A Project Report on

Statistical Analysis on Various Parameter of Flexible Couplings

A project report submitted in partial fulfilment of requirements

For the degree of M.Sc. (Statistics)

With specialization in Industrial Statistics

by

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(2022-2023)

CERTIFICATE

This is to certify that **Ms. Yeola Bhanuja Bharat, Mr. Suryawanshi Hitesh Ananda and Mr. Patil Rahul Dineshbhai** students of M.Sc. (Statistics) with specialization in Industrial Statistics, at Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon have successfully completed their project work entitled "Statistical Analysis on various parameter of flexible coupling" based on the data collection from Runflex Transmission PVT. LTD**.,** Pune during 27/01/2023 to 08/02/2023 as a part of M.Sc.(Statistics) program under my guidance and supervision during the academic year 2022-2023.

Place: Jalgaon

Date:

Dr. K. K. Kamalja
(Project Guide)
Department of Statistics
KBCNMU, Jalgaon

ACKNOWLEDGEMENT

We would like to convey our sincere regards to **Prof. R. L. Shinde**, Head, Department of Statistics, Kavayitri Bahinabai Chaudhari North Maharashtra University, and Jalgaon for seeking us the desire permission for this project in Runflex Transmission PVT. LTD., Pune.

We took this opportunity to express our sincere gratitude to our project guide **Prof. K. K. Kamalja** for his valuable guidance, kind suggestions, co-operation and constant encouragement, which enabled us to take every forward step in our project.

We would like to place on records our thanks to **Mr. Dilip Amrutkar** (Director of Runflex Transmission PVT LTD., Pune) for permitting us to carry out the project work at Runflex Transmission, Pune. It was also being a great opportunity for us to work with **Mr. Rugved Amrutkar** (Assistant Director of Runflex Transmission PVT LTD, Pune) for her guidance and supervision during the project work.

We are also thankful to **Prof. R. D. Koshti, Prof. M. C. Patil** and all concerned who have directly and indirectly helped us for successful completion of the project work.

Finally yet importantly, we are thankful to our parents for their moral support and blessing.

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Mr. Rahul Dineshbhai Patil (387437)

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Chapter 1

Introduction

1.1 Motivation

Being students of M.Sc. (statistics), we are interested in knowing how to handle real datasets for statistical analysis .We approached to *Runflex Transmission Pvt Ltd* for our project. Our project related to fieldwork and data collection at RTPL during 27/1/2023 to 8/2/2023 done by us.

In RTPL, the members had shown the practical implementation of statistical theories and techniques related to Quality Control Management and Manufacturing of observations at the field. We were interested in the applications of these theories into practice.

That is why we have chosen this as a project area of our interest. Here we have taken our best efforts to implement statistical Process Control and Time series analysis for the actual work performed at the fields. We are aware about the industrial work environment and about the practices through this project work.

1.2 Company Profile

Name of Company: Runflex Transmission Pvt Ltd.

Address: Dedge Industries, 25/7, Sinhgad Rd, Fule Market, Nanded Fata, Pandurang Industrial Area, Nanded, Pune, Maharashtra 411041

Website: www.runflextransmissions.com

Establishment: 08 May 2019

Director(s): Dilip Amrutkar and Rugved Amrutkar

Runflex Transmissions Pvt Ltd. deals in designing, developing and manufacturing Flexible Couplings & High Speed Couplings Our couplings are favoured by the engineering industry because of their construction, design and reliability in long service cycles. Our couplings are widely used in different industries that include steel, rolling mills, heavy engineering, sugar, material handling, mining, coal, power, and more.

Runflex Transmissions Pvt Ltd. a team of professionals who understands customer requirements and give total customer satisfaction with our prompt service and timely delivery of defect free products. With our precise machinery setup, we deliver highly engineered and best quality products.

With over 20 years of experience, Runflex Transmissions focus on designing and developing Couplings as per latest market trends.

Runflex Transmissions also provide alignment solutions and consultancy for failure of couplings along with technical trainings that helps industry employees to understand causes of failure of coupling. With our wide range of Couplings, we fulfil requirements of all types of industries.

1.3 Achievement of Runflex Transmissions

Owing to our rich knowledge in this domain, our organization has been competent to give a wide range of Ready Cut Shim. These products are highly esteemed for their well-built strength and durability. Our offered product is a huge achievement among our esteemed customers for owing prominent attributes. Besides this, it is manufactured using top quality components and highly developed technology to make sure proper functioning for better consequences.

1.4 Runflex Transmissions Quality Policy

- Total commitment for customer satisfaction.
- Protection of environment.
- Market leadership.
- Strive for quality excellence.
- Sustainable development of stakeholders.

1.5 Objectives of project

- To observe industrial manufacturing process.
- To observe industrial environment and culture
- To identify source and causes of variation in industrial process.
- To present a general profile about Flexible Couplings.
- To Forecast Future value based on historical data.

- To study the trend in different type of Couplings.

1.6 Scope of the Project

This project will be also helpful for those who are handling quality control tools and time series analysis of statistical experiments in private sector/industry or Manufacturing Sectors. This project is help to statistical analyser to understand the behaviour of the occurrence of error in a machine and take appropriate decision.

1.7 Field Work

We have seen various types of jobs at RTPL, Pune. Moreover, we have observed processes of measurements and recording of observations in statistically designed experiments. We have visited the Manufacturing field of Flexible Couplings .We also visited the Production fields of Pre-cut Alignment Shims and Quickaline Alignment Kit and Universal Joint. Researcher collected the corresponding data. The process of recording of observation as follows:

- Jobs were randomly selected from each lot and then labelled.
- Several characteristics of corresponding couplings are measured.

Chapter 2
Information about Flexible Couplings

2.1 About Flexible Couplings

The purpose of a flexible coupling is to transmit torque from one piece of rotating equipment to another, while accepting at the same time a small amount of misalignment. Flexible coupling misalignment is expressed, as an order of magnitude, in thousandths of an inch.

2.2 The different types of Flexible Couplings

- Disc Coupling
- Gear Coupling
- Pin Bush Coupling
- Tyre Coupling
- Nylon Sleeve Coupling
- Encoder Coupling
- Jaw Coupling
- Servo Coupling

➢ **Other Product manufacturing in RTPL**

- Universal Joint
- Precut Alignment Shims
- Quickaline Alignment Kit

2.3 Information of Various Types of couplings

➢ Gear Coupling

Runflex Gear Couplings are designed for applications where high torque and balance is required. It consists of Forged sleeve with internal gear teeth and two identical Hubs with external gear teeth. The teeth of Hub and Sleeve are continuously in contact with each other transmitting torque from one end to another end and are designed to accommodate maximum angular, parallel and axial misalignment. The teeth are crowned for maximum load carrying capacity with minimum size.

Runflex Gear Couplings are widely used in Cement plants, Conveyors and Elevators, Metal Roll in g Mills, Paper Machinery, Cranes, Dredgers, Rubber and Plastic Industries, Compressors, Fans and Blowers, Screens and other general industries.

▪ **Features**

- High power to weight ratio.
- Crown gear teeth for longer life.
- Less back lash error.
- High torque capacity.
- Compact design.
- Larger bore capacities.
- Reliable and Maintenance friendly.
- Fully interchangeable with other couplings.

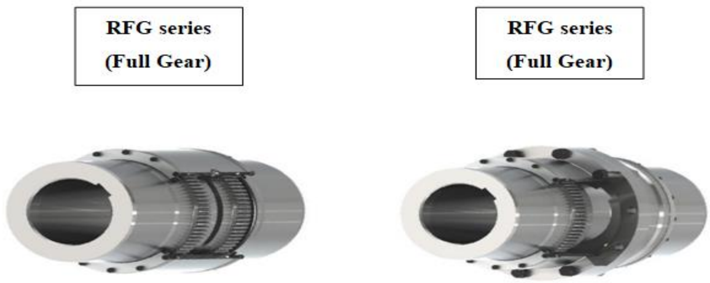


Fig 2.1 Gear Coupling

- **Selection Procedure**

RUNFLEXFULLGEARCOUPLING(RFGSERIES)

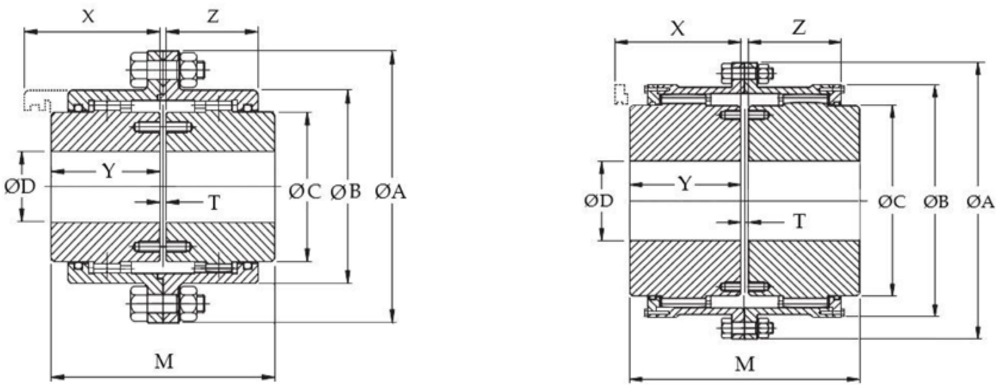


Fig 2.2 Diagram of Full Gear Coupling

Construction

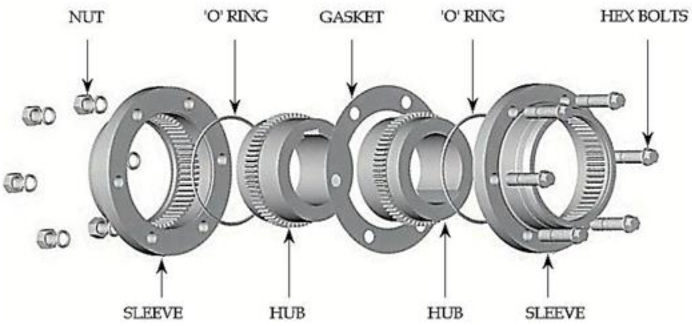


Fig 2.3 Construction of Full Gear Coupling

➢ Pin Bush Coupling

Runflex Pin Bush Couplings are used in applications that requires reliable power transmission even under various misalignment conditions.These couplings are designed to transmit high torque at maximum speeds. It transmits the torque through rubber bushes, which have excellent capacity to handle shocks and vibrations. Pin Bush Couplings have progressive increasing stiffness characteristics that ensures control of vibrations amplitude for protection of equipment.

Runflex Gear Couplings are widely used in Conveyors, Escalator, Mixers, Pumpsand other general industrial applications.

▪ **Features**

- Easy to assemble and dismantle.
- Permits drive in both directions.
- Easy replacement of flexible element.
- No lubrication required.
- Economical for long run.
- Absorbs shocks and vibration load.

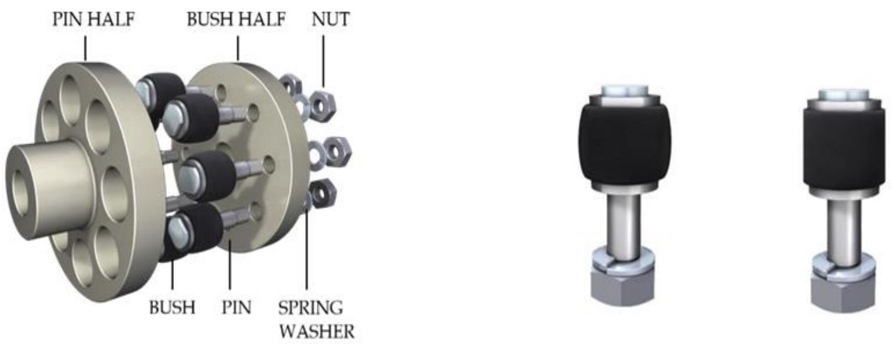
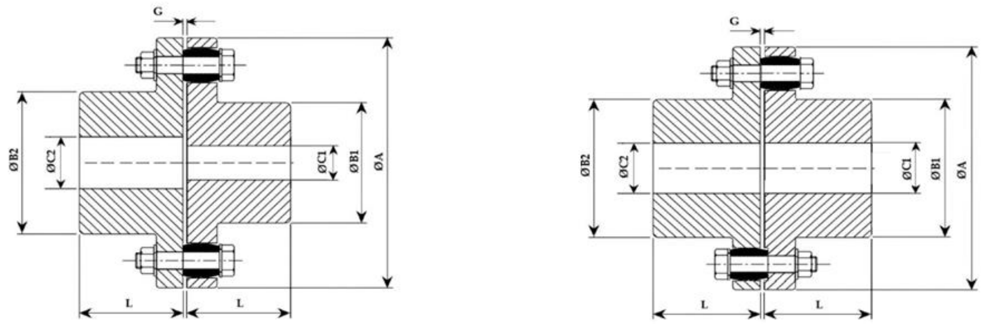


Fig 2.4 Pin Bush Coupling

- **Selection Procedure**

RUNFLEXCURVEDPINBUSHCOUPLING(RFCSERIES)



RUNFLEXPLAINPINBUSHCOUPLING(RFPSERIES)

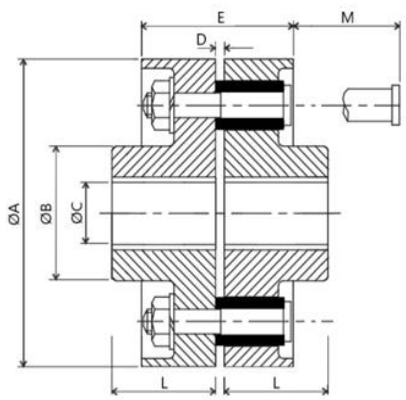


Fig 2.5 Diagram of Pin Bush Coupling

➢ Tyre Coupling

Runflex Tyre Couplings are torsion ally elastic couplings that can accommodate simultaneous maximum misalignment without imposing load on adjacent bearings. It protects equipment against vibration, impact loads and heavy shocks occurred during sudden load changes. It also has low reaction stiffness in all direction, which minimizes stress on bearings even under condition of extreme misalignment

Runflex Tyre Couplings are widely used in Cement plants ,Sugar Industries, Food & Beverage Industries, Chemical & Pharmaceutical Industries ,Power generation plants and other general industries.

- **Features**

- Maximum misalignment carrying capacity.
- Easy to assemble & dismantle.
- Back lash free.
- Dampens destructive vibrations.
- No lubrication required.
- Element scan be replaced easily

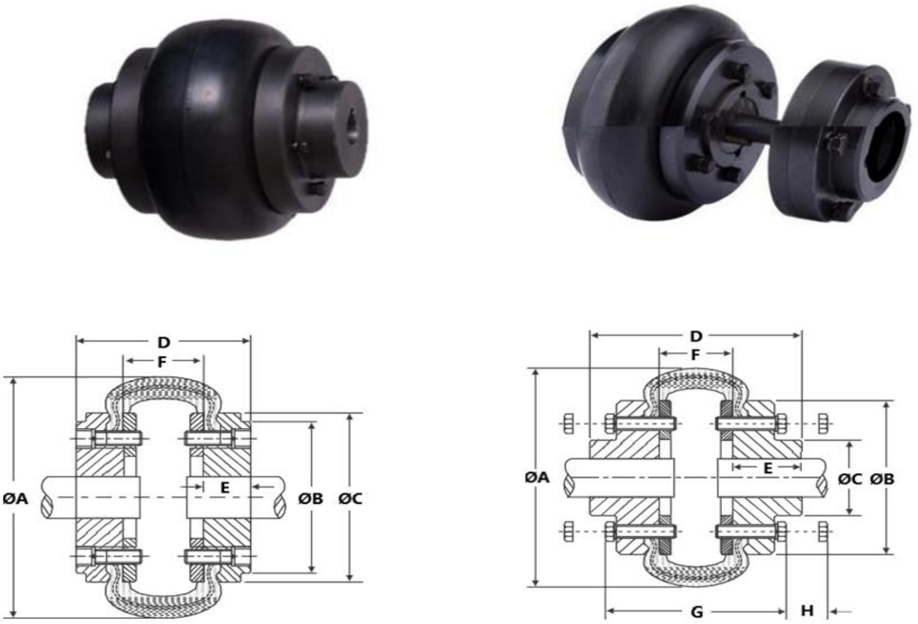


Fig 2.5 Tyre Coupling and Diagram of Tyre coupling

Chapter 3
Statistical Methods and Tools Used

3.1 Run Chart

A run chart is a graphical tool used in statistical process control (SPC) to track and analyses the performance of a process over time. It is a line graph that displays data points in chronological order along the x-axis, and the corresponding values of the process variable being measured on the y-axis.

A run chart is used to identify trends and patterns in the data such as shifts, cycles or any other changes in the process, which can be indicative of process stability or instability. It allows you to visualize the data and observe any unusual variations or systematic changes that may occur.

Key features of a run chart include:

Data Points: Each data point represents an observation of the process variable at a specific time. These points are plotted in order of occurrence.

Center Line: The center line represents the average or median value of the data. It provides a reference for comparing individual data points and detecting deviations from the expected performance.

Control Limits: Control limits are horizontal lines drawn above and below the center line, typically at a certain number of standard deviations from the average. They serve as boundaries to identify statistically significant variations in the data.

Trend Lines: Trend lines can be added to the run chart to visually represent the direction of the data over time. They help to identify long-term trends and changes in the process.

Annotations: Annotations such as notes or comments can be included on the chart to provide additional context or explanations for specific observations or events.

Run charts are commonly used in various industries and sectors to monitor processes, track performance metrics, and identify opportunities for improvement. They can be used alongside other SPC tools to gain insights into process behavior and make informed decisions about process adjustments or interventions.

3.2 Run Test

The "run test" is a non-parametric test. It is used to analyse the presence of patterns or trends in a sequence of data.

It examines whether the observations are arranged in a systematic manner or if there are random fluctuations.

