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Analysis and Comparison of Two Check Methods on a Tachometer Device

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ABSTRACT Intermediate Check is an internal quality assurance process in calibration laboratories, conducted between the annual calibration intervals. The definition of an intermediate check is the process of confirming the test/calibration results and ensuring the validity of the calibrator instrument's results, not the medical device itself. Among the calibrator instruments, one of them is the tachometer, which must undergo both calibration and intermediate checks. The intermediate check measurements are conducted on a regular schedule depending on the calibrator instrument and the testing/calibration institution. For the tachometer studied by the author, measurements were taken at three points: 1000 rpm, 3000 rpm, and 4000 rpm, in accordance with SNI ISO/IEC 17025:2017. In this study, the author compares and analyzes two tachometer check methods to determine which yields better accuracy. The two methods are: the intermediate check of the UUT (Unit Under Test) tachometer against a reference tachometer, and the UUT tachometer against a centrifuge, with results processed using control charts. At the 1000 rpm point, the first method showed an average of 999.47 rpm with a standard deviation of 0.06; at 3000 rpm, the average was 2999.48 rpm with a standard deviation of 0.05; and at 4000 rpm, the average was 3999.46 rpm with a standard deviation of 0.06.
The analysis showed that while the average values of both methods were nearly the same, the standard deviation was smaller in the method using the UUT tachometer with a reference tachometer. Based on the conclusions of this study, there is a measurable difference between the two methods, and the author recommends using the method involving the UUT tachometer and the reference tachometer.

INDEX TERMS intermediate check, tachometer, centrifuge, control chart
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I. INTRODUCTION

Medical equipment plays a crucial role in delivering public health services. To ensure continuous healthcare delivery, the equipment must always be in proper working condition. This can be achieved through regular and well-planned testing and calibration. Previous studies on inter-calibrator checks involved measuring a calibrator ruler using a steel ruler to evaluate the instrument's performance over the calibration interval [1]. Another study compared two pressure gauges with the same level of accuracy to assess measurement consistency [2].
ISO/IEC 17025:2017 does not specify which method should be used for performing intermediate checks. This lack of specification allows for different approaches, each of which may yield varying results in terms of the accuracy and precision of measuring instruments. In response to this, the author conducted an analysis comparing two commonly used methods: the standard-to-standard method and the standard-to-artifact method. In this study, the standard refers to a tachometer used as a reference instrument, while the artifact refers to a centrifuge. Specifically, the two methods being compared are a reference tachometer against a Unit Under Test (UUT) tachometer, and a tachometer against a centrifuge. The results of both methods are evaluated and analyzed using control charts to assess consistency and measurement reliability. Internal calibration quality assurance: Intermediate checks help ensure that the calibration process is carried out in accordance with applicable standards. Cost savings**:** By preventing significant deviations in standard equipment, intermediate checks can help reduce costs associated with recalibration. Improved accuracy and reliability of

calibration results: Intermediate checks help ensure that the calibration results are accurate and reliable

The results of this research can enhance understanding of the accuracy and precision of the reference tachometer compared to the UUT (Unit Under Test) tachometer, as well as between the UUT tachometer and the centrifuge. It facilitates users and calibration laboratories in the use and selection of more accurate UUT tachometer measurement checks. This research can serve as a source of information and additional knowledge, as well as reading material for students, especially those in the Electromedical Engineering Department at the Health Polytechnic of the Ministry of Health Jakarta II.

A. INTERMEDIATE CHECK

In the structure of SNI ISO/IEC 17025:2017, there are several key requirements: general requirements, structural requirements, resource requirements, process requirements, and management requirements[3]. The process requirements include ensuring the validity of results through quality assurance procedures. Quality assurance can be monitored in various ways, such as validating test results and applying statistical techniques for review.

Within quality assurance of result validity, several methods are used, including intra-personnel comparison tests**,** inter-laboratory comparisons, and intermediate checks**.**

The measurement of an object requires a specific instrument designed for that purpose. Over time, the accuracy of measuring instruments tends to degrade with continued use, making the calibration process essential [4]. In addition to calibration, intermediate check**s** are also necessary to maintain confidence in the calibration status of the instrument. The results of these intermediate checks are then used as a basis for determining whether the instrument can continue to be used for testing and calibration, needs to be repaired, or must be taken out of service.

In testing and calibration, the parameters precision and accuracy are commonly used as measurement indicators. Accuracy refers to how close a measurement result is to the true or actual value.

B. TACHOMETER

A tachometer is a measuring instrument designed to measure the rotational speed of an object. A non-contact tachometer is capable of taking measurements from a distance by using a light sensor that is highly sensitive to rotating elements. The accuracy of tachometer measurements is crucial to ensure the reliability and consistency of the data produced [6] [7].

In Testing and Calibration Laboratories, calibrators come in various types and brands depending on the specific needs of each laboratory. These laboratories are required to have calibrator instruments that match their stated capabilities. However, it is not mandatory for them to own Unit Under Test (UUT) instruments, as this also depends on each laboratory's policy.

