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# Filters Used for Roundness Error Evaluation: An Experimental Comparison Study

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# Filters Used for Roundness Error Evaluation: An Experimental Comparison Study

Fatma Abdallah Elerian*

**KEYWORDS:**
***Filters, roundness error, measurement, experimental study.***

*Abstract*—**Filtration is a necessary step in roundness measurement. The type of filter affects value of roundness error. There were many studies that explain the differences between filters theoretically and few of them have studied the differences practically. This study aims at introducing a practical comparison of the following filters (2CR50, 2CR75, 2CRPC50, 2CRPC75, Gaussian and no filter) in order to demonstrate the effect of each on roundness error values. RA-120 ROUNDTEST instrument was used for measuring out of roundness of 25 turned workpieces. Least squares reference circle (LSC), minimum zone reference circle (MZC), maximum inscribed reference circle (MIC) and minimum circumscribed reference circle (MCC) methods were used for out of roundness evaluation. The experimental study showed that the filters have a clear effect on the values of the roundness error (RONt) and 2CRPC50, 2CR50 and Gaussian filters give the lowest values of (RONt) compared to others and the relationship between them depends on relation between a sinusoidal wavelength λ and the cut-off in length λc ($\frac{\lambda}{\lambda c}$). Also from ANOVA analysis the method (LSC, MZC, MIC and MCC) used in RONt evaluation does not affect the relationship between the above-mentioned filters, but rather affects their values**

Nomenclature

| | |
|---|---|
| $H(\lambda)$ | Attenuation characteristic |
| $\lambda$ | A sinusoidal wavelength |
| $\lambda_c$ | The cut-off in length units |
| $\alpha$ | *A constant* |

## I. INTRODUCTION

THE circular shape of engineering components is one of the most critical and essential geometric forms. Due to the imperfect process of manufacturing, the feature will never be accurately round so in mechanical production control, roundness error of work parts must be measured to guarantee the right function of such parts [1]. Excessive lateral or axial run out deviations of rotating and reciprocating components during dynamic operations are avoided by evaluating roundness form deviations of circular and cylindrical features [2]. Although the concepts of roundness and circularity are similar, their actual meanings are not. Roundness is the radial difference between the circumscribed circle and the inscribed circle, whereas circularity merely defines the actual deviation of work piece dimension. Total circularity error is the difference between peak and valley [3]. For analyzing roundness profiles, filtration techniques are important [4]. Roundness profile may be assessed using metrology instruments in terms of a discrete data set. To distinguish roughness from the roundness profile, mathematical filtering might be used. Because of the inaccuracy of the measuring process and to eliminate roughness, filtering is required before evaluating measurement results in order to determine roundness values [5]. Filtering process is responsible for partitioning a surface profile into roughness,

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waviness and form. In filtering, the profile of a surface is divided into equal length segments. Then a mean line is created to record the profile slope in each segment then roughness profile is graphically produced by taking into account the point deviations out from this mean line [6], so filtering can be defined as the process of removing unwanted aspects from a recorded profile. The graphical method proved inconvenient and time-consuming. Electrical filters were quickly adopted for surface texture filtering as an automated method for deriving the mean line became necessary. In electrical filtering a voltage proportionate to the profile is sent through a two-resistor-capacitor (2RC) network. Because the 2RC network includes memory, the output is a function of both the current input and previous values. In practice, the 2RC network calculates a running average of current and prior voltages but assigns lower weights to voltages from the past. While the network's memory aids in averaging, it introduces an undesirable phase in the output by only remembering past values [6]. Whitehouse and Reason [7] digitally simulated the 2RC filter to better understand the phase behaviour and solve the problem. They used a weighting formula based on the cut-off to describe the filter. With the introduction of digital filtering, researchers [7] began to address the 2RC filter's major flaw, especially its non-linear phase. A phase-corrected 2RC filter was developed. The Gaussian filter was invented as a result, and it is still the most popular filter today. Filters are available in the evaluation software of the measuring instruments but it is not possible to say with certainty which is the best [8]. The use of scientifically specified reference filters and algorithms in new roundness assessment techniques eliminates operator interpretation [3]. Depending on the age and complexity of the instrument and the computational equipment, the amplitude transfer characteristics and phase transfer functions of the filters used in today's measuring instruments vary. Although RC and 2RC filters are no longer used in newer instruments, they are still used in older ones. More advanced instruments are computerised and utilise digital filtering to achieve zero phase transfer functions (so-called phase-correct filtering), which are generally accepted to be the only usable filters if phase shifting processes cause distortion of the observed profiles. Because all filters with a real amplitude transfer function have the required attribute, there are many viable phase-correct filters [5]. Most roundness instruments still employ the phase-correct 2RC filter, which is still one of the standard filters. Gaussian filter is based on the assumption that the residual roundness profile is roughly symmetric [9]. Most engineering needs may be met with a linear Gaussian filter [10]. Traditionally, roundness measuring was done using basic equipment like a dial indicator. After the industrial revolution, roundness measurement equipment appeared as Talyrond machine [11], coordinate measuring machine (CMM) [12], RA-120 ROUNDTEST [13] and roundness machine Round scan [14]. Despite the great precision of the measuring device, there may be residual inaccuracies in the actual measurement. As a result, several studies focus on the roundness model's sample angle distribution and filter [15] and other focus on experimental studies of roundness error evaluation method [16].