The test counts the number of runs, which are consecutive sequences of increasing or decreasing values, and compares it to the expected number of runs under the assumption of randomness.

The results of the run test can indicate the presence of serial correlation or other patterns in the data.

The run test is a non-parametric test, meaning it makes fewer assumptions about the underlying distribution of the data compared to parametric tests. However, there are a few assumptions associated with the run test:

1. Independence: The observations in the data sequence should be independent of each other. This assumption implies that each observation is not influenced by the values that come before or after it.

2. Randomness: The run test assumes that the sequence of data is generated by a random process, where each observation is equally likely to take any value within its range.

3. Homogeneity: The run test assumes that the probability of observing an increasing or decreasing run is the same throughout the sequence. In other words, the data does not exhibit any systematic changes in its properties over time.

It is important to note that violating these assumptions may affect the validity and interpretation of the run test results. Therefore, it is recommended to assess the suitability of the test for your specific dataset and consider alternative methods if necessary.

To test the hypothesis using the run test, one can follow these general steps:

Formulate the Hypotheses: Define the null hypothesis (H_0) and the alternative hypothesis (H_1) based on the characteristics of the data that we are analyzing. The null hypothesis assumes randomness, while the alternative hypothesis suggests the presence of a non-random pattern.

Define the Significance Level: Choose the significance level (α) for our test, which represents the maximum probability of rejecting the null hypothesis when it is true. Commonly used significance levels are 0.05 (5%) or 0.01 (1%).

3.3 Test of Hypothesis

- **t-test**

A t-test is a statistical test used to compare the means of two groups or assess the statistical significance of the difference between two sample means. It helps determine whether the difference between the means is likely due to chance (random variation) or represents a true difference in the populations from which the samples were taken.

The t-test is based on the t-distribution, which is similar to the normal distribution but has slightly heavier tails. The test calculates a t-value, which measures the difference between the means in terms of standard error. The t-value is then compared to a critical value from the t-distribution to determine the statistical significance.

Formulate Hypotheses: Start by stating null hypothesis (H_0) and alternative hypothesis (H_1). The null hypothesis usually assumes that there is no significant difference between the sample mean and the hypothesized population mean, while the alternative hypothesis suggests that there is a significant difference.

Calculate the Test Statistic: Compute the t-statistic using the formula:

$$t = \frac{samplemean - hypothesizedmean}{standarddeviation/sqrt(samplesize)}$$

The sample mean refers to the mean value of the data in sample, the hypothesized mean is the value that we are comparing it to, the standard deviation represents the variability in sample data, and the square root of the sample size adjusts for the uncertainty in the estimate of the standard deviation.

Determine the Degrees of Freedom: The degrees of freedom for a one-sample t-test is equal to the sample size minus one (df = n - 1), where 'n' is the number of observations in the sample.

Obtain the Critical Value: Consult a t-distribution table or use statistical software to find the critical value for the desired significance level (α) and degrees of freedom. The critical value is the threshold beyond which you reject the null hypothesis.

Compare the Test Statistic and Critical Value: Compare the absolute value of the test statistic with the critical value. If the absolute value of the test statistic is greater than the critical value, reject the null hypothesis. Otherwise, fail to reject the null hypothesis.

Interpret the Results: If the null hypothesis is rejected, it suggests that there is evidence to support a significant difference between the sample mean and the hypothesized population mean. If the null hypothesis is not rejected, it indicates that there is insufficient evidence to conclude a significant difference.

- **Paired t-test**

A paired t-test helps the data analytics to compare two means that are taken from the same data set to determine if the difference is zero. In the statistical procedure of Paired t-test also known as dependent sample t-test every data set say individual, unit or object is measured twice consequential providing the pairs of observation for paired t-Test. In simple words, this test is used to find if the mean of the dependent variable is the same in two same or related groups.

There are two competing hypotheses for paired t-test the null hypothesis and the alternative hypothesis.

The null hypothesis assumes the difference between the means of paired samples is equal to zero. On the contrary, the alternative hypothesis assumes the mean difference between the paired samples is not equal to zero. The alternative hypothesis further has an extension based on the low or high tail result.

The **hypothesis** can be represented as:

Null Hypothesis, H0: $\mu_1 = \mu_2$ or **H1**: $\mu_1 - \mu_2 = 0$

Alternative hypothesis, **H1**: $\mu_1 \neq \mu_2$ or **H1**: $\mu_1 - \mu_2 \neq 0$

Test statistic is given by,

$$t = \frac{\mu_1 - \mu_2}{SD/\sqrt{n}}$$

3.4 Statistical Quality Control

Statistical quality control is a statistical method used in the monitoring and maintaining of the quality of products and services.

- **Statistical Process Control**

Statistical process control (SPC) is a method of quality control which uses statistical methods. SPC is applied in order to monitor and control a process. Monitoring and controlling the process ensures that it operates at its full potential.

3.5 Process Capability Indices

- **Process Capability Analysis**

Statistical techniques can be helpful throughout the product cycle, including development activities prior to manufacturing, in quantifying process variability, in analyzing this variability relative to product requirements or specifications, and in assisting development and manufacturing in eliminating or greatly reducing this variability. This general activity is termed as process capability analysis. Process capability refers to the uniformity of the process.

Process Capability Analysis is an important technique used to determine how well a process meets a set of specification limits is called a process capability analysis.

- **Process Capability Ratio (Cp)**

It is frequently convenient to have a simple, quantitative way to express process capability. One way to do so is through the process capability ratio (PCR). It is denoted by C_p. For capability we use $\hat{\sigma}$,

$$C_p = \frac{USL - LSL}{6\sigma}$$

Where USL and LSL are upper and lower specification limits respectively. Usually the process standard deviation σ is unknown and must be replaced by an estimate of $\hat{\sigma}$.
We estimate $\hat{\sigma}$ as $\bar{R}$/ d2. This result is an estimate of C_p

$$\widehat{C_p} = \frac{USL - LSL}{6\hat{\sigma}}$$

The C_p has useful practical interpretation

$$P = \frac{1}{Cp} * 100$$

P is percentage of specification band used by the process.

Assume that the process has both upper and lower specification limits. For one sided specification, we define the C_P as follows,

$C_{pu} = \frac{USL-\mu}{3\sigma}$ and $C_{pl} = \frac{\mu-LSL}{3\sigma}$

The C_p is measure of the ability of the process to manufacturer products that meet specifications

- **Process Capability Index (C_{pk})**

The process capability ratio C_p does not take into consideration where the process mean is located related to specifications. C_p simply measures the spread of the specification σ relative to the 6σ spread in the process. For this purpose another process capability index is given which takes process centering into account. It is denoted by C_{pk} and is defined as,

C_{pk} = min{Cpu,Cpl}

If C_{pk} = 0, The Process mean is exactly equal to one of the specification limit.

If C_{pk} <0, The Process mean lies outside the specification limit.

If C_{pk} >1 , The Process is capable.

If C_{pk} = C_p, we can conclude that the process is centered at the midpoint of the specification.

If C_{pk} <C_p, we can conclude that process is off centered.

Chapter 4

Data Analysis and Interpretation

4.1 Data analysis of flexible coupling

➢ Disc Coupling

- Type: RL
- Size: 81
- Date: 27/01/23
- Outside Diameter (ØA):103 mm
- Hub Diameter: 57 mm
- Hub Length (Left) & (Right): 45 mm
- Bore Size Type 1 Adaptor: 32 mm
- Bore Size Type 2 Adaptor: 42 mm

For Machine No 1

Sample no 1	Parameter					
	Outside Diameter	Hub Diameter	Hub length		Bore Size	
			left	right	1 type adaptor	2 type adaptor
1	103.10	57.05	45.05	45.07	32.018	42.001
2	103.05	57.10	44.89	44.90	32.010	42.018
3	103.17	56.89	44.85	44.83	32.020	42.018
4	103.20	56.99	45.20	45.18	32.010	42.014
5	103.18	57.11	45.15	45.11	32.008	42.005
6	102.99	57.15	44.95	44.99	32.005	42.010
7	102.95	57.21	45.05	45.08	32.020	42.020
8	103.05	56.91	45.12	45.17	32.010	42.015
9	102.89	56.99	45.18	45.20	32.020	42.019
10	102.91	56.79	45.17	45.18	32.015	42.010
11	103.21	57.19	44.95	44.98	32.018	42.015
12	102.82	57.20	44.85	44.84	32.019	42.019
13	103.09	57.16	44.80	44.83	31.999	42.000
14	103.19	57.09	44.98	44.97	32.010	42.012
15	103.04	56.89	44.99	44.95	32.010	42.018
16	103.09	56.81	44.90	44.87	32.012	42.008
17	103.03	56.99	45.15	45.10	32.009	42.003
18	102.86	57.01	45.06	45.01	32.012	42.015
19	102.79	57.10	45.19	45.17	32.018	42.017
20	102.95	57.15	45.01	45.04	32.020	41.999
21	103.10	56.95	44.98	45.01	32.017	42.021
22	102.99	56.98	44.94	44.98	32.012	42.023
23	102.89	56.79	45.12	45.14	32.013	42.001
24	103.06	56.81	45.17	45.16	32.007	42.008

25	103.19	56.89	45.21	45.19	32.010	42.003
26	102.85	57.01	45.24	45.20	32.004	42.006
27	103.12	57.20	45.15	45.13	32.007	42.016
28	102.99	57.15	45.05	45.08	32.012	42.013
29	102.93	57.05	44.98	44.96	32.019	42.009
30	103.01	57.01	44.78	44.80	32.015	42.019

For Machine No 2

Sample no 2	**Parameter**					
	Outside Diameter	**Hub diameter**	**Hub length**		**Bore Size**	
			Left	**Right**	**1 type adaptor**	**2 type adaptor**
1	103.05	57.02	45.01	45.05	32.014	42.002
2	103.15	57.08	45.03	45.01	32.004	42.015
3	102.99	57.15	45.09	45.05	32.002	42.003
4	102.08	57.18	45.12	45.10	32.020	42.013
5	102.96	57.02	45.20	45.18	32.019	42.000
6	102.85	57.20	45.09	45.06	32.003	42.014
7	102.80	57.21	45.12	45.19	32.015	42.018
8	102.78	57.24	45.19	45,17	32.012	42.020
9	103.12	56.98	44.98	44.95	32.004	42.015
10	102.88	56.89	44.81	44.83	32.006	42.006
11	103.20	56.78	45.10	45.15	32.020	42.003
12	103.21	56.97	44.98	44.95	32.015	42.018
13	103.24	57.01	44.85	44.89	32.002	42.012
14	103.15	57.05	45.15	45.18	32.000	42.019
15	103.14	57.18	45.01	45.05	32.010	42.004
16	103.06	56.93	45.19	45.16	32.015	42.018
17	103.09	56.88	44.98	44.94	32.017	42.009
18	103.15	56.81	44.85	44.82	32.020	42.017
19	103.20	56.80	45.01	45.06	32.005	42.021
20	103.17	56.90	45.16	45.10	32.021	41.999
21	103.88	56.99	44.98	45.01	32.019	42.005
22	103.06	57.01	44.81	44.89	32.004	42.015
23	103.22	57.05	45.08	45.15	32.013	42.008
24	103.12	57.10	45.19	45.12	32.016	42.019
25	103.18	57.18	44.96	44.86	32.020	42.014
26	103.02	57.20	44.89	44.95	32.005	42.001
27	103.00	57.12	45.01	45.05	32.009	42.008
28	102.98	57.07	45.07	45.15	32.010	42.005
29	102.94	57.01	45.17	45.10	32.015	42.016
30	103.10	56.99	45.20	45.22	32.010	42.020

- **Descriptive Statistics:**

Descriptive statistics for parameters of Flexible Couplings of different types and size

Table: Descriptive statistics for parameter of Disc Coupling RL-81 (Day-1) Machine No.1

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	103.020	0.1210	102.790	102.930	103.040	103.100	103.210	0.01460	30
Hub Diameter	57.021	0.1310	56.790	56.905	57.010	57.150	57.210	0.01700	30
Hub length Left	45.037	0.1310	44.780	44.948	45.050	45.155	45.240	0.01720	30
Hub Length Right	45.037	0.1260	44.800	44.957	45.055	45.162	45.200	0.01580	30
Bore Size type 1 Adaptor	32.012	0.0060	31.999	32.009	32.012	32.018	32.020	0.00004	30
Bore Size type 2 Adaptor	42.012	0.0071	41.999	42.006	42.014	42.018	42.023	0.00005	30

Table: Descriptive statistics for parameter for Disc Coupling RL-81 (Day-1) Machine No.2

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	103.06	0.268	102.08	102.97	103.1	103.17	103.88	0.718	30
Hub Diameter	57.033	0.128	56.78	56.96	57.02	57.157	57.24	0.0165	30
Hub length Left	45.043	0.119	44.81	44.98	45.05	45.152	45.2	0.0142	30
Hub Length Right	45.046	0.115	44.82	44.95	45.055	45.15	45.22	0.0133	30
Bore Size type 1 Adaptor	32.011	0.00665	32	32.005	32.013	32.018	32.021	0.00004	30
Bore Size type 2 Adaptor	42.011	0.00697	41.999	42.005	42.014	42.018	42.021	0.00005	30

Table: Descriptive statistics for parameter for Disc Coupling RL-135 (Day-2) Machine No. 1

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	129.03	0.107	128.81	128.97	129.03	129.13	129.2	0.0115	25
Hub Diameter	77.037	0.125	76.78	76.95	77.06	77.145	77.21	0.0155	25
Hub length Left	55.02	0.125	54.78	54.95	55.01	55.135	55.21	0.0157	25
Hub Length Right	55.034	0.107	54.85	54.95	55.06	55.12	55.19	0.0114	25
Bore Size type 1 Adaptor	52.01	0.00681	51.998	52.002	52.01	52.016	52.021	0.00005	25
Bore Size type 2 Adaptor	70.012	0.00707	69.999	70.007	70.013	70.019	70.023	0.00005	25

Table: Descriptive statistics for parameter for Disc Coupling RL-135(Day-2) Machine No. 2

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	129.04	0.116	128.79	128.97	129.04	129.15	129.21	0.0134	25
Hub Diameter	77.007	0.119	76.79	76.925	77	77.085	77.219	0.0143	25
Hub length Left	55.094	0.179	54.81	55	55.07	55.165	55.81	0.0319	25

Hub Length Right	55.13	0.248	54.85	55.025	55.06	55.15	55.91	0.0613	25
Bore Size type 1 Adaptor	52.01	0.00657	51.999	52.005	52.009	52.017	52.021	0.00004	25
Bore Size type 2 Adaptor	70.012	0.00697	69.998	70.005	70.014	70.018	70.021	0.00005	25

Table: Descriptive statistics for parameter for Full Gear Coupling Size -220 (Day-3)

Machine No. 1

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	220.04	0.121	219.78	219.98	220.05	220.15	220.21	0.0146	23
Hub Diameter	105.02	0.117	104.78	104.95	105.03	105.09	105.22	0.0138	23
Hub Length Left	85.062	0.101	84.85	84.99	85.07	85.15	85.22	0.0102	23
Hub Length Right	85.044	0.11	84.78	84.99	85.03	85.15	85.21	0.0121	23
Bore Size Left	75.01	0.00701	74.998	75.002	75.01	75.016	75.021	0.00005	23
Bore Size Right	75.012	0.00713	74.999	75.003	75.015	75.018	75.022	0.00005	23

Table: Descriptive statistics for parameter for Full Gear Coupling Size -220 (Day-3)

Machine No. 2

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	220.05	0.13	219.78	219.98	220.07	220.17	220.21	0.0169	23
Hub Diameter	105.04	0.126	104.78	104.97	105.08	105.14	105.21	0.0159	23
Hub Length Left	85.031	0.121	84.78	84.95	85.03	85.15	85.22	0.0147	23
Hub Length Right	85.02	0.119	84.8	84.91	85.01	85.11	85.21	0.0141	23
Bore Size Left	75.01	0.00718	74.998	75.003	75.01	75.017	75.021	0.00005	23
Bore Size Right	75.01	0.00699	74.998	75.003	75.009	75.018	74.022	0.00005	23

Table: Descriptive statistics for parameter for Full Gear Coupling Size -590 (Day-4) Machine No. 1

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	590	0.118	589.78	589.91	590.01	590.1	590.17	0.014	20
Hub Diameter	400	0.122	399.8	399.88	400.03	400.1	400.19	0.0148	20
Hub Length Left	240.2	0.143	239.8	239.87	240.06	240.15	240.21	0.0205	20
Hub Length Right	240.5	0.111	239.8	239.96	240.05	240.15	240.2	0.0123	20
Bore Size Left	300.01	0.00638	300	300	300.01	300.01	300.02	0.00004	20
Bore Size Right	300.01	0.00756	300	300	300.01	300.02	300.02	0.00006	20

Table: Descriptive statistics for parameter for Full Gear Coupling Size -590 (Day-4) Machine No. 2

parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	590	0.141	589.78	589.87	590.04	590.11	590.21	0.0199	20
Hub Diameter	400.01	0.147	399.78	399.86	400.04	400.14	400.21	0.0215	20
Hub Length Left	239.99	0.14	239.79	239.84	239.98	240.13	240.22	0.0196	20
Hub Length Right	239.98	0.155	239.78	239.85	239.89	240.14	240.22	0.024	20
Bore Size Left	300.01	0.00582	300	300.01	300.01	300.02	300.02	0.00003	20

Bore Size Right	300.01	0.0083	300	300	300.01	300.02	300.02	0.00007	20

Table: Descriptive statistics for parameter for Half Gear Coupling Size-170 (Day-5) Machine No. 1