The UUT tachometer is used for comparison testing against a reference tachometer, where the UUT typically has a larger correction value than the reference tachometer. The correction value of the tachometer is determined from the calibration report, which is typically conducted once a year.

Precision, on the other hand, indicates how close repeated measurements are to each other, or the level of consistency in repeated tests [5].

The laboratory will prepare a schedule for intermediate checks in accordance with the reference standards used and for all calibrated equipment. The intermediate check schedule includes:

a. Name of the equipment;
b. Parts that must undergo intermediate checks;
c. Time of intermediate check;
d. Personnel performing the intermediate check.

The intermediate check is carried out within the time interval between calibration periods

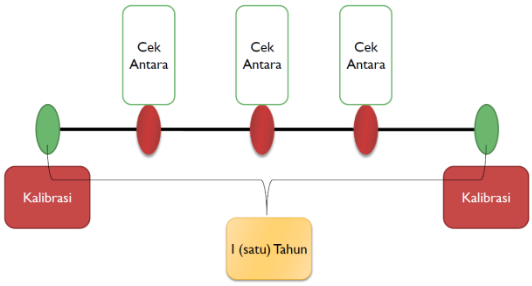


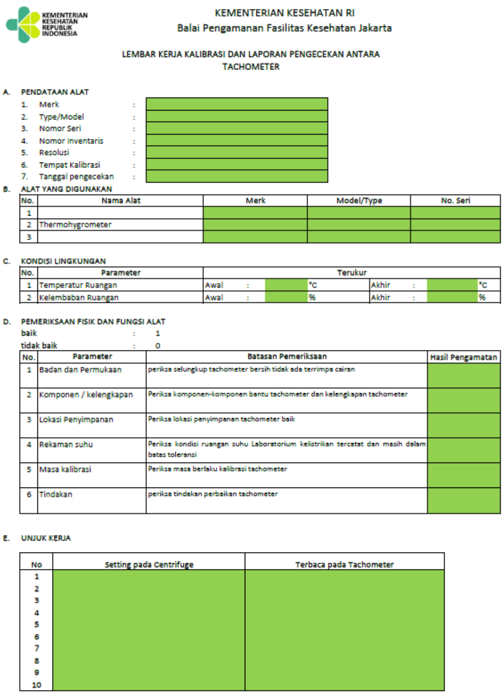
Figure 1. concept of intermediate checks within one year

Fig. 1 it indicates when the intermediate check is performed within a one-year period. However, the timing of the intermediate check depends on certain conditions, namely:

1. When needed at the time the equipment is about to be used for calibration testing;
2. The equipment is subjected to excessive load;
3. User error occurs;
4. The equipment provides suspicious results;
5. The equipment is damaged;
6. The equipment is operating outside specified limits.

Intermediate checks are carried out on all calibrator equipment, including the tachometer. For tachometers, intermediate checks are useful to maintain accuracy and monitor performance during use, especially over the calibration interval period, which is once a year. The schedule and measurement points for intermediate tachometer checks are not governed by specific SNI (Indonesian National Standard) regulations and are therefore determined by each calibration laboratory institution.

As an example, the intermediate check worksheet for tachometers at the testing and calibration laboratory is shown in Fig. 2, which represents the worksheet used by the BPAFK Jakarta institution with method document code number: 20-16/IK-PA-BPFKJ.



KEMENTERIAN KESEHATAN REPUBLIK INDONESIA

KEMENTERIAN KESEHATAN RI
Balai Pengamanan Fasilitas Kesehatan Jakarta

LEMBAR KERJA KALIBRASI DAN LAPORAN PENGECEKAN ANTARA
TACHOMETER

A. PENDATAAN ALAT
1. Merk :
2. Type/Model :
3. Nomor Seri :
4. Nomor Inventaris :
5. Resolusi :
6. Tempat Kalibrasi :
7. Tanggal pengecekan :

B. ALAT YANG DIGUNAKAN

No.	Nama Alat	Merk	Model/Type	No. Seri
1				
2	Thermohygrometer			
3				

C. KONDISI LINGKUNGAN

No.	Parameter	Terukur					
1	Temperatur Ruangan	Awal :		°C	Akhir :		°C
2	Kelembaban Ruangan	Awal :		%	Akhir :		%

D. PEMERIKSAAN FISIK DAN FUNGSI ALAT
baik : 1
tidak baik : 0

No.	Parameter	Batasan Pemeriksaan	Hasil Pengamatan
1	Badan dan Permukaan	periksa selungkup tachometer bersih tidak ada terrimpa cairan	
2	Komponen / kelengkapan	Periksa komponen-komponen bantu tachometer dan kelengkapan tachometer	
3	Lokasi Penyimpanan	Periksa lokasi penyimpanan tachometer baik	
4	Rekaman suhu	Periksa kondisi ruangan suhu Laboratorium kelistrikan tercatat dan masih dalam batas toleransi	
5	Masa kalibrasi	Periksa masa berlaku kalibrasi tachometer	
6	Tindakan	periksa tindakan perbaikan tachometer	