This study aims to compare practically the effects of the following filters on roundness error values (2CR50, 2CR75, 2CRPC50, 2CRPC75, Gaussian, and no filter) in order to assist filter selection throughout the measurement method. The out of roundness of 25 turned work pieces was measured using the RA-120 ROUNDTEST equipment. Out of roundness was assessed using the least squares reference circle (LSC), minimum zone reference circle (MZC), maximum inscribed reference circle (MIC), and minimum circumscribed reference circle (MCC) approaches. The paper is divided into several parts as follows:
The first section deals with a simplified explanation of the most famous methods used in estimating the value of the roundness error, the second section focuses on filters under study, the third section presents the experimental study and the outcomes of measurements and the fourth section is for discussion and results. Finally, the fifth section is for conclusion.

## II. ROUNDNESS EVALUATION METHODS

The least square circle technique (LSC), the minimum zone circle method (MZC), the minimum circumscribed circle method (MCC), and the maximum inscribed circle method (MIC) are all methods for calculating roundness inaccuracy [17].

### *A. Least square-circle (LSC) method.*

The difference between the radii of the circumscribed circle and the inscribed one which are concentric to the reference circle generated using the least squares approach, is used to determine roundness [18].

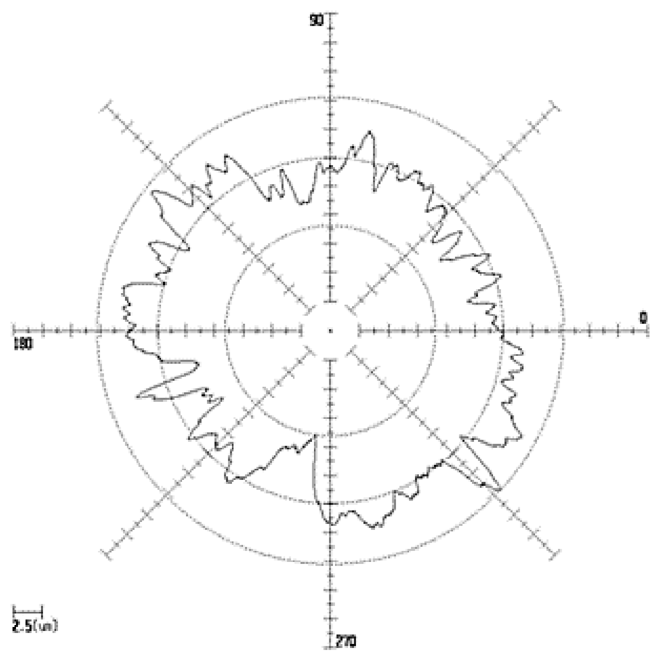



Fig.1. The Least Square Circle (LSC) method

### *B. Minimum Zone Circle (MZC) Method*

The minimal difference between the radii of concentric circumscribed and inscribed circles determines roundness. In the minimal zone centre approach, the reference circle is the mid-circle that is equidistant and concentric to each of these two circles, Figure 2 [18].

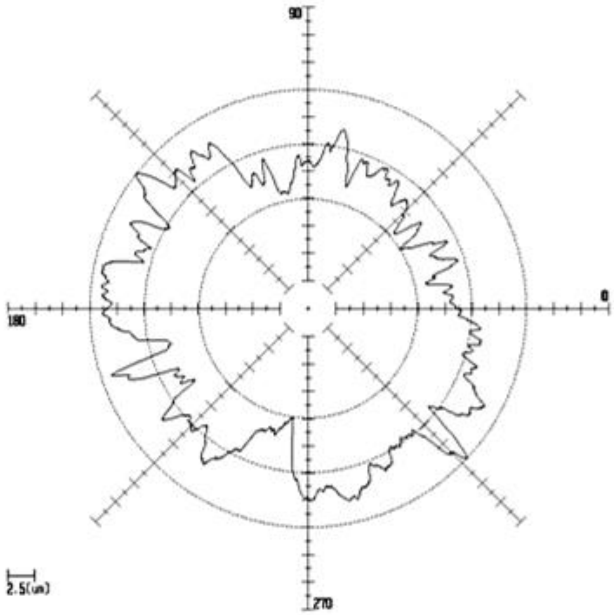



Fig.2. The Minimum zone circle (MZC) method [13]