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	170.05	0.141	169.81	169.91	170.1	170.2	170.22	0.02	20
Hub Diameter	85.006	0.124	84.78	84.923	85.02	85.105	85.19	0.0153	20
Hub Diameter	64.985	0.124	64.82	64.893	64.955	65.11	65.18	0.0154	20
Hub length Left	54.978	0.135	54.78	54.837	54.965	55.115	55.22	0.0183	20
Hub Length Right	55.057	0.0946	54.83	54.99	55.065	55.115	55.19	0.0089	20
Bore Size Left	60.012	0.00759	59.998	60.004	60.013	60.019	60.022	0.00006	20
Bore Size Right	50.009	0.00796	49.998	50.001	50.008	50.018	50.021	0.00006	20

Table: Descriptive statistics for parameter for Half Gear Coupling Size-170(Day-5) Machine No. 2

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	169.99	0.128	169.83	169.88	169.94	170.11	170.22	0.0163	20
Hub Diameter	85.045	0.135	84.81	84.915	85.065	85.173	85.22	0.0181	20
Hub Diameter	65.02	0.119	64.86	64.93	65.005	65.128	65.22	0.0142	20
Hub length Left	55.064	0.121	54.8	54.975	55.11	55.167	55.21	0.0147	20
Hub Length Right	55.026	0.124	54.8	54.91	55.075	55.117	55.21	0.0154	20
Bore Size Left	60.009	0.00804	59.998	60.001	60.008	60.015	60.022	0.00006	20
Bore Size Right	50.014	0.00684	50.001	50.009	50.014	50.021	50.022	0.00005	20

Table: Descriptive statistics for parameter for Pin Bush Coupling Size-320 (Day-6) Machine No. 1

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	319.99	0.14	319.79	319.84	320.84	320.1	320.22	0.0196	20
Hub Diameter	196	0.136	195.78	195.89	195.99	196.12	196.21	0.0186	20
Hub Diameter	212.01	0.146	211.79	211.87	212.04	212.15	212.21	0.0212	20
Hub length (L1)	125.03	0.115	124.78	124.94	125.05	125.14	125.21	0.0133	20
Hub length (L2)	124.97	0.124	124.8	124.87	124.96	125.09	125.17	0.0154	20
Bore Size Left	125.01	0.008	125	125	125.01	125.02	125.02	0.00006	20
Bore Size Right	135.01	0.00686	135	125	135.01	135.02	135.2	0.00005	20

Table: Descriptive statistics for parameter for Pin Bush Coupling Size-320 (Day-6) Machine No. 2

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	320.06	0.0258	319.86	319.97	320.08	320.16	320.21	0.0133	20
Hub Diameter	195.99	0.0299	195.8	195.88	196	196.13	196.22	0.0178	20
Hub Diameter	212.01	0.0269	211.81	211.9	212.01	212.11	212.21	0.0145	20
Hub length (L1)	125	0.0287	124.81	124.88	124.98	125.12	125.22	0.0164	20
Hub length (L2)	124.96	0.0304	124.79	124.83	124.92	125.09	125.21	0.0184	20
Bore Size Left	125.01	0.00198	125	125	125	125.02	125.02	0.00008	20
Bore Size Right	135.01	0.0158	135	135	135.01	135.02	135.02	0.00005	20

Table: Descriptive statistics for parameter for Single Universal Joint Coupling Size-8 (Day-7) Machine No. 1

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	38.025	0.132	37.78	37.93	38.01	38.14	38.21	0.0174	25
Input shaft length	29.964	0.134	29.78	29.855	29.92	30.085	30.22	0.018	25
output shaft length	29.965	0.126	29.78	29.85	29.94	30.065	30.21	0.0159	25
input Bore Size	25.009	0.00774	24.998	25	25.01	25.015	25.021	0.00006	25
Output Bore Size	20.01	0.00779	19.998	20.001	20.01	20.015	20.022	0.00006	25

Table: Descriptive statistics for parameter for Single Universal Joint Coupling Size-8 (Day-7) Machine No. 2

Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	37.982	0.123	37.78	37.875	38	38.045	38.21	0.0151	25
Input shaft length	30.02	0.121	29.79	29.925	30.01	30.125	30.21	0.0146	25
Output shaft length	29.961	0.107	29.8	29.865	29.94	30.045	30.18	0.0115	25
Input Bore Size	25.01	0.00814	24.998	25.003	25.01	25.018	25.022	0.00007	25
Output Bore Size	20.008	0.00741	19.998	20.001	20.009	20.016	20.021	0.00005	25

Table: Descriptive Statistics for parameter for Tyre Coupling Size-60 (Day-8) Machine No. 1

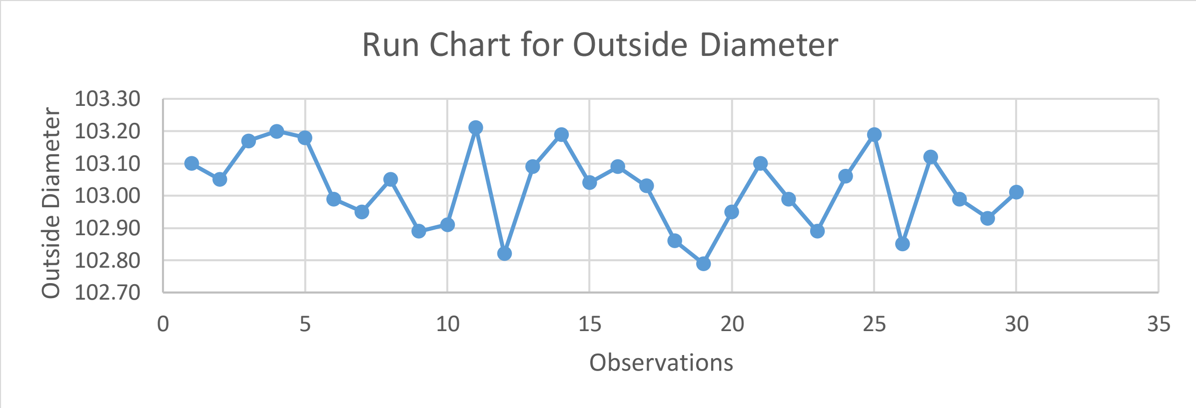
Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	165	0.14	164.78	164.85	165.02	165.12	165.22	0.0196	25
Hub Diameter	124.98	0.12	124.78	124.88	124.97	125.09	125.18	0.0145	25
Hub Length Left	37.962	0.138	37.78	37.825	37.94	38.085	38.19	0.019	25
Hub Length Right	38.006	0.155	37.78	37.83	38.04	38.155	38.22	0.0241	25
Bore Size Left	48.011	0.00827	47.998	48.003	48.013	48.019	48.022	0.00007	25
Bore Size Right	48.008	0.00761	47.998	48.002	48.005	48.014	48.022	0.00006	25

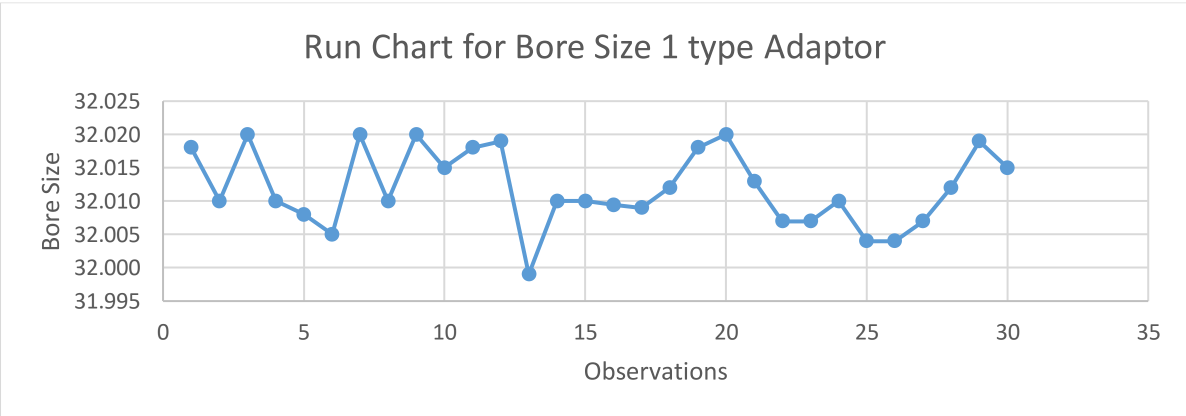
Table: Descriptive statistics for parameter for Tyre Coupling Size-60 (Day-8) Machine No. 2

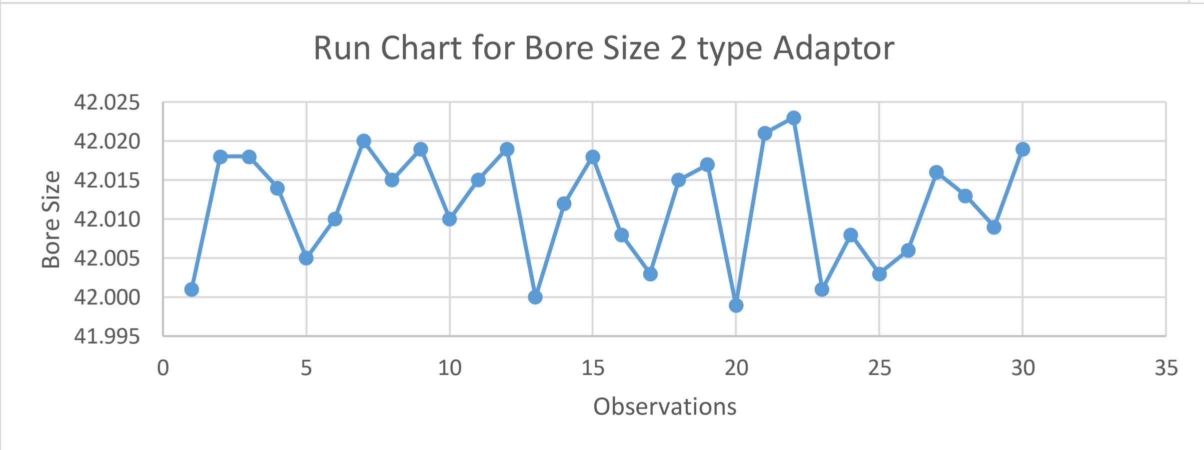
Parameters	Mean	SD	Minimum	Q1	Median	Q3	Maximum	Variance	N
Outside Diameter	164.95	0.133	164.79	164.84	164.84	165.07	165.21	0.0177	25
Hub Diameter	124.98	0.117	124.78	124.89	124.97	125.06	125.2	0.0137	25
Hub Length Left	38.07	0.131	37.78	37.97	38.08	38.185	38.22	0.0172	25
Hub Length Right	37.983	0.142	37.79	37.875	37.97	38.11	38.22	0.0202	25
Bore Size Left	48.007	0.00695	47.998	48	48.005	48.012	48.022	0.00005	25
Bore Size Right	48.009	0.00728	47.998	48.003	48.007	48.018	48.021	0.00005	25

Run Chart

Figure: Run charts for parameters Disc Coupling RL-81 for Machine No. 1



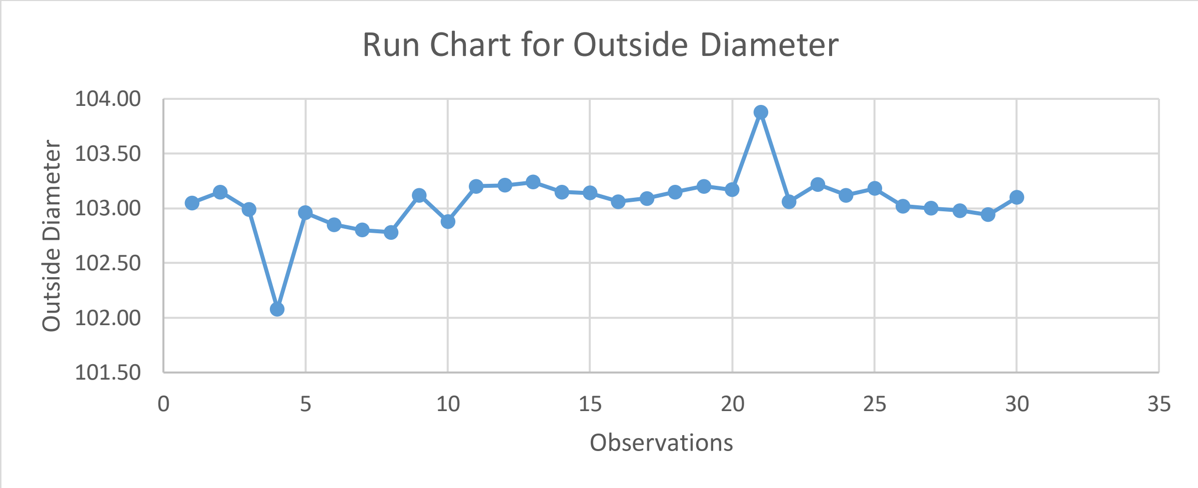


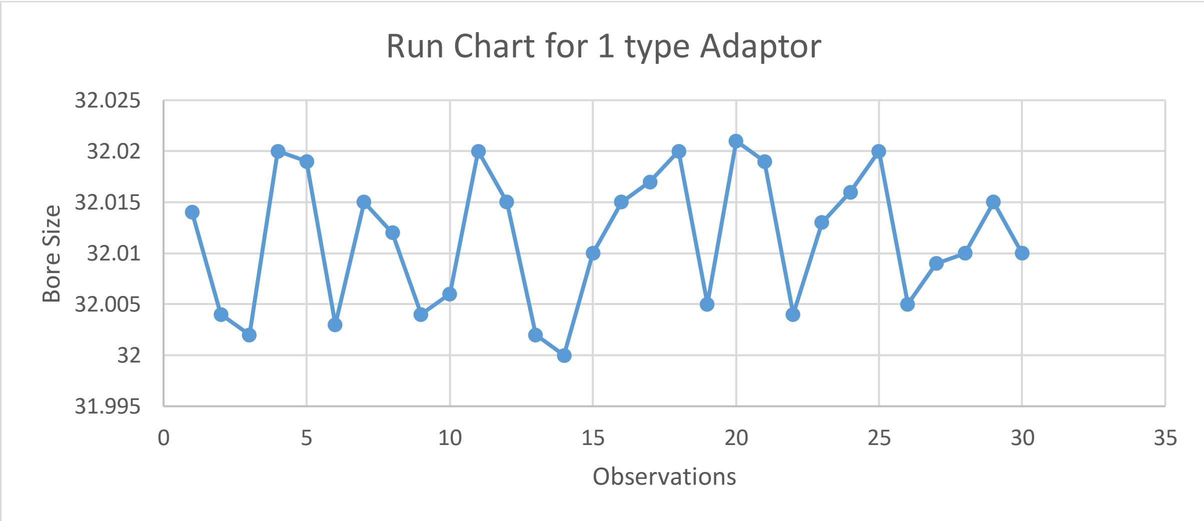


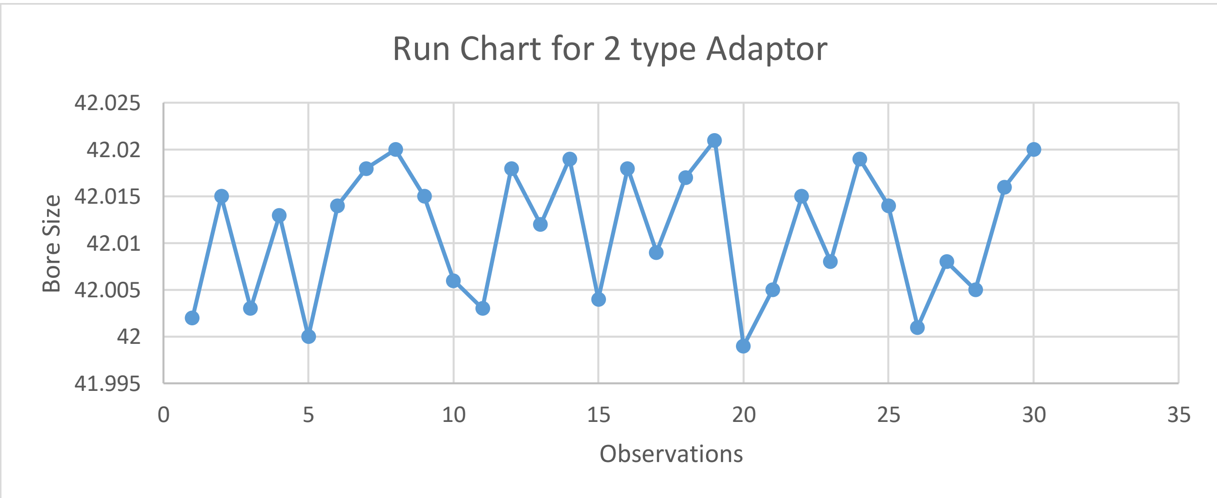
Conclusion

The run chart for the variable outside diameter demonstrates consistent performance over time. The run chart for Bore Size of 1 type Adaptor indicates as stable process, because the data points fall within a narrow range and less variability. There does not appear any significant trend for Bore Size of 2 type Adaptor.

Figure: Run charts for parameters Disc Coupling RL-81 for Machine No. 2







Conclusion

The run chart for the variable outside diameter demonstrates minimal variability and consistent performance over time. The run chart for Bore Size of 1 type Adaptor indicates as stable process, because the data points fall within a narrow range but quiet high variability, hence it impacts on stability. There does not appear any significant trend for Bore Size of 2 type Adaptor.