E. UNJUK KERJA

No	Setting pada Centrifuge	Terbaca pada Tachometer
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Figure 2. Check Worksheet Between Tachometers at BPAFK Jakarta

The Testing and Calibration Laboratory is required to have calibrator equipment in accordance with its list of capabilities. For tachometer instruments , the types are as follows:

1. Gear Rotor Tachometer
   Consists of a fixed sensor and a rotating gear wheel. Its operation involves the rotation of the rotor, with the toothed part of the rotor being the measured element.
2. DC Tachometer
   A DC generator that produces a DC output voltage proportional to the shaft speed. It works by directly converting speed into voltage. This type of tachometer is commonly used in marine instrumentation practicals.
3. Contact Tachometer
   Operates by making physical contact with the object being measured. The result is then displayed on the screen attached to the device.
4. Laser/Photo Tachometer
   Functions with a highly sensitive light sensor that detects the rotation of the UUT (Unit Under Test).

The UUT tachometer is not mandatory and depends on the respective laboratory. The UUT tachometer is used for comparison testing against the reference tachometer, where typically the UUT tachometer has a greater correction value than the reference tachometer. The correction value of a tachometer is obtained from the calibration report, which is conducted once a year.

C. CENTRIFUGE

A centrifuge is a laboratory instrument used to separate liquids or compounds based on differences in density and molecular weight. As the motor speed increases, the resulting centrifugal force also increases, allowing for optimal separation results. To avoid damaging the sample, it is essential to operate the centrifuge at a speed appropriate to the specific requirements.

The centrifuge used for intermediate checks must have a stable rotational speed and must have passed calibration verification or be deemed fit for use. It is employed in the intermediate verification of reference tachometers, which are used to compare the actual rotational speed being tested with the value displayed on the screen. Two reference tachometer methods are employed to determine which method provides the highest level of accuracy [8].

There are several parts of a centrifuge:

1. Chamber
   This part functions as a container for the samples and is the outermost part surrounding the motor and rotor
2. Motor
   This part holds the sample tubes to be spun. The motor performs the spinning process based on the principle of centrifugal force
3. Rotor
   A component that contains buttons such as the on/off switch, speed controller, and timer
4. Lid/Cover
   The top part of the centrifuge. The lid is automatic and cannot be opened while the separation process is still in progress
5. Body
   The casing, which may be box-shaped, cylindrical, or semi-spherical. The body protects the internal parts (motor/rotor/sample) and other components

There are several types of centrifuges:

a. General Purpose Centrifuge
   This type is designed to separate urine, serum, or other liquid samples. It usually operates at speeds of 0–3000 rpm and can hold 5–100 ml
b. Micro Centrifuge
   Also known as a high-speed centrifuge for spinning microtubes. The volume of microtubes is usually around 0.5–2.0 ml
c. Specialty Centrifuge

Typically used for specific and specialized purposes. Examples include microhematocrit centrifuges and blood bank centrifuges

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D. CONTROL CHART

Control charts are a technique known as a graphical method used to evaluate whether a process is under statistical quality control or not, thereby enabling problem-solving and quality improvement [9]. The intermediate check data is then analyzed using a control chart by setting limit values known as :Upper Warning Limit (UWL), Lower Warning Limit (LWL), Upper Action Limit (UAL), and Lower Action Limit (LAL) [10][11].

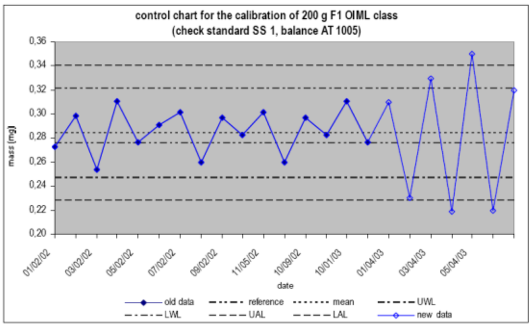

Figure 1. Control chart

There are several benefits of control chartsas shown in Fig.1:

1. Ensuring compliance with the reference value or detecting changes in the established reference point.
2. Ensuring ongoing stability of process variability and achieving uncertainty estimation or identifying changes in process variables that affect uncertainty analysis.
3. Continuously ensuring and documenting the stability of standards, as well as predicting future measurement values.
4. Supporting decision-making regarding corrective actions or process improvements.

A control diagram is a visual tool used to monitor process variations and identify whether the process remains within the expected control limits. It helps determine whether the defects in the produced products are still within the specified limits. A control chart is a specific type of graph plotted within a control diagram to display data collected from the process. [12][13]. Weaknesses of attribute control charts:

1. It is not possible to determine how far the deviation is from the specified requirements.
2. Large sample sizes can be problematic when measurements are expensive or when testing causes damage.

