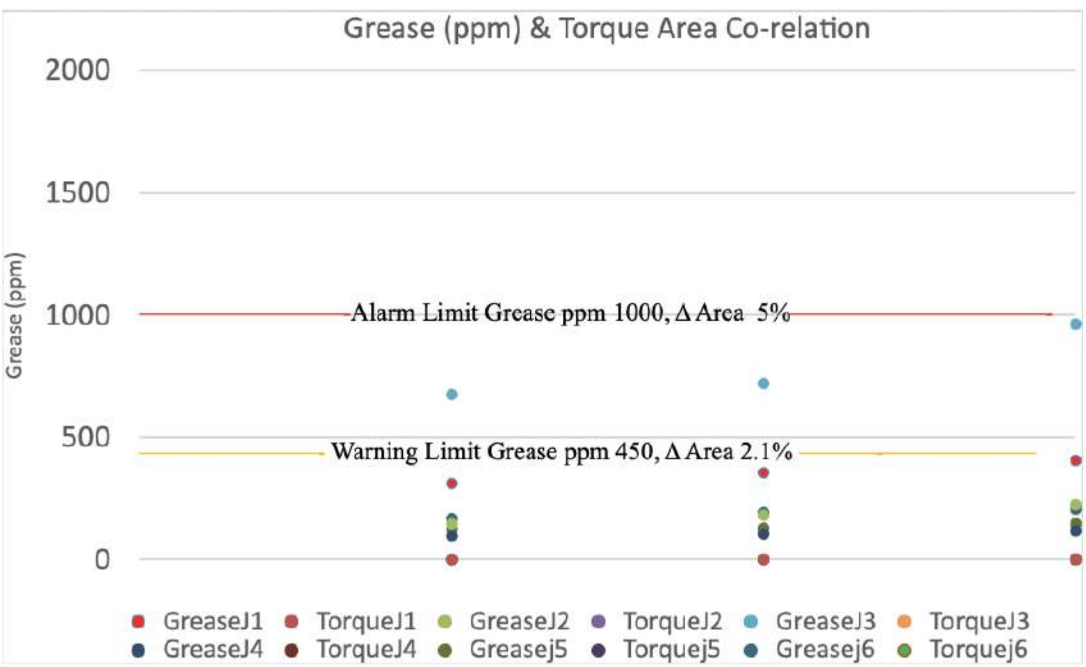
To find relation between Grease value and Torque Increase, first we need to calculate ΔArea wherein ΔArea is defined as

$$\Delta Area1 = (Torque\ Area1 - Torque\ AreaOriginal) \div (Torque\ AreaOriginal) \times 100\ \%$$

S. No.	Robot Application	Robot Name	Axis	Torque Data (Area under Curve)		ΔArea1	Torque Data (Area under Curve)	ΔArea2	Torque Data (Area under Curve)	ΔArea3
				25 March	29 March	29 March	4 April	4 April	10 April	10 April
1	Weld	561A	1	21472	21584	0.5216	21674	0.941	21885	1.9234
2	Weld	561A	2	21178	21276	0.4627	21314	0.642	21482	1.4355
3	Weld	561A	3	25874	26417	2.3000	27051	4.550	27978	8.1317
4	Weld	561A	4	14521	14589	0.4683	14674	1.054	14714	1.3291
5	Weld	561A	5	17254	17312	0.3362	17387	0.771	17432	1.0316
6	Weld	561A	6	9824	9908	0.8550	9964	1.425	9993	1.7203

Grease (ppm) & Torque Area Co-relation

GreaseJ1	X	1	2	3
	Y	312.36	356.0904	405.943056
TorqueJ1	X	1	2	3
	Y	0.521609538002981	0.940760059612519	1.92343517138599
GreaseJ2	X	1	2	3
	Y	146.32	181.4368	224.981632
TorqueJ2	X	1	2	3
	Y	0.462744357351969	0.642175842855794	1.4354518840306
GreaseJ3	X	1	2	3
	Y	675	720	963
TorqueJ3	X	1	2	3
	Y	2.3	3.82623483033161	4.95864574476308
GreaseJ4	X	1	2	3
	Y	97	105	118
TorqueJ4	X	1	2	3
	Y	0.468287308036637	1.05364644308243	1.32910956545692
Greasej5	X	1	2	3
	Y	124	129	147
Torquej5	X	1	2	3
	Y	0.336153935319346	0.770835748232294	1.03164483598006
Greasej6	X	1	2	3
	Y	168	192	207
Torquej6	X	1	2	3
	Y	0.855048859934854	1.42508143322476	1.72027687296417



Results

Based on the above study, it is clearly visible that as the ferrous content in the Robot's axis increases, beyond a limit, torque consumed by the motor for the same Robotic movement increases & if unchecked, would lead to failure.