Run Test

H_0: There is evidence of random pattern in the data

H_1: There is no evidence of random pattern in the data

Table 4.1 Run test for Disc Coupling RL-81(Day-1)

Day 1					
Disc coupling RL-81 Machine No. 1			**Disc Coupling RL-81 Machine No. 2**		
Dimension	**p-value**	**Conclusion**	**Dimension**	**p-value**	**Conclusion**
Outside Diameter	0.47	Accept H_0	Outside Diameter	0.004	Reject H_0
Hub Diameter	0.281	Accept H_0	Hub Diameter	0.01	Reject H_0
Hub Length Left	0.027	Reject H_0	Hub length Left	0.457	Accept H_0
Hub Length Right	0.142	Accept H_0	Hub Length Right	0.438	Accept H_0
Bore Size type 1 Adaptor	0.301	Accept H_0	Bore Size type 1 Adaptor	0.98	Accept H_0
Bore Size type 2 Adaptor	0.92	Accept H_0	Bore Size type 2 Adaptor	0.391	Accept H_0

Conclusion:

1. For Machine No.1, the “Outside Diameter” and "Bore Size type 2 Adaptor" variables, the p-values (0.47 and 0.92, respectively) are greater than the significance level (assuming $\alpha = 0.05$), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would fail to reject null hypothesis and conclude that these variables exhibit a random pattern.

For Machine No. 2, the “Hub Length Right" and "Bore Size type 2 Adaptor" variables, the p-values (0.438 and 0.391, respectively) are greater than the significance level (assuming $\alpha = 0.05$), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would fail to reject null hypothesis or accept the null hypothesis and conclude that these variables exhibit a random pattern.

Table: Run test for Disc Coupling RL-135 (Day-2)

Day-2	
Disc Coupling RL-135 Machine No.1	**Disc Coupling RL-135 Machine No.2**

Dimension	p-value	Conclusion	Dimension	p-value	Conclusion
Outside Diameter	0.067	Accept H_0	Outside Diameter	0.844	Accept H_0
Hub Diameter	0.077	Accept H_0	Hub Diameter	0.067	Accept H_0
Hub Length Left	0.336	Accept H_0	Hub Length Left	0.998	Accept H_0
Hub Length Right	0.009	Reject H_0	Hub Length Right	0.638	Accept H_0
Bore Size type 1 Adaptor	0.778	Accept H_0	Bore Size type 1 Adaptor	0.336	Accept H_0
Bore Size type 2 Adaptor	0.778	Accept H_0	Bore Size type 2 Adaptor	0.486	Accept H_0

Conclusion

For Machine No.1, the “Outside Diameter” and "Bore Size type 2 Adaptor" variables, the p-values (0.067 and 0.778 respectively) are greater than the significance level (assuming α = 0.05), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would accept the null hypothesis and conclude that these variables exhibit a random pattern.

For Machine No. 2, the "Outside Diameter" and "Bore Size type 2 Adaptor" variables, the p-values (0.844 and 0.486 respectively) are greater than the significance level (assuming α = 0.05), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would accept the null hypothesis and conclude that these variables exhibit a random pattern.

Table: Run test for Full Gear Coupling Size -220(Day-3)

Day-3					
Full Gear Coupling Size -220 Machine No. 1			**Full Gear Coupling Size -220 Machine No. 2**		
Dimension	**p-value**	**Conclusion**	**Dimension**	**p-value**	**Conclusion**
Outside Diameter	0.137	Accept H_0	Outside Diameter	0.007	Reject H_0
Hub Diameter	0.289	Accept H_0	Hub Diameter	0.081	Accept H_0
Hub Length Left	0.019	Reject H_0	Hub Length Left	0.001	Reject H_0
Hub Length Right	0.055	Accept H_0	Hub Length Right	0.055	Accept H_0
Bore Size Left	0.527	Accept H_0	Bore Size Left	0.055	Accept H_0
Bore Size Right	0.061	Accept H_0	Bore Size Right	0.151	Accept H_0

Conclusion:

For Machine No.1, the “Outside Diameter” and "Bore Size type 2 Adaptor" variables, the p-values (0.137 and 0.061 respectively) are greater than the significance level (assuming α = 0.05), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would accept the null hypothesis and conclude that these variables exhibit a random pattern

For Machine No.2, the “Right Hub Length" and "Bore Size type 2 Adaptor" variables, the p-values (0.055 and 0.151 respectively) are greater than the significance level (assuming α = 0.05), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we woul accept the null hypothesis and conclude that these variables exhibit a random pattern.

Table: Run test for Full Gear Coupling Size –590 (Day-4)

Day-4					
Full Gear Coupling Size -590 Machine No.1			**Full Gear Coupling Size -590 Machine No.2**		
Dimension	**p-value**	**Conclusion**	**Dimension**	**p-value**	**Conclusion**
Outside Diameter	0.168	Accept H_0	Outside Diameter	0.168	Accept H_0
Hub Diameter	0.623	Accept H_0	Hub Diameter	0.848	Accept H_0
Hub Length Left	0.103	Accept H_0	Hub Length Left	0.358	Accept H_0
Hub Length Right	0.646	Accept H_0	Hub Length Right	0.057	Accept H_0
Bore Size Left	0.335	Accept H_0	Bore Size Left	0.963	Accept H_0
Bore Size Right	0.178	Accept H_0	Bore Size Right	0.048	Reject H_0

Conclusion:

For Machine No.1, the “Outside Diameter” and "Bore Size type 2 Adaptor" variables, the p-values (0.168 and 0.178 respectively) are greater than the significance level (assuming α = 0.05), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would fail to reject null hypothesis and conclude that these variables exhibit a random pattern.

For Machine No.2, the “Outside Diameter” and "Bore Size type 1 Adaptor" variables, the p-values (0.168 and 0.963 respectively) are greater than the significance level (assuming α = 0.05), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would accept the null hypothesis and conclude that these variables exhibit a random pattern.

Table: Run test for Half Gear Coupling Size-170 (Day-5)

Day-5					
Half Gear Coupling Size-170 Machine No.1			**Half Gear Coupling Size-170 Machine No.2**		
Dimension	**p-value**	**Conclusion**	**Dimension**	**p-value**	**Conclusion**
Outside Diameter	0.609	Accept H_0	Outside Diameter	0.178	Accept H_0
Hub Diameter	0.676	Accept H_0	Hub Diameter	0.178	Accept H_0
Hub Diameter	0.212	Accept H_0	Hub Diameter	0.848	Accept H_0

Hub length Left	0.773	Accept H_0	Hub length Left	0.378	Accept H_0
Hub Length Right	0.15	Accept H_0	Hub Length Right	0.848	Accept H_0
Bore Size Left	0.286	Accept H_0	Bore Size Left	0.646	Accept H_0
Bore Size Right	0.358	Accept H_0	Bore Size Right	0.676	Accept H_0

Conclusion:

For Machine No.1, the "Outside Diameter" and "Bore Size type 2 Adaptor" variables, the p-values (0.609 and 0.358 respectively) are greater than the significance level (assuming $\alpha = 0.05$), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would accept the null hypothesis and conclude that these variables exhibit a random pattern.

For Machine No.2, the "Outside Diameter" and "Bore Size type 2 Adaptor" variables, the p-values (0.609 and 0.358 respectively) are greater than the significance level (assuming $\alpha = 0.05$), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would accept the null hypothesis and conclude that these variables exhibit a random pattern.

Table: Run test for Pin Bush Coupling Size-320 (Day-6)

Day-6					
Pin Bush Coupling Size-320 Machine No.1			**Pin Bush Coupling Size-320 Machine No.2**		
Dimension	**p-value**	**Conclusion**	**Dimension**	**p-value**	**Conclusion**
Outside Diameter	0.963	Accept H_0	Outside Diameter	0.103	Accept H_0
Hub Diameter	0.609	Accept H_0	Hub Diameter	0.609	Accept H_0
Hub Diameter	0.963	Accept H_0	Hub Diameter	0.358	Accept H_0
Hub Length (L1)	0.443	Accept H_0	Hub Length (L1)	0.358	Accept H_0
Hub Length (L2)	0.609	Accept H_0	Hub Length (L2)	0.609	Accept H_0
Bore Size Left	0.057	Accept H_0	Bore Size Left	0.013	Reject H_0
Bore Size Right	0.358	Accept H_0	Bore Size Right	0.773	Accept H_0

Conclusion:

For Machine No.1, the "Outside Diameter" and "Hub Diameter" variables, the p-values (0.963 and 0.609 respectively) are greater than the significance level (assuming $\alpha = 0.05$), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would accept the null hypothesis and conclude that these variables exhibit a random pattern.

For Machine No.2 the "Outside Diameter" and "Hub Diameter" variables, the p-values (0.103 and 0.609 respectively) are greater than the significance level (assuming $\alpha = 0.05$), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would accept the null hypothesis and conclude that these variables exhibit a random pattern.

Table: Run test for Single Universal Joint Coupling Size-8 (Day-7)

Day-7					
Single Universal Joint Coupling Size-8 Machine No. 1			**Single Universal Joint Coupling Size-8 Machine No. 2**		
Dimension	**p-value**	**Conclusion**	**Dimension**	**p-value**	**Conclusion**
Outside Diameter	0.052	Accept H_0	Outside Diameter	0.778	Accept H_0
Input Shaft Length	0.394	Accept H_0	Input Shaft Length	0.302	Accept H_0
Output Shaft Length	0.302	Accept H_0	Output Shaft Length	0.831	Accept H_0
Input Bore Size	0.778	Accept H_0	Input Bore Size	0.778	Accept H_0
Output Bore Size	0.545	Accept H_0	Output Bore Size	0.894	Accept H_0

Conclusion

For the “Outside Diameter” and " Bore Size" variables, the p-values (0.052 and 0.545 respectively) are greater than the significance level (assuming $\alpha = 0.05$), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would accept the null hypothesis and conclude that these variables exhibit a random pattern.

For the “Outside Diameter” and "Output Bore Size" variables, the p-values (0.052 and 0.545 respectively) are greater than the significance level (assuming $\alpha = 0.05$), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would accept the null hypothesis and conclude that these variables exhibit a random pattern.

Table: Run test for Tyre Coupling Size-60(Day-8) Machine No. 1

Day-8					
Tyre Coupling Size-60 Machine No. 1			**Tyre Coupling Size-60 Machine No .2**		
Dimension	**p-value**	**Conclusion**	**Dimension**	**p-value**	**Conclusion**
Outside Diameter	0.844	Accept H_0	Outside Diameter	0.31	Accept H_0
Hub Diameter	0.154	Accept H_0	Hub Diameter	0.154	Accept H_0
Hub Length Left	0.844	Accept H_0	Hub Length Left	0.51	Accept H_0
Hub Length Right	0.844	Accept H_0	Hub Length Right	0.67	Accept H_0
Bore Size Left	0.894	Accept H_0	Bore Size Left	0.31	Accept H_0
Bore Size Right	0.67	Accept H_0	Bore Size Right	0.088	Accept H_0

Conclusion:

For the “Outside Diameter” and " Bore Size Left" variables, the p-values (0.844 and 0.894 respectively) are greater than the significance level (assuming $\alpha = 0.05$), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would accept the null hypothesis and conclude that these variables exhibit a random pattern.

For the “Outside Diameter” and " Bore Size" variables, the p-values (0.31 and 0.088 respectively) are greater than the significance level (assuming $\alpha = 0.05$), indicating that there is not enough evidence to reject the null hypothesis. Therefore, we would accept the null hypothesis and conclude that these variables exhibit a random pattern.

4.4 Test of Hypothesis

- **One Sample t-test**

Here we tested the outside diameter for each variable and compare with true mean,

For example, to test for Outer Diameter of Disc Coupling with its true mean,

H_0: The mean of outside diameter is equal to 103 mm.

Vs

H_1: The mean outside diameter is not equal to 103 mm.

Decision Rule: If p-value < α (5%) then we reject H_0, at α% level of significance otherwise we fail to reject H_0.

Table: One sample t- test for Outside Diameter

	Type of Coupling	t-value	DF	p-value	Conclusion
Day-1	Disc Coupling RL-81 Machine No.1	0.96	29	0.347	Accept H_0
	Disc Coupling RL-81 Machine No.2	1.21	29	0.23	Accept H_0
Day-2	Disc Coupling RL-135 Machine No.1	1.34	24	0.192	Accept H_0
	Disc Coupling RL-135 Machine No.2	1.64	24	0.114	Accept H_0
Day-3	Full Gear Coupling Size-220 Machine No.1	1.57	22	0.13	Accept H_0
	Full Gear Coupling Size-220 Machine No.2	1.83	22	0.081	Accept H_0
Day-4	Full Gear Coupling Size-590 Machine No.1	-0.17	19	0.867	Accept H_0
	Full Gear Coupling Size-590 Machine No.2	0.08	19	0.938	Accept H_0
Day-5	Half Gear Coupling Size-170 Machine No.1	1.71	19	0.104	Accept H_0
	Half Gear Coupling Size-170 Machine No.2	-0.44	19	0.666	Accept H_0
Day-6	Pin Bush coupling Size-320 Machine No. 1	-0.24	19	0.813	Accept H_0
	Pin Bush coupling Size-320 Machine No. 2	2.37	19	0.029	Reject H_0
Day-7	Single Universal Joint Coupling Size-8 Machine No.1	0.94	24	0.357	Accept H_0
	Single Universal Joint Coupling Size-8 Machine No.2	-0.73	24	0.471	Accept H_0
Day-8	Tyre Coupling Size-60 Machine No.1	0.04	24	0.966	Accept H_0
	Tyre Coupling Size-60 Machine No.2	-1.82	24	0.082	Accept H_0

Based on the table of t-tests, here are the conclusions for each type of coupling:

Table: Conclusion for One Sample t-test for Hub length

	Type of Coupling	Conclusion
Day-1	Disc Coupling RL-81 Machine No.1	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 1
	Disc Coupling RL-81 Machine No.2	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 2
Day-2	Disc Coupling RL-135 Machine No.1	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 1
	Disc Coupling RL-135 Machine No.2	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 2.
Day-3	Full Gear Coupling Size-220 Machine No.1	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 1
	Full Gear Coupling Size-220 Machine No.2	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 2
Day-4	Full Gear Coupling Size-590 Machine No.1	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 1
	Full Gear Coupling Size-590 Machine No.2	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 2
Day-5	Half Gear Coupling Size-170 Machine No.1	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 1
	Half Gear Coupling Size-170 Machine No.2	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 2
Day-6	Pin Bush coupling Size-320 Machine No. 1	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 1
	Pin Bush coupling Size-320 Machine No. 2	Reject H_0, there is a significant difference between sample mean and targeted mean for machine 2
Day-7	Single Universal Joint Coupling Size-8 Machine No.1	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 1
	Single Universal Joint Coupling Size-8 Machine No.2	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 2
Day-8	Tyre Coupling Size-60 Machine No.1	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 1
	Tyre Coupling Size-60 Machine No.2	Accept H_0, there is no any significant difference between sample mean and targeted mean for machine 2

In general, the conclusions indicate that for most types of couplings and days tested, there is no significant difference between the outside diameter and target value of diameter. However, for the particular "Pin Bush coupling Size-320" (Machine No.2) there is a significant difference in the outside diameter compared the null hypothesis.

Table: One Sample t-test for Hub Length

	Type of Coupling	t-value	Degree of Freedom	p-value	Conclusion
Day-1	Disc Coupling RL-81(Machine No.1)	1.35	29	0.192	Accept H_0
	Disc Coupling RL-81(Machine No.2)	1.44	29	0.161	Accept H_0
Day-2	Disc Coupling RL-135 (Machine No.1)	1.49	24	0.148	Accept H_0
	Disc Coupling RL-135 (Machine No.2)	0.3	24	0.766	Accept H_0
Day-3	Full Gear Coupling Size-220 (Machine No.1)	0.62	22	0.54	Accept H_0
	Full Gear Coupling Size-220 (Machine No. 2)	1.62	22	0.119	Accept H_0
Day-4	Full Gear Coupling Size-590 (Machine No.1)	-0.09	19	0.928	Accept H_0

	Full Gear Coupling Size-590 (Machine No. 2)	0.23	19	0.822	Accept H_0
Day-8	Tyre Coupling Size-60 (Machine No.1)	-0.66	24	0.513	Accept H_0
	Tyre Coupling Size-60 (Machine No. 2)	-0.99	24	0.332	Accept H_0

Conclusion: Based on the table of t-tests, here are the conclusions for each type of coupling:

Table: Conclusion for One Sample t-test for Hub Length

	Type Of Coupling	Conclusion
Day-1	Disc Coupling RL-81(Machine No.1)	Accept H_0, there is no significant difference between the sample mean and targeted mean for Machine No.1
	Disc Coupling RL-81 (Machine No.2)	Accept H_0, there is no significant difference between the sample mean and targeted mean for Machine No.2
Day-2	Disc Coupling RL-135(Machine No.1)	Accept H_0, there is no significant difference between the sample mean and targeted mean for Machine No.1
	Disc Coupling RL-135(Machine No.2)	Accept H_0, there is no significant difference between the sample mean and targeted mean for Machine No.2
Day-3	Full Gear Coupling Size-220(Machine No.1)	Accept H_0, there is no significant difference between the sample mean and targeted mean for Machine No.1
	Full Gear Coupling Size-220(Machine No.2)	Accept H_0, there is no significant difference between the sample mean and targeted mean for Machine No. 2
Day-4	Full Gear Coupling Size-590(Machine No.1)	Accept H_0, there is no significant difference between the sample mean and targeted mean for Machine No. 1
	Full Gear Coupling Size-590(Machine No.2)	Accept H_0, there is no significant difference between the sample mean and targeted mean for Machine No. 2
Day-8	Tyre Coupling Size-60(Machine No.1)	Accept H_0, there is no significant difference between the sample mean and targeted mean for Machine No.1
	Tyre Coupling Size-60(Machine No.2)	Accept H_0, there is no significant difference between the sample mean and targeted mean for Machine No.2

In summary, for most types of couplings and days tested, there is no significant difference in the hub length. However, for the "Tyre Coupling Size-60" Machine No.2 there is a significant difference in the hub length compared to the null hypothesis.

- **Paired t-test for Hub Lengths**

To determine if there is a significant difference between the Left Hub Lengths and Right Hub Lengths of the disc coupling, we can perform a paired t-test.