Steps for creating a statistical control chart for attribute data (Besterfield, 1998) [14]:

1. Determine the objectives to be achieved.
2. Determine the number of samples and the number of observations.
3. Collect the data.
4. Determine the center line and control limits
5. Revise the chart if any points fall outside the control limits (due to special causes)

II. RESEARCH METHODS

A. RESEARCH DESIGN

The method used in this study is quantitative descriptive by observing and comparing measurement results. The measurements were carried out using primary data collection, specifically by comparing a reference tachometer with a Unit Under Test (UUT) tachometer of the same brand and model. Additionally, primary data were collected from a single UUT tachometer and a centrifuge at the Electrical Laboratory of BPAFK Jakarta. Measurements were taken thirty times over a period of twenty days for both methods: tachometer-to-tachometer and tachometer-to-centrifuge. Data were collected at three speed points: the lower point at 1000 rpm, the mid-point at 3000 rpm, and the upper point at 4000 rpm, in order to evaluate the accuracy of the instruments. This study was conducted because the tachometer with serial number 634492, as the UUT, is a new device that has never undergone an intermediate check in the calibration division. Meanwhile, the reference tachometer and centrifuge belong to another division but are still located within the BPAFK Jakarta laboratory.

B. CONCEPTUAL FRAMEWORK

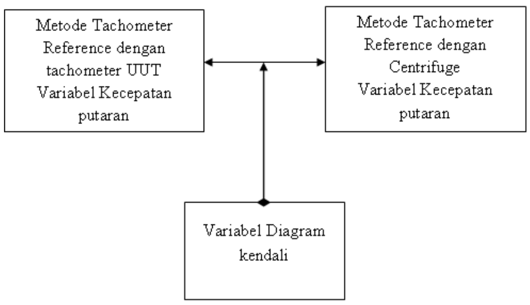

Figure 2 . Conceptual Framework of Proposed Study

The conceptual framework in Fig. 2 of this study consists of three variables. This research uses the control chart variable as a statistical analysis tool for the measurement results of rotational speed. The control chart is used to analyze the rotational speed measurement data obtained from intermediate checks using two different methods. The study reviews the method of using a reference tachometer and a Unit Under Test (UUT) tachometer to examine rotational speed as a variable, and compares it with the method of checking the UUT tachometer against a centrifuge, also using rotational speed as a variable. For these two variables, the study compares both methods—each utilizing rotational speed measurement through a tachometer UUT as a calibrator—which are then analyzed using control charts. The control chart is used to determine which method is more suitable for conducting intermediate checks. The intermediate check method for the UUT tachometer must have been calibrated in accordance with the Ministry of Health Regulation No. 54 of 2015, once every year, and must meet the following requirements :Environmental Conditions

1. Room temperature: 25 ºC ± 5 ºC
2. Relative humidity: 50 %RH ± 20 %RH

C. DATA COLLECTION TECHNIQUES AND RESEARCH INSTRUMENT

1. Data Collection Techniques

In this study, two measurement methods were carried out, and for each method, thirty data points were collected over a period of twenty days at a single measurement point..

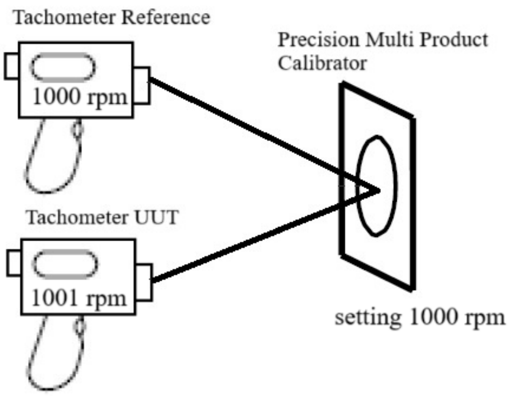

Figure 3. Illustration of measuring the tachometer reference method with the UUT tachometer measuring point 1000 rpm

Fig. 3 illustrates the intermediate check method between the reference tachometer and the UUT tachometer at the lower measurement point of 1000 rpm. Subsequently, the precision multi-product calibrator was set to the mid-point of 3000 rpm and the upper point of 4000 rpm, with 30 data points collected at each of those settings.

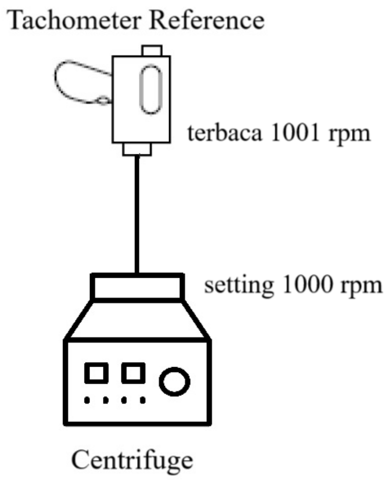

Figure 4. Illustration of measuring the tachometer reference method with a centrifuge measuring point 1000 rpm

Fig.4 this is an illustration of the intermediate check method between the reference tachometer and the centrifuge at the lower measurement point of 1000 rpm. In Figure 4, the centrifuge is set to 1000 rpm, and the reference tachometer reads 1001 rpm. A total of 30 measurements were recorded at this point. Subsequently, the centrifuge was set to the mid-point of 3000 rpm and the upper point of 4000 rpm, with 30 data points collected at each setting.