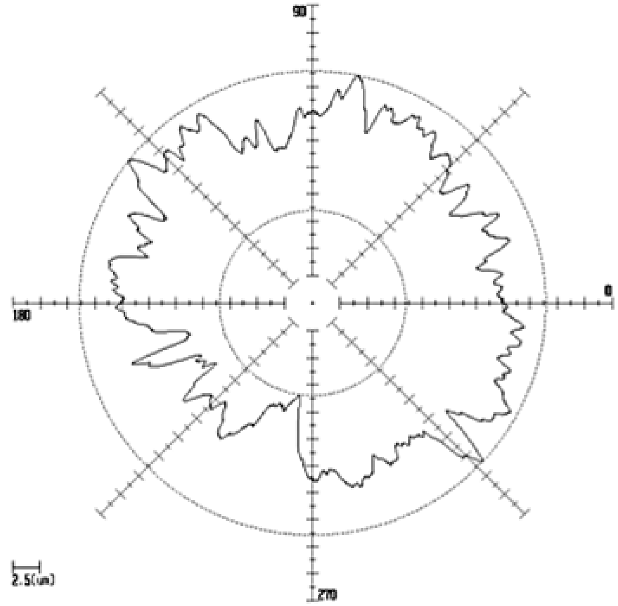



Fig.4. The Minimum circumscribed circle (MCC) method.

### *C. Maximum Inscribed Circle (MIC) Method*

The difference between the radii of the greatest inscribed circle and the concentric circumscribed circle is used to determine roundness. The greatest inscribed circle is used as the reference circle in this approach, Figure 3 [18].

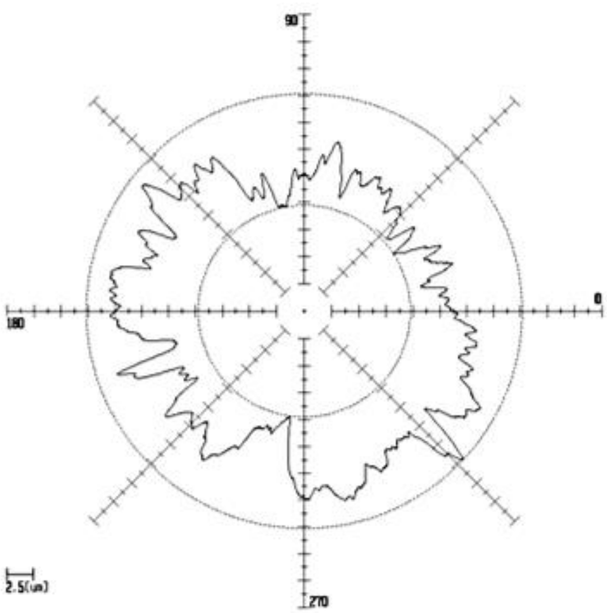



Fig.3. The Maximum inscribed circle (MIC) method

### *D. Minimum Circumscribed Circle (MCC)*

The difference between the radii of the smallest circumscribed circle and the concentric inscribed circle is used to determine roundness. In this approach, the reference circle is the smallest circumscribed circle, Figure 4 [18].

## III. Filters

The filter's goal is to provide weights that reduce the amplitude of sinusoids of various wavelengths. As a result, the amplitude transmission characteristics of the filter are referred to as the filter curve. The phase offset of different sinusoidal wavelengths must also be given in order to completely describe a filter in the frequency domain. The transmission characteristics of a filter are the sum of the amplitude and phase characteristics of the filter. The 2RC filter was first implemented in real-time. Profile points were supplied to a 2RC network as voltage signals as the instrument traversed the surface. The filtered output was recorded as a voltage signal, which was then translated to height units.

The 2RC filter has several flaws: (a) it causes phase distortion in the roughness profile; (b) it necessitates separate roughness and waviness filters; and (c) it causes edge distortion. The Gaussian filter was added to address some of the difficulties with the 2RC filter and it is digitally implemented. It has no phase distortion, and the complementary definitions of the high pass and low pass filters allow it to achieve both roughness and waviness with just one filter. Edge distortion is also a problem with the Gaussian filter. [6]. There are five types of filters used in RA-120 instrument [13] as listed in Table 1:

Table 1
Filters of RA-120 instrument [6].

| Name | Amplitude transmittance at the cut-off wavelength | Characteristic of amplitude | Characteristic of phase |
|---|---|---|---|
| *2CR50* | 50% | 2CR | ----------------- |
| *2CR75* | 75% | 2CR | ----------------- |
| *2CRPC50* | 50% | 2CR | Type with phase correction |
| *2CRPC75* | 75% | 2CR | Type with phase correction |
| *Gaussian* | 50% | Gaussian | Type with phase correction |

The next sections will go over each of the above filter characteristics briefly. Each filter's characteristic of attenuation will be represented as a high-pass filter.

***2CR50 Filter***

*2CR50* filter has the same characteristics of attenuation as a pair of C-R circuits linked in series with the same time constant. The characteristic of attenuation is -12dB/oct and the transmission of amplitude at the cut-off point is 50%. For 2D profile filtering, λ is a sinusoidal wavelength and $\lambda_c$ is the cut-off in length units [6].

2CR50 Filter attenuation characteristic

$$H(\lambda) = \frac{1}{1+\left(\frac{\lambda}{\lambda_c}\right)^2} \quad (1)$$

***2CR75 Filter***

*2CR75* filter is identical to the 2CR50 one with the exception that the transmission of amplitude at the cut-off value is 75% [6].