H_0: The mean of Left Hub Length is equal to the mean of Right Hub Length Vs.

H_1: The mean of Left Hub Length is not equal to the mean of Right Hub Length.

Decision Rule: If p-value < α (5%), then we reject H_0 at α% level of significance otherwise we fail to reject H_0.

Table: Paired t-test for Left Hub Length and Right Hub Length

	Type of Coupling	t-value	DF	p-value	Conclusion
Day-1	Disc Coupling RL-81 Machine No.1	-0.06	29	0.952	Accept H_0
	Disc Coupling RL-81 Machine No.2	-0.4	29	0.691	Accept H_0
Day-2	Disc Coupling RL-135 Machine No.1	-1.36	24	0.188	Accept H_0

	Disc Coupling RL-135 Machine No.2	-0.77	24	0.449	Accept H_0
Day-3	Full Gear Coupling Size-220 Machine No.1	1.78	22	0.090	Accept H_0
	Full Gear Coupling Size-220 Machine No.2	0.35	22	0.733	Accept H_0
Day-4	Full Gear Coupling Size-590 Machine No.1	-0.6	19	0.554	Accept H_0
	Full Gear Coupling Size-590 Machine No.2	0.07	19	0.943	Accept H_0
Day-5	Half Gear Coupling Size-170 Machine No.1	-1.8	19	0.087	Accept H_0
	Half Gear Coupling Size-170 Machine No.2	1	19	0.331	Accept H_0
Day-6	Pin Bush coupling Size-320 Machine No.1	1.49	19	0.153	Accept H_0
	Pin Bush coupling Size-320 Machine No.2	1.02	19	0.322	Accept H_0
Day-7	Single Universal Joint Coupling Size-8 Machine No.1	-0.02	24	0.981	Accept H_0
	Single Universal Joint Coupling Size-8 Machine No.2	1.8	24	0.084	Accept H_0
Day-8	Tyre Coupling Size-60 Machine No.1	-1.13	24	0.268	Accept H_0
	Tyre Coupling Size-60 Machine No.2	2.96	24	0.007	Reject H_0

Based on the above table of paired t-test results for hub lengths, the conclusions for each coupling type are as follows:

Table: Conclusion for paired t-test for Left Hub Length and Right Hub Length

	Type of Coupling	**Conclusion**
Day-1	Disc Coupling RL-81 Machine No.1	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No. 1.
	Disc Coupling RL-81 Machine No.2	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No 2.
Day-2	Disc Coupling RL-135 Machine No.1	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No. 1.
	Disc Coupling RL-135 Machine No.2	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No 2.
Day-3	Full Gear Coupling Size-220 Machine No.1	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No. 1.
	Full Gear Coupling Size-220 Machine No.2	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No 2.
Day-4	Full Gear Coupling Size-590 Machine No.1	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No. 1.
	Full Gear Coupling Size-590 Machine No.2	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No 2.
Day-5	Half Gear Coupling Size-170 Machine No.1	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No. 1.
	Half Gear Coupling Size-170 Machine No.2	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No 2.

Day-6	Pin Bush coupling Size-320 Machine No.1	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No. 1.
	Pin Bush coupling Size-320 Machine No.2	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No 2.
Day-7	Single Universal Joint Coupling Size-8 Machine No.1	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No. 1.
	Single Universal Joint Coupling Size-8 Machine No.2	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No 2.
Day-8	Tyre Coupling Size-60 Machine No.1	Accept H_0, which means there is no significant difference between the Left hub length and Right hub length for this coupling type for Machine No. 1.
	Tyre Coupling Size-60 Machine No.2	Reject H_0, which means there is significant difference between the Left hub length and Right hub length for this coupling type for Machine No.2

In summary, for most of the coupling types tested, there is no significant difference between the Left hub length and Right hub length. However, for Tyre Coupling Size-60 for Machine No.2, there is a significant difference observed.

➢ Process Capability Indices Report for Outside Diameter

Table: Process Capability Indices Report for Outside Diameter

	Types of Coupling	C_p	C_{pl}	C_{pu}	C_{pk}	**PPM (Observed)**	**PPM (Expected Overall)**	**PPM (Expected Within)**
Day-1	Disc Coupling RL-81 Machine No.1	0.42	0.4	0.44	0.47	100000	325043.86	20819.57
	Disc Coupling RL-81 Machine No.2	0.38	0.49	0.27	0.27	200000	467317.00	283040.00
Day-2	Disc Coupling RL-135 Machine No.1	0.73	0.84	0.63	0.63	0	71760.32	36375.29
	Disc Coupling RL-135 Machine No.2	0.55	0.65	0.44	0.44	120000	101207.40	118383.23
Day-3	Full Gear Coupling Size-220 Machine No.1	0.72	0.86	0.58	0.58	86956.52	115468.24	46595.67
	Full Gear Coupling Size-220 Machine No.2	1.32	1.65	1	1	130434	150800.45	1411.08
Day-4	Full Gear Coupling Size-590 Machine No.1	0.69	0.67	0.71	0.67	50000	91381.89	38594.74
	Full Gear Coupling Size-590 Machine No.2	0.39	0.4	0.39	0.39	150000	156803.93	241589.91

Day-5	Half Gear Coupling Size-170 Machine No.1	0.51	0.57	0.64	0.57	50000	118908.51	71123.58
	Half Gear Coupling Size-170 Machine No.2	0.45	0.57	0.33	0.33	150000	186725.41	206022.32
Day-6	Pin Bush coupling Size-320 Machine No.1	0.47	0.46	0.49	0.46	150000	153482.00	156386.28
	Pin Bush coupling Size-320 Machine No.2	0.58	0.75	0.4	0.4	100000	125788.29	125657.21
Day-7	Single Universal Joint Coupling Size-8 Machine No.1	0.41	0.46	0.36	0.36	120000	136602.75	227943.22
	Single Universal Joint Coupling Size-8 Machine No.2	0.52	0.47	0.57	0.47	120000	106937.55	123365.38
Day-8	Tyre Coupling Size-60 Machine No.1	0.49	0.49	0.49	0.49	160000	153083.15	141224.33
	Tyre Coupling Size-60 Machine No.2	0.51	0.39	0.63	0.39	240000	158684.00	15896.79

Conclusions for above table for Machine No. 1:

- **Disc Coupling RL- 81**

The process capability is relatively low, with C_{pk} is 0.42 . The observed PPM values are high, indicating the presence of defects. Improvement is needed to reduce defects and improve process capability.

- **Disc Coupling RL-135**

The process capability is moderate, with a C_{pk} value is 0.63. The observed PPM value is relatively low, indicating better performance in meeting specifications.

- **Full Gear Coupling Size-220**

The process capability is good, with a C_{pk}value of 0.58. The observed PPM value is relatively low, suggesting good performance in meeting specifications.

- **Full Gear Coupling Size-590**

The process capability is moderate, with a C_{pk}value of 0.67. The observed PPM value is relatively high, indicating the presence of defects. Improvement is needed to reduce defects.

- **Half Gear Coupling Size-170**

The process capability is moderate, with a C_{pk}value of 0.57. The observed PPM value is relatively high, suggesting the need for improvement.

- **Pin Bush Coupling Size-320**

The process capability is moderate, with a C_{pk} value of 0.46. The observed PPM value is relatively high suggesting the need for improvement.

- **Pin Bush Coupling Size-320**

The process capability is moderate, with a C_{pk} value of 0.75. The observed PPM value is relatively high, indicating room for improvement.

- **Single Universal Joint Coupling Size-8**

The process capability is moderate, with a C_{pk} value of 0.36. The observed PPM value is relatively low, suggesting good performance in meeting specifications.

- **Tyre Coupling Size-60**

The process capability is moderate, with a C_{pk} value of 0.49. The observed PPM value is relatively low, suggesting good performance in meeting specifications.

Conclusions for Machine No. 2 from above table

- **Disc Coupling RL-81**

The process capability is relatively low, with C_{pk} values of 0.27. The observed PPM values are high, indicating a significant number of defects. Improvement is needed to bring the observed PPM closer to the expected values.

- **Disc Coupling RL-135**

The process capability is moderate, with a C_{pk} value of 0.63. The observed PPM value is low, indicating better performance in meeting specifications. The process shows good control and capability.

- **Full Gear Coupling Size-220**

The process capability is good, with a C_{pk} value of 0.58. The observed PPM value is relatively low, suggesting good performance in meeting specifications.

- **Full Gear Coupling Size-590**

The process capability is moderate, with a C_{pk} value of 0.67. The observed PPM value is high, indicating the presence of defects. Improvement is needed to reduce defects and meet the expected PPM values.

- **Half Gear Coupling Size-170**

The process capability is moderate, with a C_{pk} value of 0.57. The observed PPM value is relatively high, suggesting the need for improvement.

- **Pin Bush Coupling Size-320**

The process capability is moderate, with a C_{pk}value of 0.46. The observed PPM value is relatively high, indicating room for improvement. Improvement is needed to bring the observed PPM closer to the expected values.

- **Single Universal Joint Coupling Size-8**

The process capability is moderate, with a C_{pk}value of 0.46. The observed PPM value is relatively high, indicating the presence of defects. Improvement is needed to bring the observed PPM closer to the expected values.

- **Tyre Coupling Size-60**

The process capability is good, with a C_{pk}value of 0.49. The observed PPM value is relatively low, suggesting good performance in meeting specifications.

Chapter 5
Forecasting the Sales of Couplings

5.1 Introduction

The sales of flexible couplings are an essential aspect of any industrial manufacturing company. Flexible couplings are mechanical devices used to connect two shafts together while accommodating misalignment, reducing vibration, and transmitting torque. Analyzing the sales data of flexible couplings in terms of the number of units sold over time is crucial for understanding market trends, predicting future demand, and making informed business decisions.

5.2 Time Series Analysis

- **Why we use Time series?**

Time series analysis is used for the above data because it involves the analysis and modeling of data that is collected and recorded over a series of consecutive time periods. In this case, the data represents the monthly values of different types of couplings from January 2020 to March 2023.

Time series analysis allows us to understand the patterns, trends, and characteristics of the data over time. It helps in identifying any underlying patterns, seasonality, or trends that might exist in the data. By analyzing the historical data, we can make predictions and forecasts for future values of the time series.

In the given data, time series analysis can be used to analyze the historical behavior of each type of coupling and make predictions or forecasts for future values. It can help in identifying any recurring patterns, seasonal variations, or trends in the demand for different couplings over time. This information can be valuable for production planning, inventory management, and decision-making in the manufacturing industry.

A non-stationary data in the data in which mean and variance of data is not constant over time. Before we use time series the data must be converted to stationary data.

5.3 SARIMA

The SARIMA (Seasonal Autoregressive Integrated Moving Average) model is an extension of the ARIMA (Autoregressive Integrated Moving Average) model that incorporates seasonal components. It is a powerful time series-forecasting model that can capture both the non-seasonal and seasonal patterns in a dataset.

The SARIMA model is characterized by three main components: the autoregressive (AR) component, the integrated (I) component, and the moving average (MA) component. Each component represents a different aspect of the time series data.

1. Autoregressive (AR) Component: The AR component captures the relationship between the current value of the time series and its previous values. It assumes that the current value can be explained by a linear combination of the past values. The order of the autoregressive component, denoted by "p," indicates the number of lagged values considered.

2. Integrated (I) Component: The integrated component is used to make the time series stationary. Stationarity means that the statistical properties of the data do not change over time. If the data is not stationary, differencing is applied to transform it into a stationary series. The order of differencing, denoted by "d," indicates the number of times the differencing operation is applied.

3. Moving Average (MA) Component: The MA component captures the dependency between the current value and the residual errors from previous periods. It assumes that the current value is related to the errors of the previous values. The order of the moving average component, denoted by "q," indicates the number of lagged errors considered.

In addition to these three components, the SARIMA model incorporates the seasonal components, which include seasonal autoregressive (SAR), seasonal integrated (SI), and seasonal moving average (SMA) terms. The seasonal components capture the seasonal patterns in the data. The seasonal order of the SARIMA model is denoted by (P, D, Q, s), where P, D, and Q represent the seasonal AR, seasonal differencing, and seasonal MA orders, respectively, and "s" represents the length of the seasonal cycle.

The parameters (p, d, q) and (P, D, Q, s) of the SARIMA model are determined by analyzing the autocorrelation and partial autocorrelation plots of the time series data. These plots provide insights into the appropriate orders of the AR, I, and MA components, as well as the seasonal orders.

The parameters of the SARIMA model are defined as follows:

The SARIMA (Seasonal Autoregressive Integrated Moving Average) model has several parameters that need to be specified to define the model accurately. Here's a description of each parameter:

1. p (AR Order): The autoregressive order represents the number of lagged observations of the dependent variable included in the model. It captures the relationship between the current value of the time series and its past values.
2. d (Differencing Order): The differencing order represents the number of times the time series needs to be differenced to achieve stationarity. Differencing removes the trend and makes the time series stationary.
3. q (MA Order): The moving average order represents the number of lagged forecast errors (residuals) included in the model. It captures the dependency between the current value and the errors of the previous values.
4. P (Seasonal AR Order): The seasonal autoregressive order represents the number of lagged observations at the seasonal frequency included in the model. It captures the relationship between the current value and its past values at the seasonal intervals.
5. D (Seasonal Differencing Order): The seasonal differencing order represents the number of times the time series needs to be differenced at the seasonal frequency to achieve stationarity.
6. Q (Seasonal MA Order): The seasonal moving average order represents the number of lagged forecast errors at the seasonal frequency included in the model. It captures the dependency between the current value and the errors of the previous values at the seasonal intervals.
7. S (Seasonal Period): The seasonal period represents the number of observations per season in the time series. It defines the length of the seasonal cycle.

These parameters help define the structure and behavior of the SARIMA model and determine how it captures the patterns and dependencies in the time series data.

When fitting a SARIMA model, the selection of appropriate values for these parameters is often done through automated techniques such as examining the autocorrelation and partial autocorrelation plots or using model selection criteria like AIC (Akaike Information Criterion) or BIC (Bayesian Information Criterion).

Once the SARIMA model is fitted to the data, it can be used for forecasting future values of the time series. By incorporating the autoregressive, differencing, moving average, and seasonal components, the SARIMA model can capture and model the complex patterns and dependencies present in the data, leading to accurate forecasts and improved understanding of the time series behavior.

- **Ljung box test**

The Ljung (**pronounced Young) Box test** (sometimes called the modified Box-Pierce or just the Box test) is a way to test for the absence of serial autocorrelation, up to a specified lag k.

Null Hypothesis (H_0): model does not show lack of fit (or the model is just fine).

Alternate Hypothesis ($H_!$): model does show a lack of fit.

5.4 Data and Data Description

Month	Disc Coupling	Gear Coupling	Pin Bush Coupling	Universal Joint	Tyre Coupling
Jan-20	120	18	54	6	18
Feb-20	108	30	24	12	5
Mar-20	150	24	42	30	20
Apr-20	60	12	6	5	7
May-20	90	24	12	18	12
Jun-20	102	30	14	12	24
Jul-20	120	36	18	6	12
Aug-20	132	24	30	12	30
Sep-20	168	42	24	18	12
Oct-20	180	36	12	30	18
Nov-20	156	24	24	36	24
Dec-20	126	48	30	24	12
Jan-21	144	60	48	30	24
Feb-21	96	72	60	42	30
Mar-21	126	90	66	60	48
Apr-21	90	48	30	12	12
May-21	108	60	48	30	24
Jun-21	120	90	42	36	48
Jul-21	108	108	60	24	60
Aug-21	156	72	72	30	54
Sep-21	180	84	48	48	72
Oct-21	162	96	36	24	90
Nov-21	144	90	72	42	66
Dec-21	132	108	48	30	48
Jan-22	180	90	72	48	36
Feb-22	150	102	84	72	48
Mar-22	210	108	120	84	72
Apr-22	120	60	48	36	36
May-22	150	84	72	48	60

Jun-22	180	108	90	60	72
Jul-22	168	132	72	54	60
Aug-22	180	126	96	72	48
Sep-22	156	150	60	60	72
Oct-22	210	120	84	48	96
Nov-22	180	108	78	72	60
Dec-22	150	120	72	90	48
Jan-23	200	110	80	54	40
Feb-23	180	120	90	80	52
Mar-23	230	135	130	94	80

- **Description of the Data:**

The provided data represents the sales of different types of couplings over a period of time from January 2020 to March 2023. The data includes the number of units sold for each type of coupling in each month. The different types of couplings included in the data are:

- Disc Coupling
- Gear Coupling
- Pin Bush Coupling
- Universal Joint
- Tyre Coupling

The format of the data is structured as a table with columns representing the months (Jan-20 to Mar-23) and rows representing the sales of each coupling type. The values in the table indicate the number of units sold for each coupling type in a particular month.

5.5 Forecasting for sales data of Flexible coupling

We consider monthly coupling sale from 2020 to 2022 and study the trends in it. To forecast the sales we model it using R software.