2. Research Instrument

In this study, the data collection methods used by the author include primary data collection, interviews, and documentation. The author employed primary data collection using a reference tachometer with a UUT tachometer, as well as a reference tachometer with a centrifuge. The study was conducted by measuring rotational speed at three points: the lower point at 1000 rpm, the mid-point at 3000 rpm, and the upper point at 4000 rpm. According to SNI ISO/IEC 17025:2017 [3] [15], intermediate checks can be performed at the lower, middle, and upper points. Accordingly, the author used two methods and three measurement points: lower, middle, and upper. The research uses the following research instrumentation :

1. Tachometer merk Compact
2. Centrifuge merk Hettich
3. Precision Multi Product Calibrator

D. DATA ANALYSIS TECHNIQUE AND METHODS OF DATA PRESENTATION

In conducting data analysis, the author uses a descriptive quantitative method, in which the analysis and conclusion are based on data previously obtained through testing and evaluation. The initial stage of data analysis involves the categorization of the collected data [16].

1. Average

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

Where,

ẋ = average value of measurements
xi = random values of measurement data x1, x2, …,xi
n = amount of data retrieved

The average (mean) is one of the measures of central tendency in statistics used to represent an entire set of data with a single value. This average is often used to indicate the general "central value" of a group of numbers [17].

2. Standard deviation [18]

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2}{(n-1)}}$$

Where,

Σ = sum
σ = standard deviation

Standard deviation is a statistical measure that indicates the amount of variation or dispersion in a set of data. The smaller the standard deviation, the closer the data values are to the mean; the larger the standard deviation, the more spread out the data values are from the mean.

3. Correction
Correction = standard – UUT (*Unit Under Test*)

The difference between the value of the standard and the value indicated by the test instrument. In other words, the correction is the difference between the true value (standard) and the value measured by the unit under test (UUT)

4. Upper Warning Limit (UWL)

$$UWL = \bar{x} + (2 \times \sigma)$$

The Upper Warning Limit (UWL) is a threshold used in quality control and statistical process control to signal that a process may be deviating from normal performance and requires attention. It acts as an early warning that the process might be trending out of control even if it's still within formal control limits.

5. Lower Warning Limit (LWL)

$$LWL = \bar{x} - (2 \times \sigma)$$

The Lower Warning Limit (LWL) is a statistical threshold used in quality control or process monitoring to give an early warning that a process may be shifting below its expected performance level even if it's still technically within control limits. It acts as a caution zone if data points fall below this limit, it signals that the process might be drifting and should be checked before it becomes unstable.

6. Upper Action Limit (UAL)

$$UAL = \bar{x} + (3 \times \sigma)$$

The Upper Action Limit (UAL) is a critical threshold in quality control and statistical process monitoring that indicates a point at which immediate corrective action should be taken to bring the process back under control. If a data point exceeds the UAL, it typically signals that the process is out of control and requires intervention. Unlike the Upper Warning Limit (UWL), which is a cautionary threshold, the UAL indicates that the process has exceeded a critical level and action must be taken.

7. Lower Action Limit (LAL)

$$LAL = \bar{x} - (3 \times \sigma)$$

The LAL is a limit set below the Lower Warning Limit (LWL). When a measurement falls below this point, it's considered a serious deviation from normal process behavior suggesting that the process is out of control on the low side and must be corrected immediately.

III. RESULTS AND EXPLANATION

In this study, data were collected at three engine speed measurement points: a low point at 1000 rpm, a mid-point at 3000 rpm, and a high point at 4000 rpm. Measurements were taken 30 times per day, over a period of 20 days, resulting in a total of 600 data points .

1. UUT Tachometer Measurement Results with Tachometer reference

TABLE I UUT TACHOMETER MEASUREMENT WITH TACHOMETER REFERENCE POINT 1000 RPM

No	Mean	x	LWL	UWL	LAL	UAL
1	999,37	0,33	0,11	0,35	0,05	0.41
2	999,43	0,27	0,11	0,35	0,05	0.41
3	999,43	0,27	0,11	0,35	0,05	0.41
4	999,43	0,27	0,11	0,35	0,05	0.41
5	999,47	0,23	0,11	0,35	0,05	0.41
6	999,53	0,17	0,11	0,35	0,05	0.41
7	999,37	0,33	0,11	0,35	0,05	0.41
8	999,43	0,27	0,11	0,35	0,05	0.41
9	999,43	0,27	0,11	0,35	0,05	0.41
10	999,50	0,20	0,11	0,35	0,05	0.41
11	999,43	0,27	0,11	0,35	0,05	0.41

12	999,60	0,10	0,11	0,35	0,05	0.41
13	999,53	0,17	0,11	0,35	0,05	0.41
14	999,47	0,23	0,11	0,35	0,05	0.41
15	999,47	0,23	0,11	0,35	0,05	0.41
16	999,53	0,17	0,11	0,35	0,05	0.41
17	999,43	0,27	0,11	0,35	0,05	0.41
18	999,47	0,23	0,11	0,35	0,05	0.41
19	999,50	0,20	0,11	0,35	0,05	0.41
20	999,57	0,13	0,11	0,35	0,05	0.41

Based on the data in Table 1,, the accuracy of the UUT (Unit Under Test) tachometer at the lower measurement point of 1000 rpm shows an average reading of 999.47 rpm with a standard deviation of 0.06.