2CR75 Filter attenuation characteristic is

$$H(\lambda) = \frac{1}{1+\left(\frac{\lambda}{\sqrt{3}\lambda_c}\right)^2} \quad (2)$$

***2CRPC75 Filter***

*2CRPC75* filter has the same characteristic of amplitude as 2CR75 but is phase corrected [13].

***2CRPC50 Filter***

*2CRPC50* filter has the same characteristic of amplitude as 2CR50 but is phase corrected [13].

***Gaussian filter***

*Gaussian filter* has a characteristic of attenuation equal to -11.6dB/oct approximately and the transmission of amplitude at the cut-off value is 50% [6].

Gaussian filter attenuation characteristic

$$H(\lambda) = 1 - e^{-\pi\left(\frac{\alpha \cdot \lambda_c}{\lambda}\right)^2} \quad (3)$$

$$\alpha = \sqrt{\frac{ln2}{\pi}} = 0.4697 \quad (4)$$

***Comparison between 2CR50, 2CR75 and Gaussian filters in terms of amplitude.***

Figures 5 represents difference in the amplitude characteristics of a 2CR50 and a Gaussian filter, Figure 6 shows the difference between 2CR75 and a Gaussian one and Figure 7 represents difference in the amplitude characteristics of a 2CR50 and 2CR75 filter.

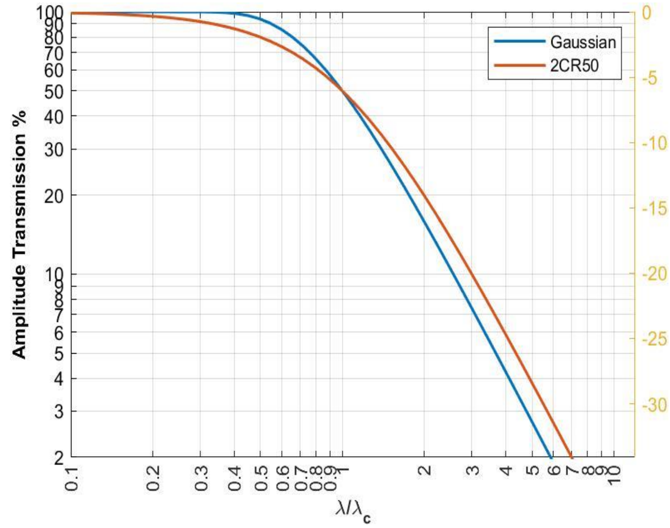



Fig. 5. The difference in amplitude characteristics between Gaussian and 2CR50 Filters

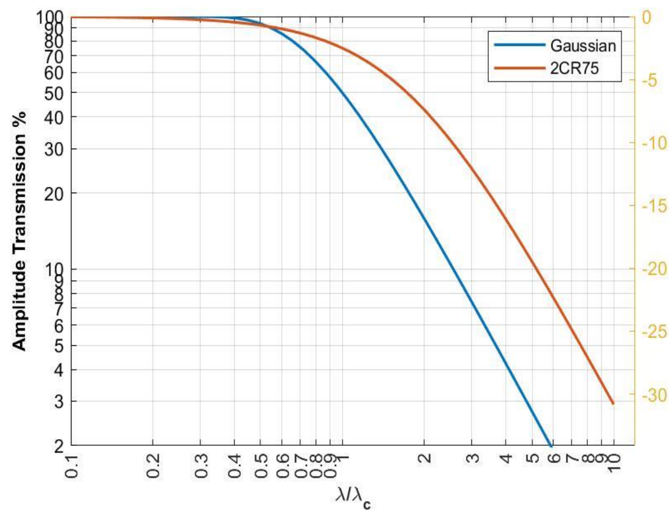



Fig. 6. The difference in amplitude characteristics between Gaussian and 2CR75 filters

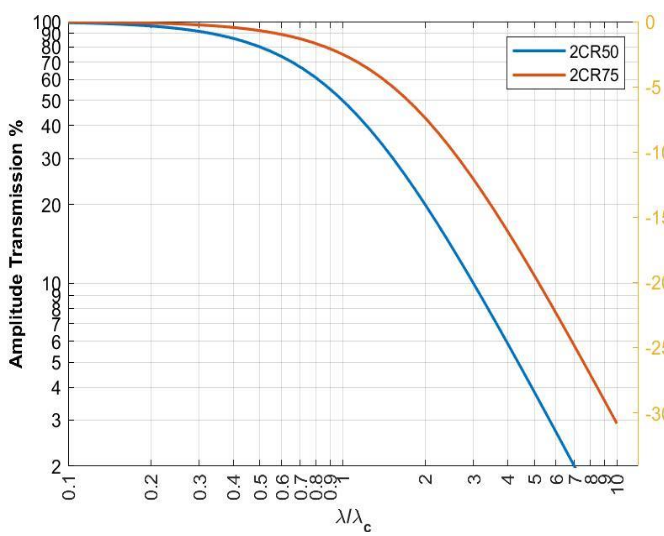



Fig. 7. Attenuation characteristic of 2CR50 and 2CR75 filters

***Comparison Between Low Pass Filter And High Pass Filter.***

A low-pass filter only sends out low frequencies (wavelengths greater than the cut-off). A low-pass filter is similar to an averaging filter in that it smoothed out the profile. A filter can also be made to only transmit high-frequency signals. A high-pass filter is one such filter. Because phase deviations vary with wavelength, output waveforms travelling through generic 2CR filters may be warped. The responses of a low-pass filter and a high-pass filter to a square wave input are shown in Figure8.