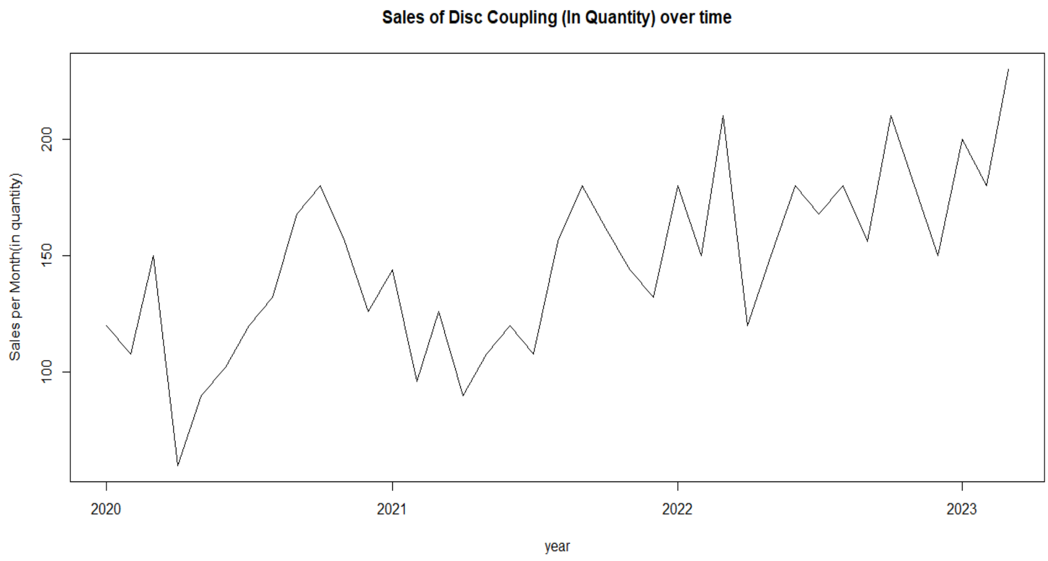
- **R Code**

```
# Required packages
library(readxl)
library(forecast)

library(tidyverse)

library(tseries)
#Loading data
df=read_xlsx("C:/Users/DELL/Desktop/Project/sales.xlsx");
data=df$`Disc Coupling`
ts_data=ts(data, frequency =12,start=c(2020,1));
# Plotting trend plot
start_date =as.Date("2020-01-01")
end_date =as.Date("2023-03-31")
forecast_dates =seq(start_date, end_date, by ="month")
plot(forecast_dates,ts_data, main ="Sales of Disc Coupling (In Quantity
) over time", xlab ="year", ylab ="Sales per Month(in quantity)",type="
l")

# Fit best model
model=auto.arima(ts_data); #Fit the model
#To check residuals are iid or not
Box.test(model$residuals, lag=12, type="Ljung-Box");

#Forecasting
forecast_data=forecast(model, level=c(95),h=12);
print(forecast_data);

#Plot the Forecasted value
plot(forecast_data, main ="Forecasted Monthly Sales of Disc Coupling (I
n Quantity)", xlab ="year", ylab ="sales per months(in quantity)");

#Generate diagnostic Plot
tsdiag=tsdiag(model);
```

➢ **Modelling and forecasting the Disc Coupling sale**

We fit the model to monthly sale of number of Disc Couplings from 2020 to 2023. The ‘forecast’ package in R is used to fit the time series model. The results of the fitted model and its summary is given in the following.

- **Variation in sales of disc coupling**



Model fitted: ARIMA (1, 0, 0) (1, 1, 0) [12] with drift

Model parameters:

	ar1	sar1	drift
	0.4172	-0.5359	2.0634
s.e.	0.1782	0.1839	0.4357

Model adequacy: sigma^2 = 471.3: log likelihood = -121.95

AIC=251.9 AICc=253.72 BIC=257.08

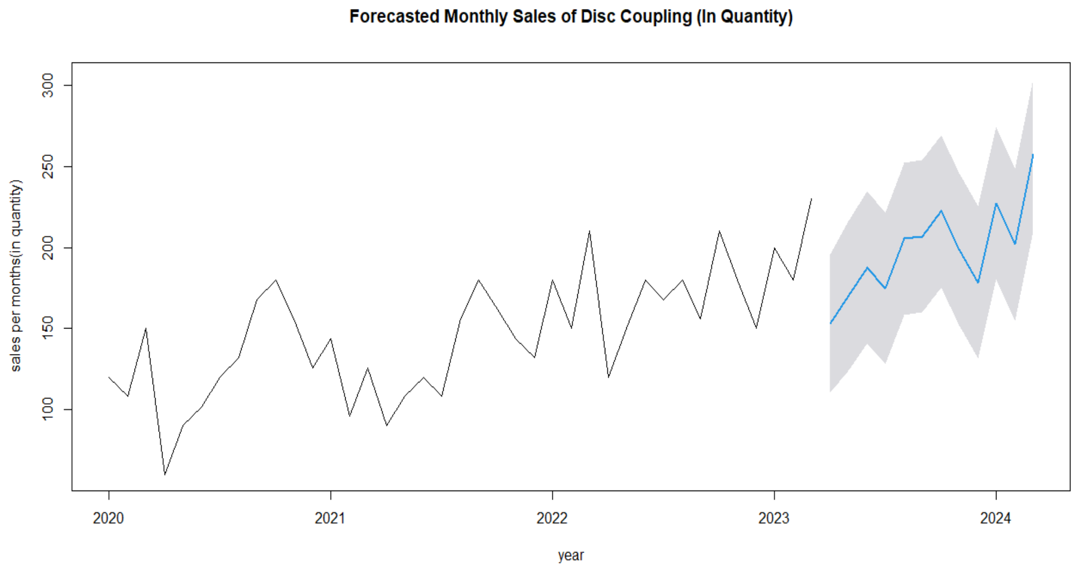
The term "with drift" indicates that the model includes a constant term or an intercept, allowing for a non-zero mean or trend in the data.

Here the Best model is ARIMA(1,0,0)(1,1,0)[12] with drift where non seasonal parameter :p=1,d=0,q=0 and seasonal parameter : P=1,D=1,Q=0,S=12.

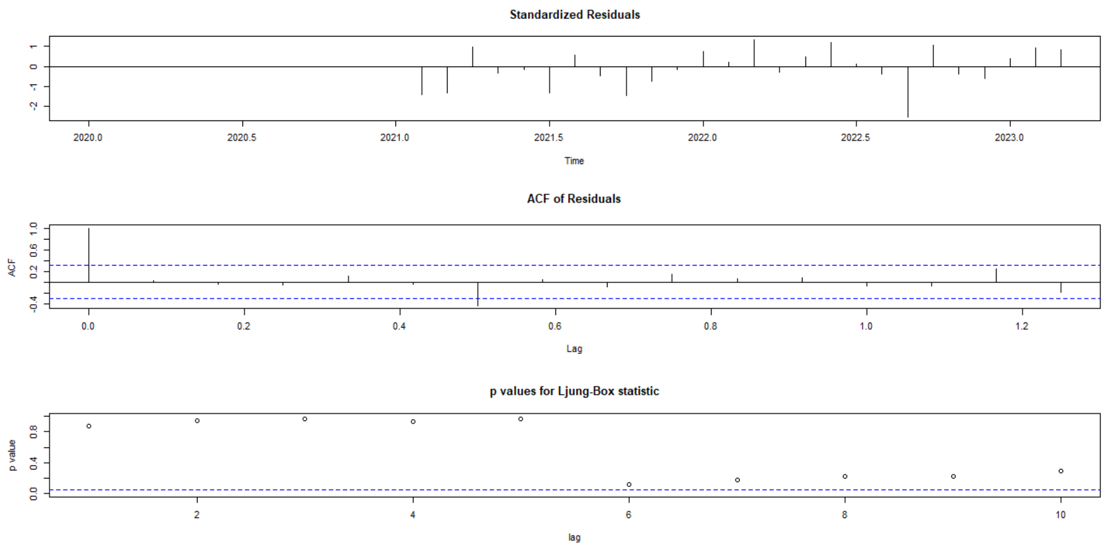
Ljung Box Test: X-squared = 12.552, df = 12, p-value = 0.4024

- **Forecasting using an ARIMA model**

Here forecast values for future year by using ARIMA (1,0,0)(1,1,0)[12] with drift model.



- **Ljung Box plot**



- **Forecasted Future Value of Monthly Sales of Disc Coupling (In Quantity)**

Observed that the Future Sale of Disc Coupling is increasefor next one year.

Month	Forecast Value	95% LCL	95% UCL
Apr 2023	153.21	110.66	195.76
May 2023	170.22	124.11	216.32

Jun 2023	187.83	141.14	234.53
Jul 2023	174.69	127.90	221.49
Aug 2023	205.51	158.69	252.32
Sep 2023	207.03	160.22	253.85
Oct 2023	222.36	175.54	269.19
Nov 2023	198.76	151.94	245.58
Dec 2023	178.39	131.57	225.21
Jan 2024	227.31	180.49	274.14
Feb 2024	201.95	155.13	248.77
Mar 2024	257.31	210.49	304.13

- **The Forecasted Value of Monthly Sales of Disc Coupling is given below**

Month	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23
Forecasted Value	153.21	170.22	187.83	174.69	205.51	207.03
Month	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24
Forecasted Value	222.36	198.76	178.93	227.31	201.95	257.31

➢ **Modelling and forecasting the Gear Coupling sale**

We fit the model to monthly sale of number of Gear Couplings from 2020 to 2023. The ‘forecast’ package in R is used to fit the time series model. The results of the fitted model and its summary is given in the following.

Model fitted : ARIMA(0,1,0)(1,0,0)[12]

Model parameters :

	sar1
	0.6106
s.e.	0.1278

Model adequacy: sigma^2 = 235: log likelihood = -159.94

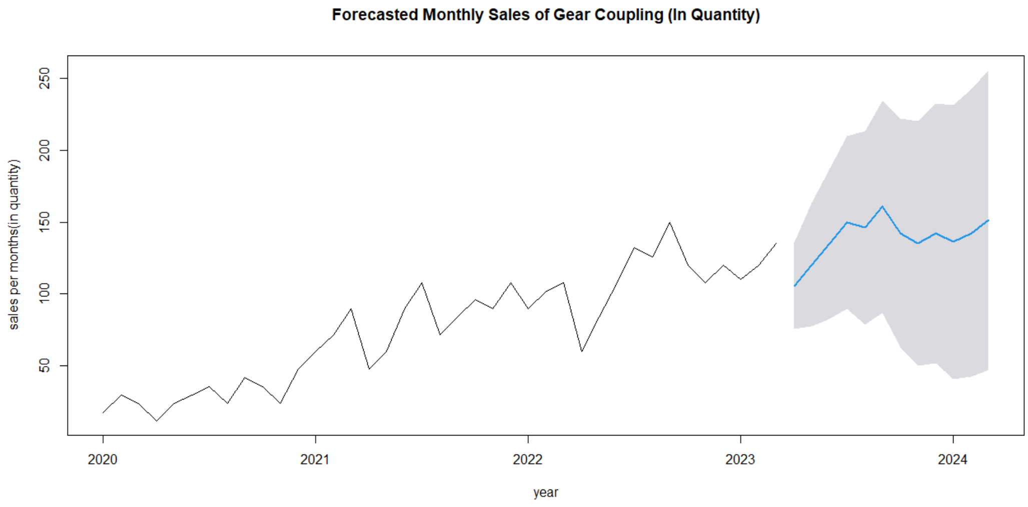
AIC=323.88 AICc=324.23 BIC=327.16

Here the best fitted model is ARIMA(0,1,0)(1,0,0)[12] where non seasonal parameter p=0,d=1,q=0 and seasonal parameter P=1,D=0,Q=0,S=12.

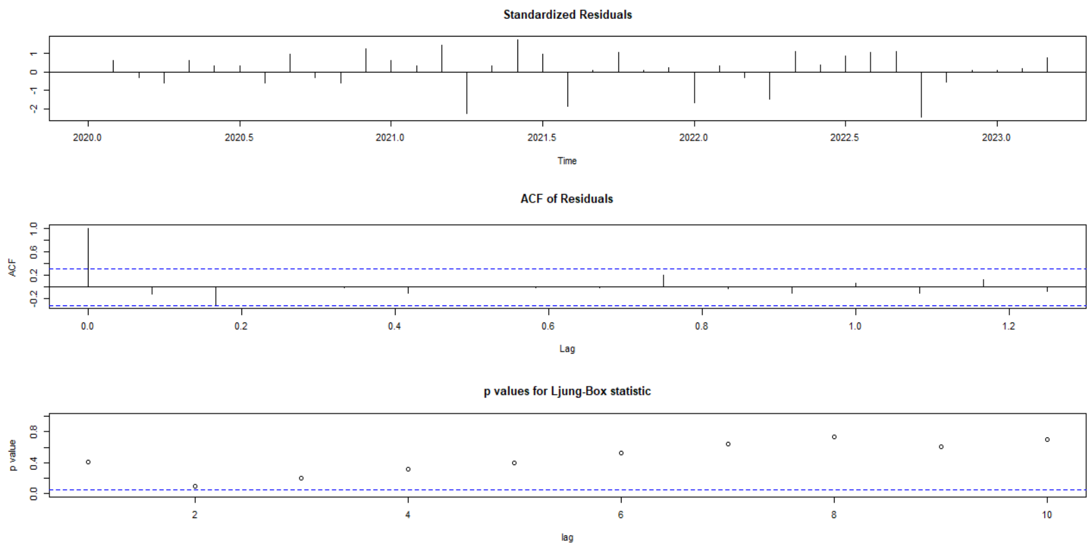
Ljung Box Test : X-squared = 8.0835, df = 12, p-value = 0.7786

- **Forecasting using an ARIMA model**

Here forecast values for future year by using ARIMA(0,1,0)(1,0,0)[12] model.



- **Ljung Boxplot**



- **The Forecasted Value of Monthly Sales of Gear Coupling is given below**

Month	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23
Forecasted Value	105.69	120.34	135	149.65	145.99	160.64
Month	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24
Forecasted Value	142.32	135	142.32	136.22	142.32	151.48

➢ **Modelling and forecasting the Pin Bush Coupling sale**

We fit the model to monthly sale of number of Pin Bush Couplings from 2020 to 2023. The 'forecast' package in R is used to fit the time series model. The results of the fitted model and its summary is given in the following.

Model fitted: ARIMA(0,0,0)(0,1,0)[12] with drift

Model parameters: drift=2.1049, SE(drift) = 0.2370

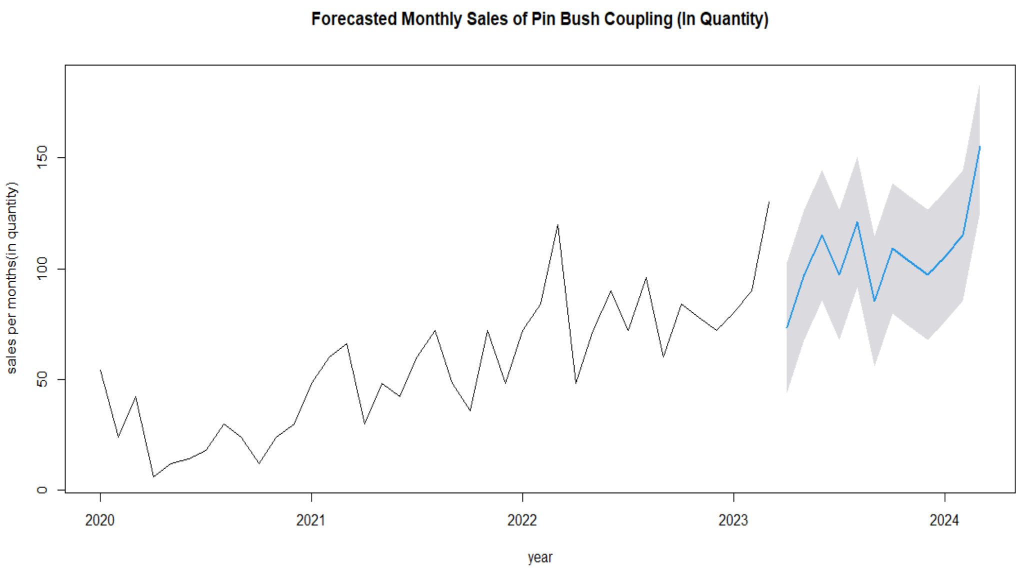
Model adequacy: sigma^2 = 226.8: log likelihood = -111.03

AIC=226.06 AICc=226.56 BIC=228.65

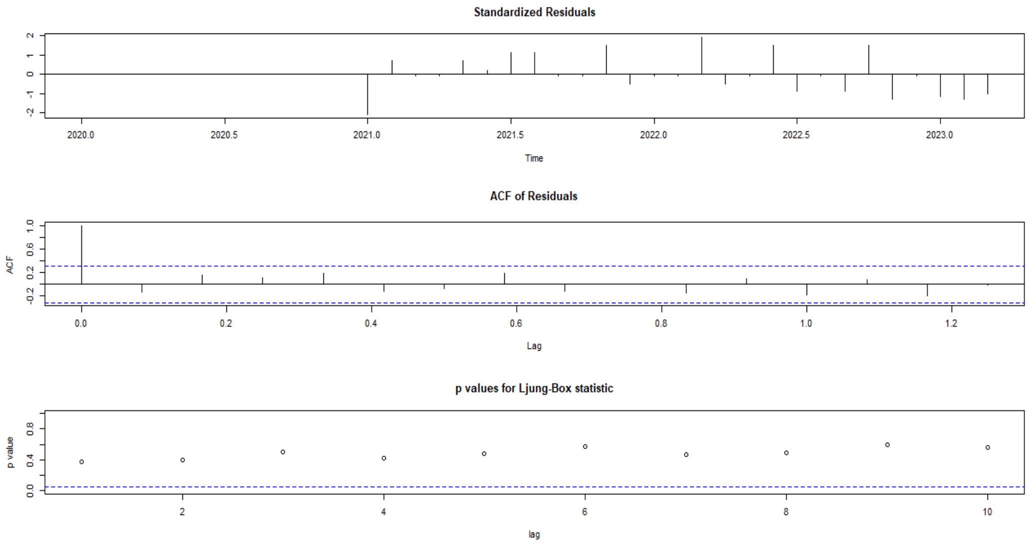
- **Ljung Box Test results: X-squared = 10.96, df = 12, p-value = 0.5324**

- **Forecasting using an ARIMA model**

Here forecast values for future year by using ARIMA(0,0,0)(0,1,0)[12] with drift model.