TABLE II UUT TACHOMETER MEASUREMENT WITH TACHOMETER REFERENCE POINT 3000 RPM

No	Mean	x	LWL	UWL	LAL	UAL
1	2999,50	0,10	0,02	0,22	-0,03	0,27
2	2999,50	0,10	0,02	0,22	-0,03	0,27
3	2999,40	0,20	0,02	0,22	-0,03	0,27
4	2999,40	0,20	0,02	0,22	-0,03	0,27
5	2999,50	0,10	0,02	0,22	-0,03	0,27
6	2999,43	0,17	0,02	0,22	-0,03	0,27
7	2999,40	0,20	0,02	0,22	-0,03	0,27
8	2999,50	0,10	0,02	0,22	-0,03	0,27
9	2999,50	0,10	0,02	0,22	-0,03	0,27
10	2999,50	0,10	0,02	0,22	-0,03	0,27
11	2999,50	0,10	0,02	0,22	-0,03	0,27
12	2999,50	0,10	0,02	0,22	-0,03	0,27
13	2999,60	0,00	0,02	0,22	-0,03	0,27
14	2999,50	0,10	0,02	0,22	-0,03	0,27
15	2999,50	0,10	0,02	0,22	-0,03	0,27
16	2999,47	0,13	0,02	0,22	-0,03	0,27
17	2999,50	0,10	0,02	0,22	-0,03	0,27
18	2999,40	0,20	0,02	0,22	-0,03	0,27
19	2999,50	0,10	0,02	0,22	-0,03	0,27
20	2999,50	0,10	0,02	0,22	-0,03	0,27

Based on the data Table2, tachometer at the lower measurement point of 3000 rpm shows an average reading of 2999.48 rpm with a standard deviation of 0.05.

TABLE III UUT TACHOMETER MEASUREMENT WITH TACHOMETER REFERENCE POINT 4000 RPM

No	Mean	x	LWL	UWL	LAL	UAL
1	3999,40	0,10	-0,09	0,18	-0,16	0,25
2	3999,43	0,07	-0,09	0,18	-0,16	0,25
3	3999,50	0,00	-0,09	0,18	-0,16	0,25
4	3999,40	0,10	-0,09	0,18	-0,16	0,25
5	3999,33	0,17	-0,09	0,18	-0,16	0,25
6	3999,50	0,00	-0,09	0,18	-0,16	0,25
7	3999,40	0,10	-0,09	0,18	-0,16	0,25
8	3999,47	0,03	-0,09	0,18	-0,16	0,25
9	3999,53	-0,03	-0,09	0,18	-0,16	0,25
10	3999,43	0,07	-0,09	0,18	-0,16	0,25
11	3999,43	0,07	-0,09	0,18	-0,16	0,25
12	3999,57	-0,07	-0,09	0,18	-0,16	0,25
13	3999,40	0,10	-0,09	0,18	-0,16	0,25
14	3999,50	0,00	-0,09	0,18	-0,16	0,25
15	3999,53	-0,03	-0,09	0,18	-0,16	0,25
16	3999,53	-0,03	-0,09	0,18	-0,16	0,25
17	3999,40	0,10	-0,09	0,18	-0,16	0,25
18	3999,47	0,03	-0,09	0,18	-0,16	0,25
19	3999,37	0,13	-0,09	0,18	-0,16	0,25
20	3999,57	-0,07	-0,09	0,18	-0,16	0,25

Based on Table 3,, the accuracy of the UUT (Unit Under Test) tachometer at the lower measurement point of 4000 rpm shows an average reading of 3999.46 rpm with a standard deviation of 0.06.

2. Reference Tachometer Measurement Results with Centrifuge

TABLE IV UUT TACHOMETER MEASUREMENT WITH CENTRIFUGE POINT 1000 RPM

No	Mean	x	LWL	UWL	LAL	UAL
1	1000,20	-0,50	-0,47	0,02	-0,59	0.14
2	999,87	-0,17	-0,47	0,02	-0,59	0.14
3	999,87	-0,17	-0,47	0,02	-0,59	0.14
4	999,93	-0,23	-0,47	0,02	-0,59	0.14
5	999,80	-0,10	-0,47	0,02	-0,59	0.14
6	1000,00	-0,30	-0,47	0,02	-0,59	0.14
7	999,93	-0,23	-0,47	0,02	-0,59	0.14
8	999,83	-0,13	-0,47	0,02	-0,59	0.14
9	1000,00	-0,30	-0,47	0,02	-0,59	0.14
10	999,80	-0,10	-0,47	0,02	-0,59	0.14
11	1000,27	-0,57	-0,47	0,02	-0,59	0.14
12	999,83	-0,13	-0,47	0,02	-0,59	0.14
13	999,83	-0,13	-0,47	0,02	-0,59	0.14
14	999,77	-0,07	-0,47	0,02	-0,59	0.14
15	1000,00	-0,30	-0,47	0,02	-0,59	0.14
16	999,93	-0,23	-0,47	0,02	-0,59	0.14
17	999,90	-0,20	-0,47	0,02	-0,59	0.14
18	999,70	0,00	-0,47	0,02	-0,59	0.14
19	999,93	-0,23	-0,47	0,02	-0,59	0.14
20	999,83	-0,13	-0,47	0,02	-0,59	0.14