On the basis of above study, Maruti Suzuki India Limited Gurgaon plant Weld Shop Maintenance team has planned to replace this Robot's J3 axis reducer on 22 May 2023 to prevent unexpected failure and Maruti Suzuki India Limited has updated their predictive maintenance standards from analyzing ferrous content every 6 months to real-time data based Torque Area monitoring.

S.No	Condition	Old Standard (Grease Analysis)	New Standards (ΔArea)
1	Normal	$0<x<450$	$0< \Delta_{Area} <2.1\%$
2	Under Observation	$450<x<1000$	$2.1< \Delta_{Area} <5\%$
3	Alarm (Reducer Replacement)	$1000<x$	$5< \Delta_{Area}$

Table 8 New Conditional Analysis for Ferrous Content

Maruti Suzuki India Limited maintenance has started to implement this programme in their lines and have implemented it in 43 of their total 614 Robots in Maruti Suzuki India Limited Gurgaon Plant Weld Shop 2-3 and plan to complete it by September 2023.

Future Improvements

On discussion with Maruti Suzuki India Limited maintenance team, following improvements points have been identified which Maruti Suzuki India Limited is planning to implement:

1) Automation: Currently robot's data logging is in auto mode but Torque area generation needs to be done manually by importing data log file into the programme.

2) Runtime Improvement: While executing a programme for calculating Torque area, it takes around 20-25 minutes to execute. Maruti Suzuki India Limited Maintenance team is in discussion with their IT Team to optimize/reduce the programme runtime.

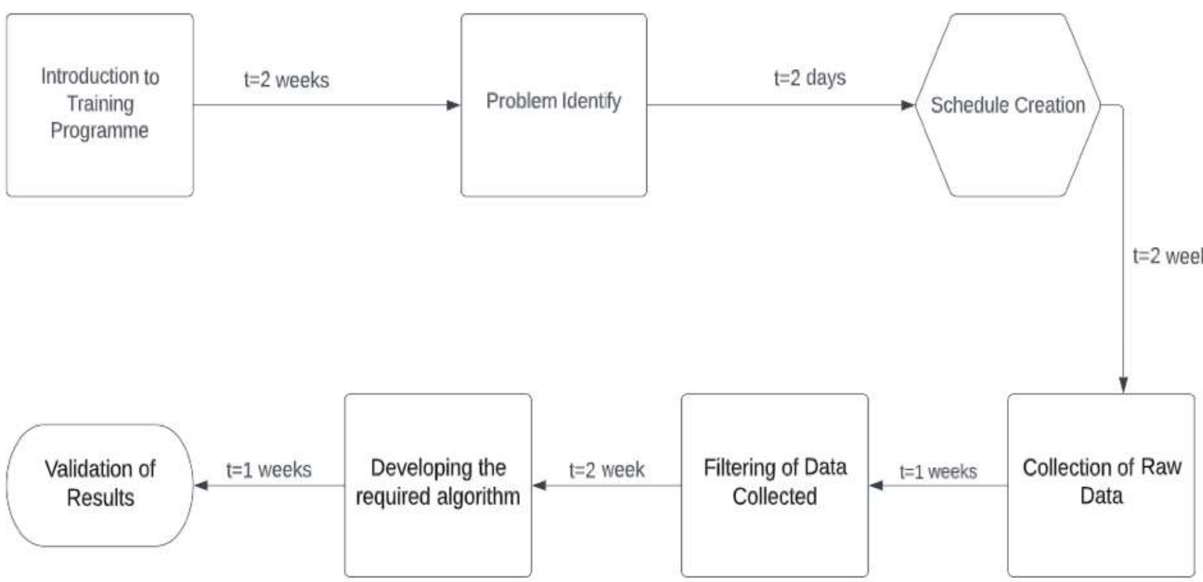
LEARNING OUTCOMES / EXPERIENCE

1) Technical Skills

Learned new technical skills like using the Jupyter text editor for working on Pandas data frames by using previously known algorithm development knowledge. Also understood methods to read a data file and store the output of the algorithm in a suitable place.

2) Project Management

Managed the project to completion within the stipulated time period by using PERT (Program Evaluation and Review Technique). It is a statistical tool used in project management, which was designed to analyze and represent the tasks involved in completing a given project. It is commonly used in conjunction with CPM (Critical Path Method).



PERT: Project Flow Chart

3) Team Work

Worked with a group of interns. Effectively divided the task amongst ourselves to optimize the time needed for completion of our project.

4) Change Management

Got firsthand experience of implementing a change in the existing process by keeping in mind the cost effectiveness of the proposed changes. Ensured that the change proposed for maintenance of reducers is independent of other manufacturing processes.

5) Leadership Skills

Effectively led the team of 3 interns to achieve our desired results within the stipulated time period.

6) Creativity & Learnability

Solved the preexisting problem by proposing various creative solutions. If a solution fails, then come up with a new solution by solving the problem.

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