- **Ljung Box plot**



- **The Forecasted Value of Monthly Sales of Pin Bush Coupling is given below**

Month	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23
Forecasted Value	73.26	97.26	115.26	97.26	121.26	85.26
Month	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24
Forecasted Value	109.26	103.26	97.26	105.26	115.26	155.26

- **Modelling and forecasting the Universal Joint Coupling sale**

We fit the model to monthly sale of number of Universal Joint Coupling from 2020 to 2023. The forecast package in R is used to fit the time series model. The results of the fitted model and its summary is given in the following.

Model fitted: ARIMA(0,0,0)(1,1,0)[12] with drift

Model parameters:

	sar1	drift
	-0.4515	1.7384
s.e.	0.2234	0.1526

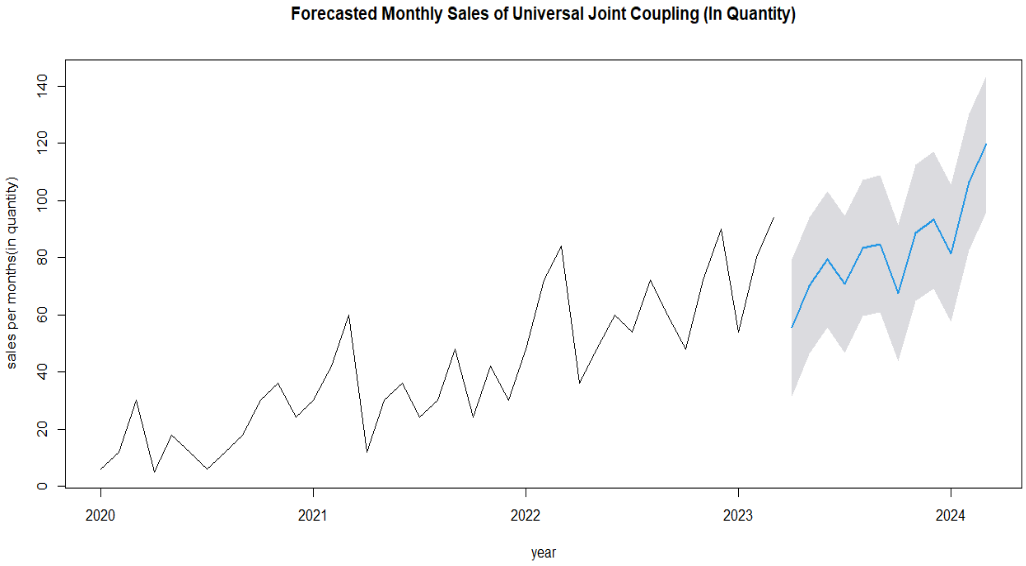
Model adequacy: sigma^2 = 148.8: log likelihood = -106.18

AIC=218.36 AICc=219.4 BIC=222.24

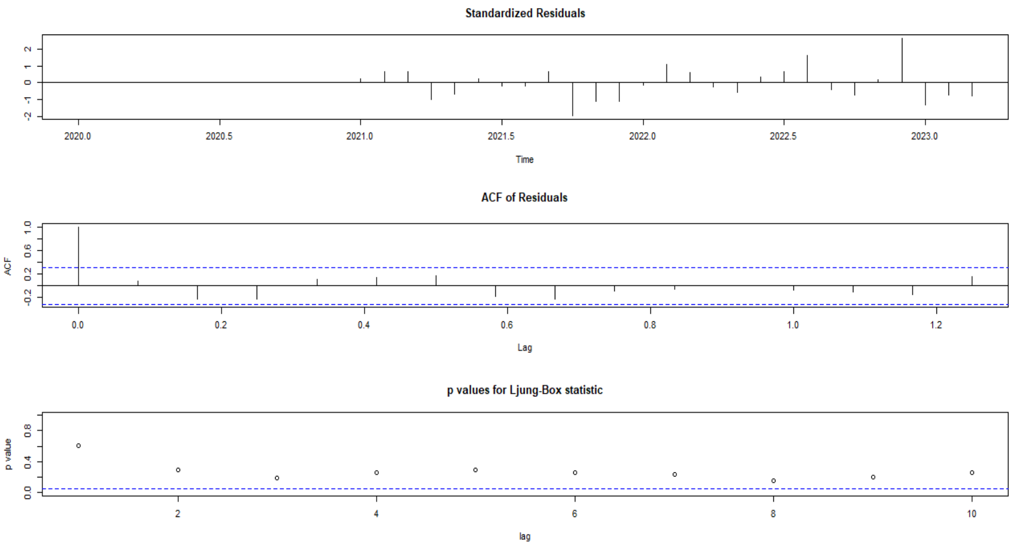
Ljung Box Test: X-squared = 12.766, df = 12, p-value = 0.3862

- **Forecasting using an ARIMA model**

Here forecast values for future year by using ARIMA(0,0,0)(1,1,0)[12] with drift model.



- **Ljung Box plot**



- **The Forecasted Values of Monthly Sales of Universal Joint Coupling are given below:**

Month	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23
Forecasted Value	55.44	70.15	79.44	70.73	83.31	84.86
Month	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24

Forecasted Value	67.44	88.74	93.19	81.57	106.67	119.76

➢ Modelling and forecasting the Tyre Coupling sale

We fit the model to monthly sale of number of Tyre Couplings from 2020 to 2023. The ‘forecast’ package in R is used to fit the time series model. The results of the fitted model and its summary is given in the following.

Model fitted: ARIMA(0,1,0)(0,1,0)[12]

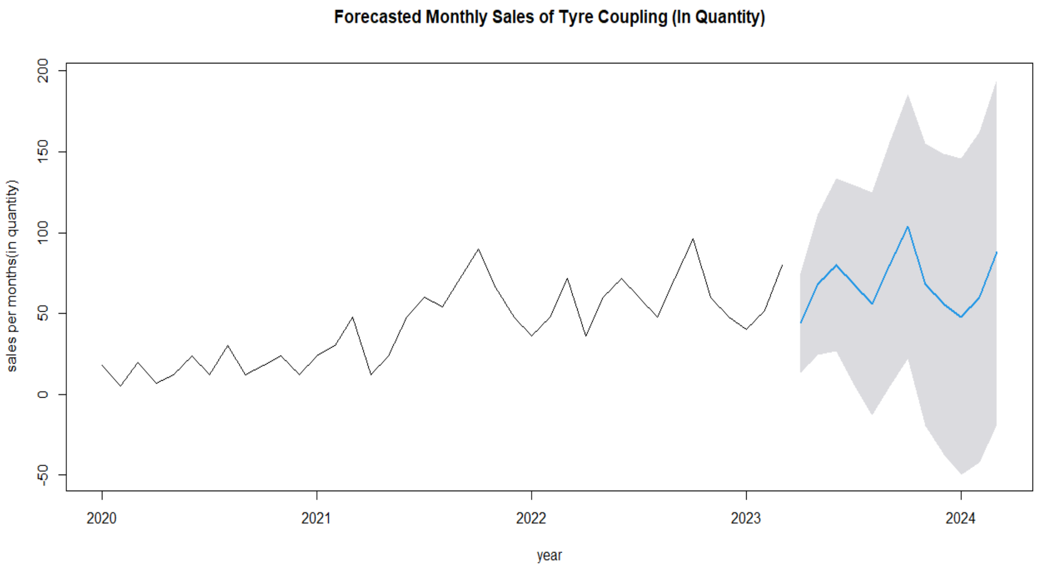
Model adequacy: sigma^2 = 248.2: log likelihood = -108.58

AIC=219.15 AICc=219.32 BIC=220.41

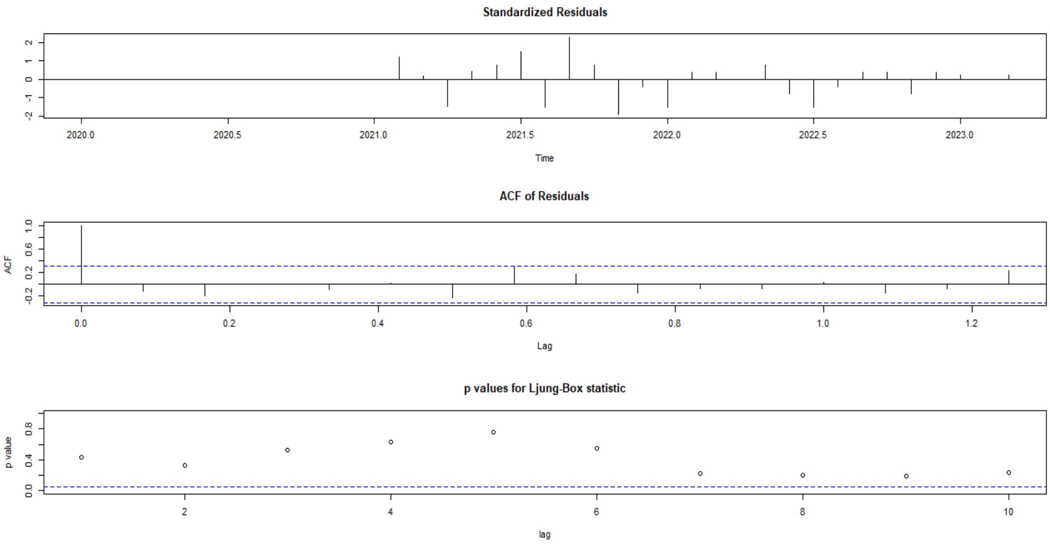
Ljung Box Test : X-squared = 13.08, df = 12, p-value = 0.3632

- **Forecasting using an ARIMA model**

Here forecast values for future year by using ARIMA(0,1,0)(0,1,0)[12] model.



- **Ljung Box plot**



- **The Forecasted Values of Monthly Sales of Tyre Coupling are given below**

Month	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23
Forecasted Value	44	68	80	68	56	80
Month	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24
Forecasted Value	104	68	56	48	60	88

Chapter 6

Overall Conclusion

We have two types of data one data set were collected from the field and Another data is past sales data of flexible couplings in terms of the number of units sold over time.

6.1 Conclusion on the data collected from the field:

- Here in some run chart, systematic pattern is observed. That indicates it has interference of human in this process. Hence, we would like to suggest that, make the process automation.
- We perform some statistical test to check the left and right hub lengths are same. So it gives the result that the hub length of left and right side are significantly same for all days except one day on that day the production of tyre coupling was going so that day the process is not good, and other days the process is good.
- To check the performance of two machines, we have performed process capability on the given parameters of the coupling. We observed that machine no.1 has better performance than machine no 2.

6.2 Conclusion on secondary data of sales data of flexible couplings

- From the sales data of flexible coupling, we observed trend plot and from the trend plot, we conclude that the company is growing significantly good.
- We observed sales data of different type of coupling in which the production of disc coupling and gear coupling were on large scale.
- After forecasting, we observed that the future number of sales of couplings is increasing. Therefore, company is growing significantly good.

Reference

- https://openai.com/blog/chatgpt
- D.C. Montgomery (2002) Introduction to Statistical Quality control, JohnWiley and Sons.
- Introduction to time series and forecasting Peter J. Brock well and Richard A. Davis
- **Website:** https://www.runflextransmissions.com
- **Software:**
  R software

  MS-Excel

  Minitab

Appendix

Appendix.1 Data of Disc Coupling Type - RL , Size- 135

Day-2 machine 1								Day-2 Machine							
		Parameter								Parameter					
		Outside diameter	Hub diameter	Hub length		Bore Size				Outside diameter	Hub diameter	Hub length		Bore Size	
				Left	Right	1 type adaptor	2 type adaptor					Left	Right	1 type adaptor	2 type adaptor
Require Dimension		129	77	55	55	52	70	Require Dimension		129	77	55	55	52	70
ACTUAL DIMENSION	1	129.02	77.08	54.98	55.01	52.017	70.010	ACTUAL DIMENSION	1	128.98	77.04	55.20	55.15	52.016	70.014
	2	129.18	77.18	54.80	54.85	52.007	70.020		2	129.03	77.18	55.17	55.12	52.009	70.018
	3	129.04	77.02	55.15	55.10	52.009	70.015		3	129.21	77.01	55.07	55.01	52.006	70.020
	4	129.15	76.98	55.01	55.08	52.001	70.019		4	129.05	76.96	55.10	55.04	52.013	70.015
	5	128.99	76.87	55.21	55.19	52.005	70.010		5	129.15	76.93	54.96	54.85	52.020	70.006
	6	128.91	76.83	54.94	54.98	52.014	70.015		6	129.04	76.83	55.19	55.15	52.001	70.003
	7	128.85	76.97	55.17	55.15	51.999	70.019		7	128.87	76.97	55.08	55.06	52.010	70.018
	8	129.12	77.03	55.02	55.08	52.013	70.000		8	128.97	76.79	54.98	55.06	52.006	70.012
	9	129.02	77.08	55.09	55.06	52.012	70.012		9	129.05	77.07	55.81	55.91	52.014	70.019
	10	129.17	77.17	55.18	55.14	52.010	70.018		10	129.15	77.17	55.01	54.96	52.017	70.004
	11	129.20	77.06	55.05	55.08	52.016	70.008		11	129.20	77.02	55.16	55.23	52.004	70.018
	12	129.03	77.19	54.96	54.99	52.021	70.003		12	129.01	76.89	55.19	55.15	51.999	70.009
	13	129.05	77.20	54.86	54.89	52.018	70.015		13	129.16	76.98	55.11	55.01	52.006	70.017
	14	129.15	76.93	54.78	54.85	52.002	70.017		14	128.99	77.21	55.07	54.98	52.001	70.021
	15	129.07	76.98	54.98	54.95	52.009	69.999		15	128.87	77.06	55.03	55.06	52.008	69.999
	16	129.06	77.07	55.01	55.15	52.010	70.021		16	129.05	76.95	54.98	55.09	52.018	70.005
	17	129.01	77.21	55.17	55.10	52.001	70.023		17	129.13	76.92	54.87	54.97	52.014	70.015
	18	128.99	77.11	55.21	55.19	52.013	70.001		18	129.02	76.80	54.81	55.91	52.017	70.008
	19	128.91	76.99	55.12	55.14	52.018	70.008		19	129.17	76.90	54.99	55.04	52.005	70.019
	20	129.07	76.93	54.99	55.04	52.003	70.003		20	129.00	77.00	55.03	55.12	52.003	70.014
	21	129.13	76.85	55.01	55.09	52.011	70.006		21	128.87	77.08	55.07	55.04	52.021	69.998
	22	128.99	76.78	55.09	55.03	52.016	70.016		22	128.93	77.17	55.15	55.06	52.019	70.008
	23	128.85	77.12	54.85	54.89	51.998	70.013		23	129.05	76.98	55.05	55.16	52.009	70.005
	24	128.81	77.19	54.88	54.87	52.017	70.009		24	129.21	77.09	55.09	55.04	52.006	70.016
	25	128.95	77.11	54.99	54.95	52.001	70.019		25	128.79	77.18	55.17	55.07	52.016	70.020

Appendix.2 Data of Full Gear Coupling Size -220

Day-3 machine 1								day-3 machine 2							
		Parameter								Parameter					
		Outside diameter (ØA)	Hub diameter (ØC)	Hub length (Y)		Bore size(ØD)				Outside diameter (ØA)	Hub diameter (ØC)	Hub length (Y)		Bore size(ØD)	
				left	right	left side	right side					left	right	left side	right side
Required dimension		220	105	85	85	75	75	Required dimension		220	105	85	85	75	75
ACTUAL DIMENSION	1	220.19	105.04	85.10	85.09	75.007	75.002	ACTUAL DIMENSION	1	219.99	105.02	85.02	85.05	75.001	75.003
	2	220.05	104.98	85.07	85.05	75.009	75.015		2	219.91	105.08	85.05	85.10	75.006	74.999
	3	220.01	104.95	85.01	85.03	75.001	75.003		3	219.85	105.12	85.09	84.89	75.010	75.007
	4	219.99	105.03	84.98	85.01	75.005	75.012		4	219.80	105.00	85.19	84.99	75.018	75.014
	5	219.80	105.07	84.96	84.99	75.002	75.000		5	219.78	105.08	85.22	85.11	75.014	75.018
	6	219.90	105.17	84.87	84.91	74.999	75.003		6	219.90	105.12	85.15	85.14	75.021	75.021
	7	220.03	104.99	85.01	85.05	75.013	75.014		7	219.98	104.99	85.05	85.21	74.999	75.018
	8	220.15	105.04	85.09	85.01	75.012	75.018		8	220.05	104.95	84.99	84.91	75.003	75.013
	9	220.21	104.87	85.11	85.07	75.010	75.015		9	220.01	104.87	84.91	84.99	75.009	75.008
	10	220.17	104.81	85.16	85.20	75.016	75.009		10	220.07	104.82	84.85	84.89	75.014	75.018
	11	220.08	104.78	85.21	85.19	75.021	75.002		11	220.12	104.78	84.78	84.95	75.019	75.007
	12	220.03	104.91	85.15	85.21	75.019	74.999		12	220.17	104.85	84.83	85.15	75.014	75.003
	13	220.08	105.06	85.05	85.10	75.002	75.012		13	220.21	104.98	84.91	85.18	75.002	75.008
	14	219.98	105.18	85.01	84.95	75.018	75.015		14	220.18	105.05	84.99	85.08	74.998	75.014
	15	219.78	105.11	84.97	84.91	75.009	75.020		15	220.12	105.12	85.04	84.99	75.008	75.009
	16	220.01	105.07	84.85	84.78	75.010	75.017		16	220.07	105.18	85.15	84.81	75.012	75.018
	17	220.09	104.99	85.10	85.01	75.020	75.021		17	220.03	105.21	85.20	85.01	75.019	75.022
	18	220.10	104.84	85.20	85.15	75.001	75.018		18	220.19	105.15	85.16	85.08	75.021	75.010
	19	219.96	105.01	85.17	85.19	75.015	75.022		19	220.18	105.14	85.12	85.10	75.012	75.002
	20	219.86	105.09	85.22	85.17	75.006	75.016		20	220.21	105.19	85.03	85.17	75.006	74.998
	21	220.18	105.15	84.99	84.93	75.011	75.012		21	220.15	105.21	85.01	84.95	75.002	75.003
	22	220.17	105.22	85.05	84.99	75.016	75.018		22	220.11	105.10	84.95	84.90	75.009	75.009
	23	220.09	104.99	85.10	85.02	74.998	75.015		23	220.06	104.97	85.03	84.80	75.017	75.007