Based on Table 4, the accuracy of the UUT (Unit Under Test) tachometer at the lower measurement point of 1000 rpm shows an average reading of 999.41 rpm with a standard deviation of 0.14.

TABLE V UUT TACHOMETER MEASUREMENT WITH CENTRIFUGE POINT 3000 RPM

No	Mean	x	LWL	UWL	LAL	UAL
1	2999,90	-0,30	0,93	0,68	-1,33	1,09
2	3000,07	-0,47	0,93	0,68	-1,33	1,09
3	2999,80	-0,20	0,93	0,68	-1,33	1,09
4	2999,70	-0,10	0,93	0,68	-1,33	1,09
5	2999,00	0,60	0,93	0,68	-1,33	1,09
6	3000,13	-0,53	0,93	0,68	-1,33	1,09
7	3000,07	-0,47	0,93	0,68	-1,33	1,09
8	2999,87	-0,27	0,93	0,68	-1,33	1,09
9	2999,67	-0,07	0,93	0,68	-1,33	1,09
10	2999,03	0,57	0,93	0,68	-1,33	1,09
11	3000,27	-0,67	0,93	0,68	-1,33	1,09
12	2999,83	-0,23	0,93	0,68	-1,33	1,09
13	2999,47	0,13	0,93	0,68	-1,33	1,09
14	2999,47	0,13	0,93	0,68	-1,33	1,09
15	3000,13	-0,53	0,93	0,68	-1,33	1,09
16	2999,67	-0,07	0,93	0,68	-1,33	1,09
17	3000,13	-0,53	0,93	0,68	-1,33	1,09
18	2999,87	-0,27	0,93	0,68	-1,33	1,09
19	2999,70	-0,10	0,93	0,68	-1,33	1,09
20	2999,67	-0,07	0,93	0,68	-1,33	1,09

Based on Table 5, the accuracy of the UUT (Unit Under Test) tachometer at the lower measurement point of 3000 rpm shows an average reading of 2999.47 rpm with a standard deviation of 0.34.

TABLE VI UUT TACHOMETER MEASUREMENT WITH CENTRIFUGE POINT 4000 RPM

No	Mean	x	LWL	UWL	LAL	UAL
1	3999,83	-0,33	-0,51	0,36	-0,73	0,58
2	3999,60	-0,10	-0,51	0,36	-0,73	0,58
3	3999,40	0,10	-0,51	0,36	-0,73	0,58
4	3999,13	0,37	-0,51	0,36	-0,73	0,58
5	3999,47	0,03	-0,51	0,36	-0,73	0,58
6	3999,77	-0,27	-0,51	0,36	-0,73	0,58
7	3999,77	-0,27	-0,51	0,36	-0,73	0,58
8	3999,77	-0,27	-0,51	0,36	-0,73	0,58
9	3999,47	0,03	-0,51	0,36	-0,73	0,58
10	3999,57	-0,07	-0,51	0,36	-0,73	0,58
11	4000,10	-0,60	-0,51	0,36	-0,73	0,58
12	3999,73	-0,23	-0,51	0,36	-0,73	0,58
13	3999,97	-0,47	-0,51	0,36	-0,73	0,58
14	4000,00	-0,50	-0,51	0,36	-0,73	0,58
15	3999,47	0,03	-0,51	0,36	-0,73	0,58
16	3999,77	-0,27	-0,51	0,36	-0,73	0,58
17	3999,93	-0,43	-0,51	0,36	-0,73	0,58
18	3999,77	-0,27	-0,51	0,36	-0,73	0,58
19	3999,87	-0,37	-0,51	0,36	-0,73	0,58
20	3999,60	-0,10	-0,51	0,36	-0,73	0,58

Based on Table 6, the accuracy of the UUT (Unit Under Test) tachometer at the lower measurement point of 4000 rpm shows an average reading of 3999.70 rpm with a standard deviation of 0.24

3. Comparison of each measuring point

a. 1000rpm

The first result (Tachometer UUT compared with the Reference Tachometer) showed an average of 999.47 rpm with a standard deviation of 0.06. as shown in Fig. 5 The second result (Tachometer UUT compared with the Centrifuge) showed an average of 999.91 rpm with a standard deviation of 0.14. The difference indicates some variation in measurement or differing test conditions. While both average values are fairly accurate, the second result has a higher standard deviation, meaning the data points tend to deviate more from the mean compared to the first result.