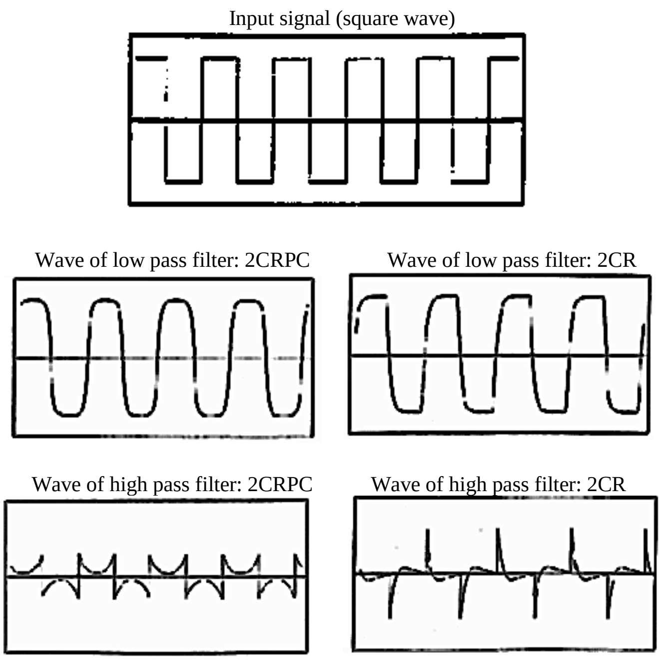



Fig. 8. Comparison low pass filter and high pass filter .

## IV. Experimental Study

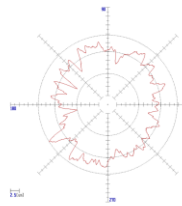
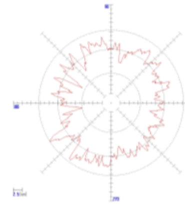
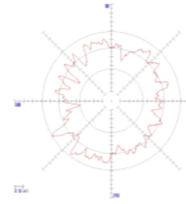
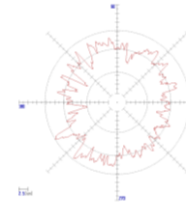
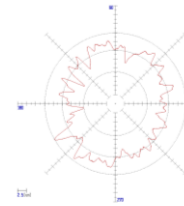
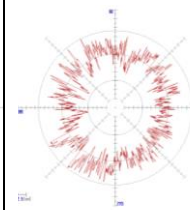
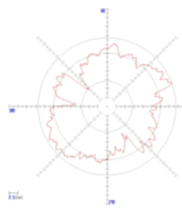
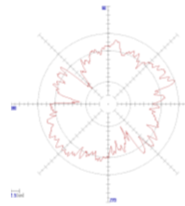
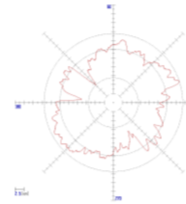
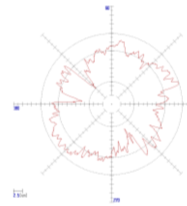
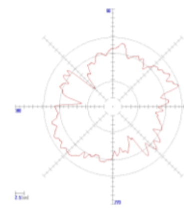
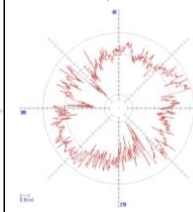
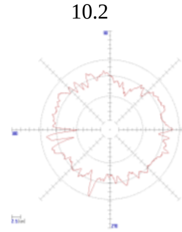
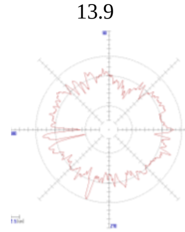
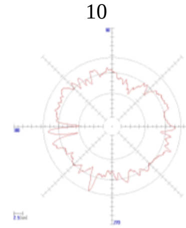
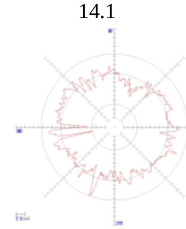
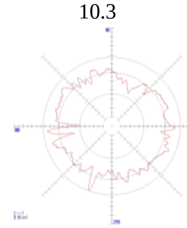
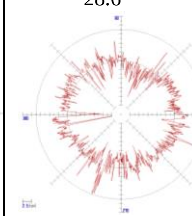
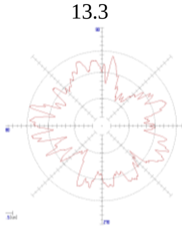
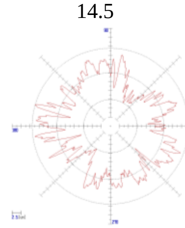
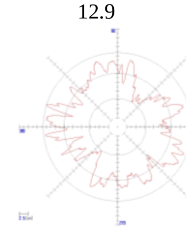
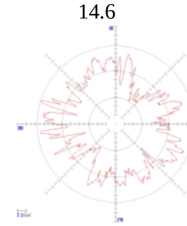
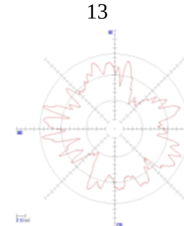
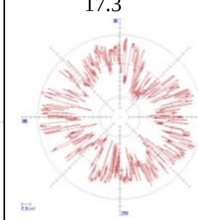
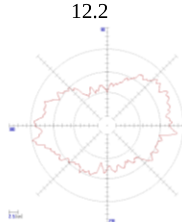
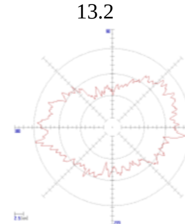
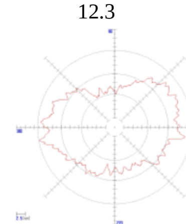
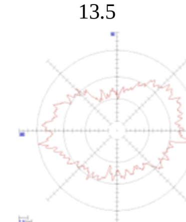
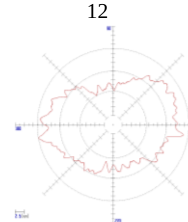
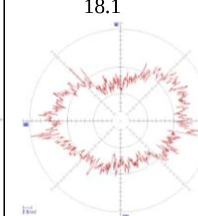
RA-120 Roundtest is one of the most widely used tools for measuring roundness. Such a device collects raw data and filters using various algorithms. Filters and analytic software are used to calculate the out of roundness. RA-120 Rountest utilised in the experiment allows for the selection of (2CR50, 2CR75, 2CRPC50, 2CRPC75, Gaussian and no filters) as well as four types of approaches (LSCI, MZCI, MICI and MCCI) with variable wave numbers in terms of undulations per revolution (UPR). Roundness error (RONt) were measured for a 25 cylindrical mild steel specimens using filters and approaches listed above, Figure 9.