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Appendix.3 Data of Full Gear coupling size-590

Day-4 machine 1								Day-4 machine 2							
		Parameter								parameter					
		Outside diameter (ØA)	Hub diameter (ØC)	Hub length (Y)		Bore size(ØD)				Outside diameter (ØA)	Hub diameter (ØC)	Hub length (Y)		Bore size(ØD)	
				left	right	left side	right side					left	right	left side	right side
Required dimension		590	400	240	240	300	300	Required dimension		590	400	240	240	300	300
ACTUAL DIMENSION	1	590.10	399.80	239.83	239.80	300.008	300.022	ACTUAL DIMENSION	1	590.11	399.89	239.99	239.82	300.016	300.018
	2	590.17	399.80	240.17	239.94	300.006	300.014		2	589.83	400.07	239.85	240.18	300.009	300.019
	3	589.99	399.98	239.82	240.16	300.007	300.015		3	589.91	400.16	240.02	239.78	300.008	299.999
	4	589.91	399.88	240.05	240.03	299.999	300.004		4	590.13	400.08	240.10	240.22	300.019	300.020
	5	589.87	400.04	240.08	239.97	300.008	300.012		5	590.09	399.87	239.83	239.90	300.000	300.020
	6	589.81	400.10	239.91	240.20	300.016	300.021		6	590.11	399.95	239.87	240.12	300.006	300.015
	7	589.78	399.96	240.21	239.96	299.999	300.020		7	590.21	400.1	239.79	239.89	300.019	299.999
	8	590.05	399.90	240.08	240.02	300.006	300.018		8	589.91	399.86	239.83	240.17	300.011	300.022
	9	590.10	399.95	239.99	240.02	300.010	300.010		9	590.09	400.21	239.84	239.84	300.017	300.016
	10	589.97	399.86	239.86	240.07	299.998	300.007		10	589.83	400.21	240.02	240.13	300.008	300.017
	11	590.10	400.10	240.14	240.18	300.008	300.020		11	590.19	400.04	239.90	239.86	300.009	299.998
	12	590.07	400.05	239.80	240.04	300.016	299.999		12	589.99	400.17	240.12	239.85	300.009	300.017
	13	589.81	399.82	240.21	239.88	300.018	299.999		13	590.11	399.83	240.19	240.10	300.016	300.011
	14	589.91	400.03	239.91	240.07	300.008	300.005		14	589.87	400.07	239.91	240.17	300.011	300.022
	15	590.10	400.09	240.09	239.95	300.012	300.009		15	589.87	400.04	240.22	239.88	299.998	300.001
	16	590.05	400.11	240.20	240.12	300.001	300.001		16	590.13	399.78	240.13	240.06	300.017	300.012
	17	590.03	400.06	240.15	240.20	300.003	300.004		17	589.78	399.82	239.98	240.14	300.004	300.003
	18	590.17	400.18	240.03	240.18	300.014	300.011		18	589.99	400.03	240.13	239.81	300.009	300.013
	19	589.95	400.19	239.84	240.11	300.007	300.001		19	590.11	400.18	239.84	239.86	300.010	300.013
	20	589.97	400.05	240.12	240.10	300.020	300.010		20	589.79	399.79	240.15	239.86	300.012	300.003

Appendix.4 Data of Half Gear coupling size-170

Day-5 machine 1									Day-5 machine 2								
		Parameter									Parameter						
		Outside Diameter (ØA)	Hub diameter		Hub length		Bore Size				Outside Diameter (ØA)	Hub diameter		Hub length		Bore Size	
			ØB	ØC	P	Y	Ød1	Ød2				ØB	ØC	P	Y	Ød1	Ød2
Required Dimension		170	85	65	55	55	60	50	Required Dimension		170	85	65	55	55	60	50
ACTUAL DIMENSION	1	170.19	84.81	65.11	55.14	54.95	60.012	50.000	ACTUAL DIMENSION	1	170.00	84.91	64.89	55.14	55.06	60.022	50.010
	2	169.92	84.96	65.03	54.78	55.19	60.021	50.001		2	170.22	85.04	65.01	55.18	55.19	60.021	50.011
	3	169.81	85.09	64.89	54.95	55.09	60.015	50.010		3	169.90	85.18	65.13	54.80	55.14	60.000	50.022
	4	170.20	84.98	64.83	54.81	55.09	60.000	50.020		4	169.97	85.12	64.97	54.93	55.21	60.011	50.018
	5	169.90	85.02	64.94	54.79	55.19	60.007	50.001		5	170.03	85.21	65.21	54.97	55.10	60.007	50.011

	6	170.10	85.19	64.95	55.10	55.03	60.003	50.001		6	169.91	85.15	65.13	55.11	54.87	60.005	50.006
	7	170.14	85.18	64.83	54.94	54.94	60.008	50.020		7	169.89	85.00	64.94	54.91	54.83	60.005	50.002
	8	170.14	85.13	64.90	54.97	55.12	60.019	50.011		8	170.17	84.93	65.05	55.21	54.87	60.015	50.022
	9	170.13	84.99	64.91	54.97	54.99	60.020	50.007		9	169.91	84.81	64.93	55.16	55.07	60.010	50.017
	10	169.85	84.78	65.15	55.04	55.09	60.013	50.006		10	170.13	84.89	64.86	55.11	54.91	60.002	50.008
	11	170.21	85.14	65.18	54.96	55.18	60.002	50.009		11	170.10	85.07	64.93	55.21	55.13	60.018	50.010
	12	170.22	85.02	65.18	55.16	54.99	60.022	50.002		12	170.03	84.96	65.22	55.11	54.99	59.998	50.021
	13	169.91	85.03	64.96	54.89	55.07	60.017	50.007		13	170.20	85.06	65.12	55.01	55.09	59.999	50.014
	14	169.89	84.82	64.82	54.94	54.99	60.012	50.016		14	170.11	85.22	65.10	54.99	54.80	59.998	50.006
	15	169.91	85.06	65.11	54.82	55.04	59.998	50.021		15	169.87	85.12	65.00	54.99	54.91	60.009	50.017
	16	170.22	84.91	65.16	55.12	55.10	60.012	50.010		16	169.83	84.84	64.90	54.90	55.12	60.014	50.001
	17	170.10	84.84	64.93	55.22	54.83	60.021	50.020		17	169.86	84.88	64.93	55.15	55.11	59.999	50.022
	18	170.03	84.97	64.98	55.14	55.19	60.015	50.018		18	169.88	85.21	65.01	55.03	54.95	60.012	50.014
	19	170.20	85.09	65.00	55.00	55.02	60.016	49.999		19	169.84	85.08	65.21	55.21	55.08	60.021	50.019
	20	170.01	85.11	64.84	54.82	55.06	60.002	49.998		20	169.90	85.21	64.86	55.17	55.09	60.006	50.022

Appendix.5 Data of Pin bush coupling size-320

Day-6 machine 1								
		Parameter						
		outside Diameter (ØA)	Hub diameter		Hub length		Bore size	
			ØB1	ØB2	L1	L2	ØC1	ØC2
Required Dimension		320	196	212	125	125	125	135
ACTUAL DIMENSION	1	319.88	196.03	212.15	125.05	124.91	125.011	135.015
	2	320.07	195.91	211.87	124.87	125.06	124.998	135.020
	3	320.21	195.90	211.79	124.91	125.14	125.018	135.010
	4	320.07	196.08	211.90	125.05	124.80	125.022	135.015
	5	320.12	196.19	211.82	124.95	125.03	125.000	135.001
	6	320.08	196.00	212.09	125.21	125.11	125.000	135.013
	7	319.95	195.89	212.21	125.10	124.97	125.011	135.004
	8	319.82	196.21	211.87	125.14	125.17	125.018	135.010
	9	319.79	195.84	211.91	125.05	124.81	125.020	135.017
	10	319.87	196.13	212.15	125.06	124.93	125.010	135.017
	11	320.01	195.94	212.10	125.15	125.08	125.017	135.001
	12	319.83	195.98	212.15	125.13	124.95	125.006	135.022
	13	320.09	196.17	211.82	124.97	124.87	125.022	135.003
	14	320.10	195.78	212.03	124.93	124.89	125.002	135.022

Day-6 machine 2								
		Parameter						
		Outside Diameter (ØA)	Hub diameter		Hub length		Bore size	
			ØB1	ØB2	L1	L2	ØC1	ØC2
Required Dimension		320	196	212	125	125	125	135
ACTUAL DIMENSION	1	320.19	196.15	211.90	124.85	124.79	124.998	134.999
	2	320.18	195.88	212.20	125.01	125.13	125.007	135.007
	3	320.00	195.80	211.89	124.95	124.84	125.021	135.011
	4	320.07	196.01	212.11	125.08	125.21	124.998	135.010
	5	320.07	196.13	212.09	125.03	124.85	125.008	135.013
	6	319.92	195.93	212.11	125.02	124.83	125.000	134.999
	7	320.11	195.88	211.90	124.83	124.84	125.018	135.002
	8	320.05	196.16	212.08	125.19	124.99	125.006	135.005
	9	320.09	195.91	212.21	124.93	125.13	125.020	135.021
	10	320.11	196.00	211.83	125.12	124.94	125.001	135.015
	11	320.14	196.12	212.05	124.89	124.90	125.000	135.013
	12	320.16	196.22	211.84	125.22	125.00	125.016	135.011
	13	319.87	195.94	211.95	125.13	124.90	124.999	135.019
	14	319.86	196.02	212.00	124.83	124.82	125.020	135.000

	15	319.81	195.95	212.00	124.90	124.81	125.012	135.001		15	320.20	195.81	212.12	125.13	125.01	125.007	135.016
	16	320.22	195.86	212.17	125.14	124.87	125.000	135.007		16	320.03	196.10	212.02	125.12	124.82	125.002	135.019
	17	320.10	196.11	212.15	124.96	125.09	125.020	135.008		17	320.14	196.04	212.00	124.88	124.82	125.002	135.014
	18	319.80	196.07	211.84	124.78	125.01	125.008	135.011		18	319.96	196.13	212.11	124.81	125.18	124.999	135.003
	19	320.07	196.19	212.05	125.17	124.8	125.016	135.014		19	320.21	195.82	211.81	124.93	125.00	125.021	135.015
	20	319.96	195.81	212.19	125.04	125.12	125.009	135.015		20	319.86	195.83	211.99	124.95	125.11	124.998	135.018

Appendix.6 Data of Single Universal joint Coupling size-8

Day-7 machine 1							Day-7 machine 2						
		Parameter							Parameter				
		Outerside diameter (ØA)	shaft length		Bore Size (ØD)				Outerside diameter (ØA)	shaft length		Bore Size (ØD)	
			Input shaft (C)	Output shaft (C)	Input	Output				Input shaft (C)	Output shaft (C)	Input	Output
Required Dimension		38	30	30	25	20	Required Dimension		38	30	30	25	20
ACTUAL DIMENSION	1	38.20	29.78	30.06	25.021	20.022	ACTUAL DIMENSION	1	38.04	29.94	29.83	25.016	20.009
	2	38.01	30.02	30.07	25.003	19.999		2	37.84	29.89	30.06	25.010	20.009
	3	37.86	29.80	29.85	25.010	20.006		3	38.16	30.17	29.89	24.998	19.999
	4	38.14	30.14	29.94	25.015	20.000		4	37.95	30.15	30.05	24.999	20.000
	5	37.93	30.15	29.93	24.999	19.999		5	37.90	30.07	29.86	25.020	19.999
	6	38.21	30.22	30.17	25.019	20.016		6	38.00	30.01	29.84	25.015	20.005
	7	38.20	30.06	29.91	25.009	20.015		7	37.99	29.93	29.91	25.017	19.998
	8	37.98	29.88	30.21	24.999	20.016		8	38.21	30.19	29.87	25.017	20.021
	9	38.20	29.87	29.99	24.999	20.010		9	37.91	30.12	30.12	25.001	20.000
	10	37.78	30.13	29.85	25.012	20.007		10	38.02	29.79	30.02	25.009	20.017
	11	38.01	29.85	29.85	25.018	20.013		11	38.04	30.02	30.02	25.006	20.009
	12	38.10	29.89	30.02	25.018	20.013		12	38.03	29.98	29.94	25.022	20.002
	13	37.79	29.86	29.78	25.000	20.000		13	38.13	30.21	29.97	25.020	20.009
	14	38.14	29.81	30.16	25.008	20.011		14	38.12	30.21	30.04	25.008	20.018
	15	37.98	29.83	29.90	24.998	20.012		15	37.84	29.99	30.13	25.010	20.016
	16	37.83	30.19	30.06	25.011	20.003		16	38.05	29.95	29.85	24.999	20.004
	17	37.97	29.95	29.83	25.013	20.022		17	37.85	30.07	29.88	25.022	20.019
	18	38.14	29.90	29.99	24.998	20.013		18	38.19	29.90	30.18	25.007	20.010
	19	37.93	30.06	30.07	25.015	20.009		19	38.03	30.13	29.80	25.011	20.008
	20	38.01	29.93	29.79	25.014	20.000		20	37.91	29.92	29.93	25.008	20.001
	21	38.04	30.11	29.98	25.020	20.021		21	38.00	30.08	30.09	25.021	20.010
	22	37.93	29.89	30.12	25.004	20.022		22	37.83	29.97	29.90	25.000	20.001
	23	38.16	29.84	29.79	25.014	20.007		23	37.93	29.86	29.84	25.020	20.018
	24	38.12	30.03	29.94	25.006	20.007		24	37.80	29.85	29.98	25.005	20.019
	25	37.96	29.92	29.87	25.001	19.998		25	37.78	30.09	30.02	25.000	20.010

Appendix.7 Data of Tyre Coupling Size-60

Day-8 machine 1								Day-8 machine 2							
		Parameter								Parameter					
		Outerside Diameter (ØA)	Hub diameter(ØB)	Hub Length E		Baor size(ØD)				Outside Diameter (ØA)	Hub diameter(ØB)	Hub Length E		Baor size(ØD)	
				left	right	left	right					left	right	left	right
Required dimension		165	125	38	38	48	48	Required dimension		165	125	38	38	48	48
ACTUAL DIMENSION	1	164.93	125.05	37.87	38.19	48.022	48.014	ACTUAL DIMENSION	1	164.80	125.20	38.08	37.89	48.000	48.005
	2	165.21	124.88	38.02	38.13	48.013	48.006		2	164.99	125.08	38.08	37.89	48.012	48.020
	3	165.22	124.86	38.07	37.82	48.004	48.003		3	165.07	125.00	38.15	38.06	47.999	48.002
	4	164.81	124.80	37.80	38.17	48.000	48.009		4	165.11	124.78	38.07	38.16	48.000	47.998
	5	165.00	124.94	37.99	38.08	48.020	48.002		5	164.84	124.79	38.11	37.79	48.000	48.012
	6	165.12	124.97	37.87	37.78	48.014	48.002		6	164.89	124.97	38.08	37.94	47.999	48.001
	7	165.05	124.97	38.19	38.19	48.016	48.002		7	165.02	124.84	37.85	37.88	48.015	48.020
	8	165.02	125.09	37.82	37.86	48.022	48.014		8	165.11	125.03	38.19	38.21	48.008	48.004
	9	165.19	124.94	38.11	37.78	48.020	48.006		9	164.84	125.03	37.86	37.81	48.013	48.007
	10	164.86	125.10	37.78	38.00	48.013	48.004		10	164.87	125.16	38.16	38.08	48.005	48.017
	11	164.89	125.14	37.83	37.88	47.999	48.003		11	164.89	124.98	38.18	37.90	48.018	48.003
	12	165.07	124.78	37.79	38.06	48.018	48.005		12	165.02	124.89	37.98	38.05	48.011	48.019
	13	165.08	124.83	38.02	38.14	48.010	48.020		13	165.08	124.86	38.16	37.97	48.009	48.002
	14	164.82	125.02	38.08	38.18	48.000	47.998		14	165.05	124.93	37.96	37.97	47.998	48.003
	15	164.78	125.06	38.13	38.13	48.017	48.022		15	165.12	124.94	38.20	38.22	48.004	48.010
	16	165.13	125.06	38.07	38.07	48.008	48.003		16	164.79	124.89	38.16	37.88	48.012	48.001
	17	164.95	124.94	38.16	37.81	48.009	48.010		17	164.87	125.14	38.19	37.87	48.007	48.018
	18	165.08	124.91	37.90	37.83	48.012	48.022		18	164.86	125.15	37.93	37.81	48.003	48.010
	19	165.13	124.88	38.09	38.04	48.002	48.013		19	164.78	124.97	37.78	37.83	48.022	48.009
	20	164.79	125.12	38.16	37.96	47.998	48.019		20	165.11	125.00	38.22	37.98	48.018	48.021
	21	164.85	125.08	37.94	38.22	48.014	48.016		21	164.79	125.06	38.20	38.22	48.012	48.021
	22	164.85	125.13	37.84	37.83	48.022	48.004		22	165.04	124.96	38.06	37.84	48.001	48.009
	23	165.10	125.08	37.81	37.83	47.999	47.998		23	165.21	125.06	38.02	38.19	48.000	48.006
	24	165.13	125.18	37.80	37.97	48.007	47.998		24	164.78	124.81	38.21	38.14	48.003	48.006
	25	164.97	124.79	37.91	38.20	48.022	48.002		25	164.86	124.90	37.86	38.00	48.004	48.007