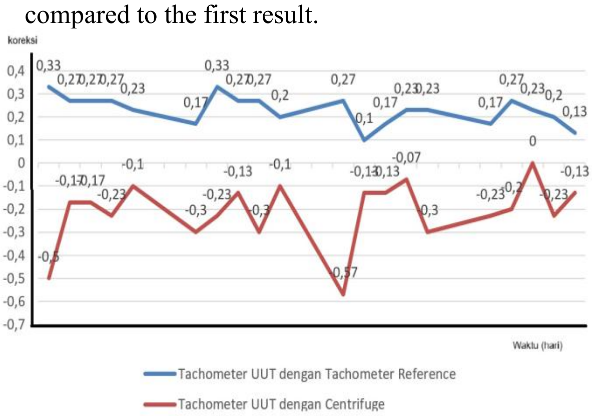

Figure 5. Comparison measuring point 1000 rpm

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b. 3000 rpm

The first result (Tachometer UUT compared with the Reference Tachometer) showed an average of 2999.48 rpm with a standard deviation of 0.05. as shown in Fig. 6. The second result (Tachometer UUT compared with the Centrifuge) showed an average of 2999.77 rpm with a standard deviation of 0.34. The difference indicates some variation in measurement or differing test conditions. While both average values are fairly accurate, the second result has a higher standard deviation, meaning the data points tend to deviate more from the mean compared to the first result.

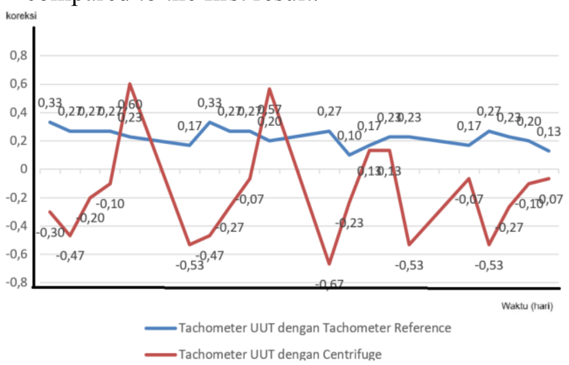

Figure 6. comparison measuring point 3000 rpm

c. 4000 rpm

The first result (Tachometer UUT compared with the Reference Tachometer) showed an average of 3999.46 rpm with a standard deviation of 0.06 as shown in Fig. 7.. The second result (Tachometer UUT compared with the Centrifuge) showed an average of 3999.70 rpm with a standard deviation of 0.24. The difference indicates some variation in measurement or differing test conditions. While both average values are fairly accurate, the second result has a higher standard deviation, meaning the data points tend to deviate more from the mean compared to the first result.

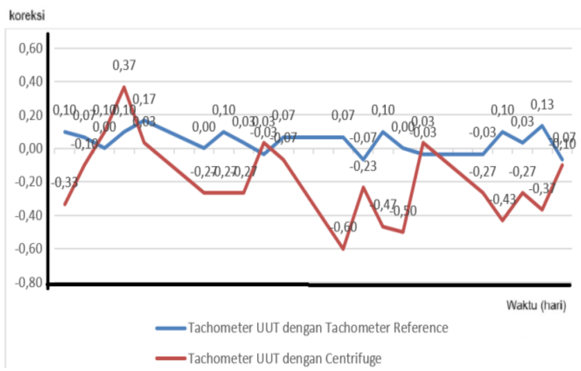

Figure 7. comparison measuring point 4000 rpm

4. Analysis of Intermediate Check Results

Based on the analysis and comparison between the UUT tachometer paired with a reference tachometer and the UUT tachometer paired with a centrifuge, both methods demonstrated sufficient accuracy[3]. However, a notable difference was observed in their standard deviations. According to the National Standardization Agency (BSN), as stated in SNI ISO/IEC 17025:2017 [19] Clause 7.7 regarding process requirements and quality assurance, the preferred method for intermediate checks is one that produces an average reading close to the setpoint with a low standard deviation [20]. In comparison to previous studies, the first referenced journal utilized an intermediate check method using a ruler calibrator against a steel ruler or artifact, while the second study employed a pressure gauge-to-pressure gauge method , both involving instruments with similar accuracy or resolution. This study takes a different approach by applying two comparison methods simultaneously to determine which yields more accurate and reliable results. To ensure accurate results with minimal variation, the findings of this study suggest that the intermediate check method using the UUT tachometer and the reference tachometer offers superior performance. Therefore, the author recommends this method as the most appropriate for conducting intermediate checks of tachometers.

IV. RESULTS AND DISCUSSION

Based on the research conducted and the results of data analysis, it can be concluded that there is a difference in measurement values between the two comparison methods used for testing the tachometer. Among these methods, the comparison using the Unit Under Test (UUT) tachometer against the reference tachometer produced more accurate and precise results. Therefore, this method is recommended by the author for use in intermediate checks of tachometer instruments.

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