Each specimen has a diameter of 28 mm and was turned under various cutting conditions: feed of (0.08 and 0.1 mm/rev), speed of (460, 955, and 1200 rpm), and cutting depth of (0.5, 1.0, 2.0) mm. The roundtest RA-120 instrument, which was used to measure roundness has a high accuracy, high precision, dependability, and durability air-bearing type turntable, as well as the ability to quickly and easily centre and level the workpiece on the turntable. The RONt and profile for each measurement are obtained using approaches of (LSC, MZC, MIC and MCC) and filters of (2CR-50, 2CR-75, 2CRPC-50, 2CRPC-75, Gaussian and no filter) with a 50 UPR cut-off as it is suitable for high pass filter as shown in Table 2, whereas in Table 3 profiles obtained with filters using LSC approaches is shown. Figures 10, 11, 12, 13 and 14 show a comparison among filters independent of the method employed. From the previous Figures, it can be concluded that the RONt values using ۲CR50, 2CRPC50 filters are less than when using 2CR75, 2CRPC75 filters affected by the values of Amplitude transmittance at the cut-off and RONt values utilizing 2CR50 and 2CRPC50 filters are lower than the Gaussian filter when the ratio $\frac{\lambda}{\lambda c}$ is less than 1, whereas RONt values using Gaussian are less than 2CR50, 2CRPC50 filters when the ratio $\frac{\lambda}{\lambda c}$ is more than 1, Figures 5,6,7. From Figure 15, and Table 2 it can be concluded that the type of method used in calculating the RONt values does not affect the relationship between the above-mentioned filters, but rather affects their values, as shown in Table 3 and Figure 16 after using one way ANOVA statistical method.

Fig.9. Measuring of (RONt) value by RA-120

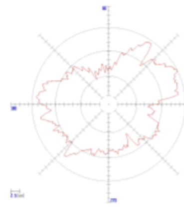
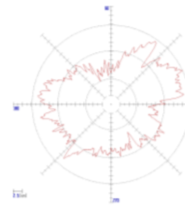
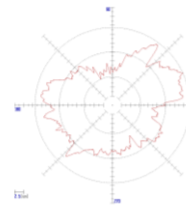
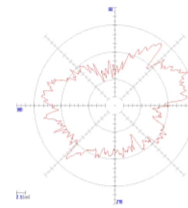
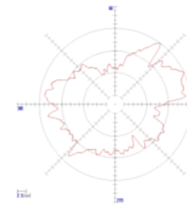
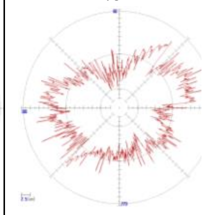
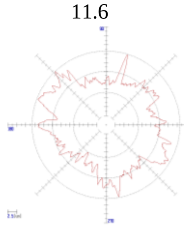
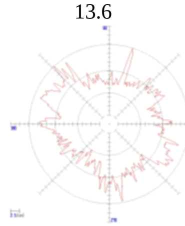
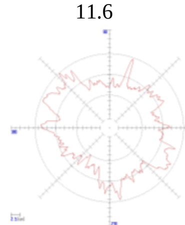
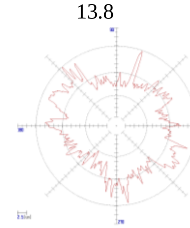
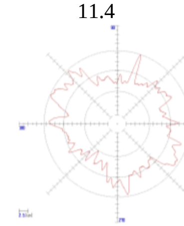
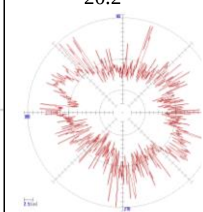
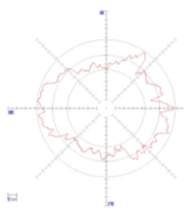
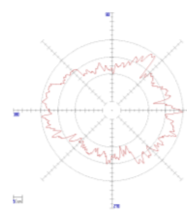
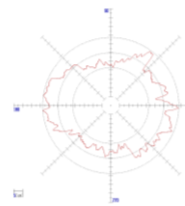
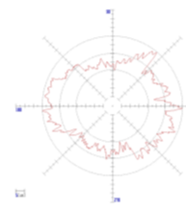
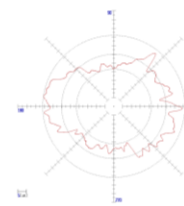
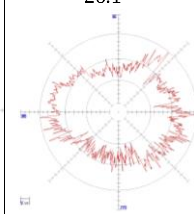
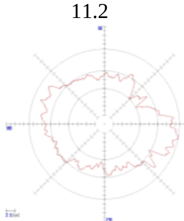
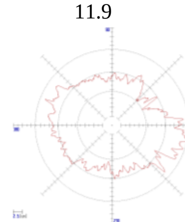
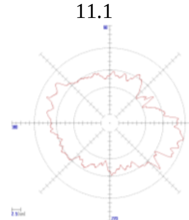
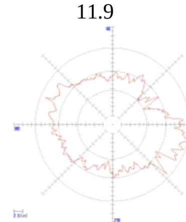
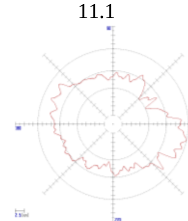
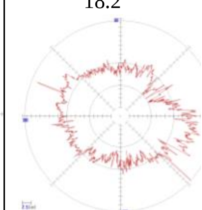
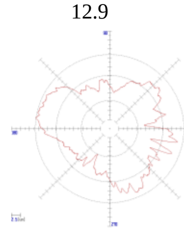
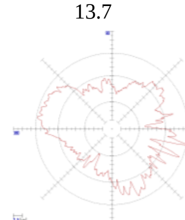
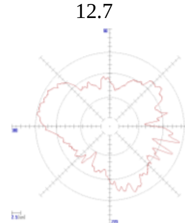
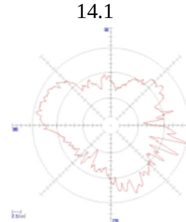
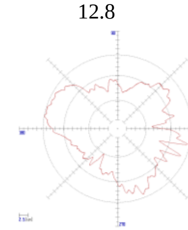
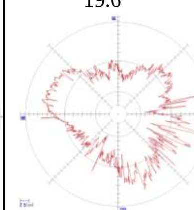
Table 2
Some values of roundness error (RONt) and some profiles using (LSC, MZC, MIC and MCC) methods and filters of (2CR-50, 2CR-75, 2CRPC-50, 2CRPC-75, Gaussian and no filter).

**RONt values (μm)**

| **Speci men no** | **Met hod** | **Filters** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **2CR-50** | **2CR-75** | **2CRPC-50** | **2CRPC-75** | **Gaussian** | **No filter** |
| *1* | LSC | 10.9 | 12.1 | 10.6 | 11.7 | 10.9 | 14 |
| | |  |  |  |  |  |  |
| | MZC | 10.1 | 11.4 | 9.8 | 11 | 10.1 | 13.8 |
| | MIC | 11.1 | 12.3 | 10.8 | 11.9 | 11.1 | 14.1 |
| | MCC | 11.2 | 12.6 | 11 | 11.9 | 11.3 | 14.6 |
| *2* | LSC | 12.2 | 13.5 | 12.4 | 13.5 | 12.4 | 17.2 |
| | |  |  |  |  |  |  |
| | MZC | 11.1 | 12.7 | 11 | 12.2 | 10.8 | 16.8 |
| | MIC | 14.5 | 16.9 | 14.2 | 15.9 | 13.8 | 22 |
| | MCC | 11.6 | 13.7 | 11.3 | 12.9 | 11.1 | 17.3 |
| *3* | LSC | 10.2 | 13.9 | 10 | 14.1 | 10.3 | 28.6 |
| | |  |  |  |  |  |  |
| | MZC | 8.5 | 12.1 | 10 | 12.2 | 10.3 | 24.3 |
| | MIC | 8.9 | 12.3 | 8.9 | 12.3 | 9 | 24.5 |
| | MCC | 9.2 | 13 | 9 | 13.2 | 9 | 26.7 |
| *4* | LSC | 13.3 | 14.5 | 12.9 | 14.6 | 13 | 17.3 |
| | |  |  |  |  |  |  |
| | MZC | 12.8 | 14 | 12.4 | 13.8 | 12.6 | 17 |
| | MIC | 15.7 | 16.2 | 15.8 | 16.5 | 16.3 | 17.6 |
| | MCC | 13.7 | 15.2 | 13.6 | 15 | 13.8 | 17.2 |
| *5* | LSC | 12.2 | 13.2 | 12.3 | 13.5 | 12 | 18.1 |
| | |  |  |  |  |  |  |
| | MZC | 11 | 12.2 | 11.1 | 12.3 | 10.7 | 16.1 |
| | MIC | 12.4 | 14.1 | 12.6 | 14.2 | 12.5 | 17.6 |
| | MCC | 10.9 | 12.5 | 11 | 12.4 | 11.1 | 17.4 |

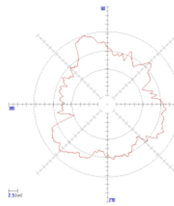
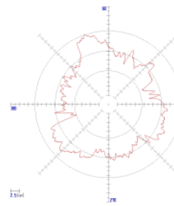
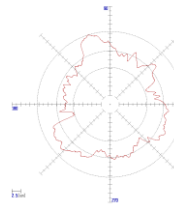
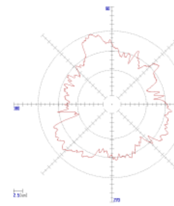
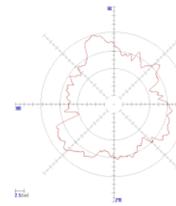
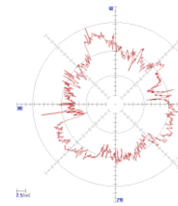
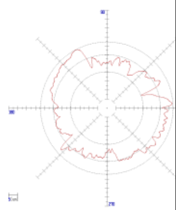
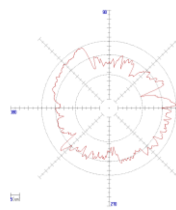
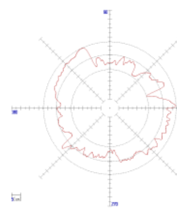
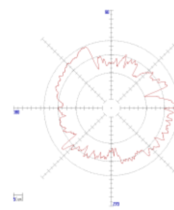
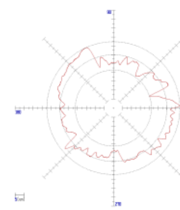
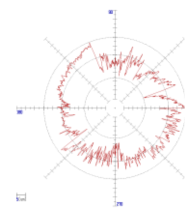
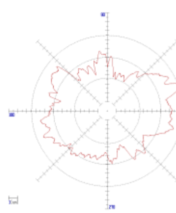
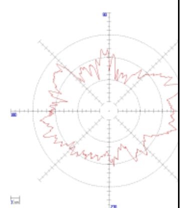
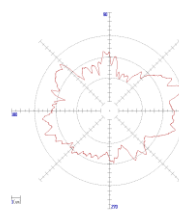
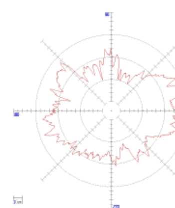
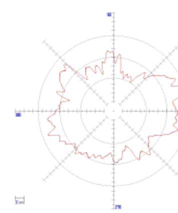
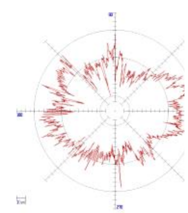
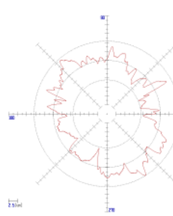
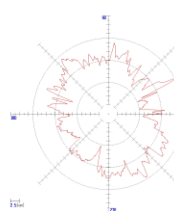
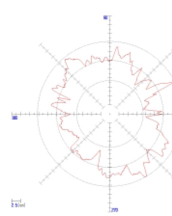
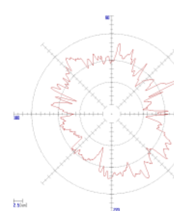
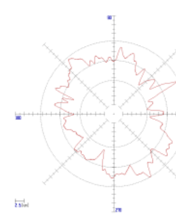
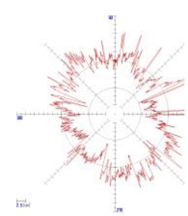
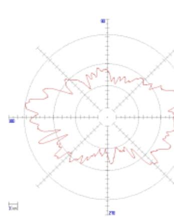
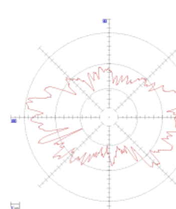
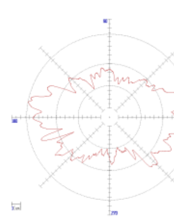
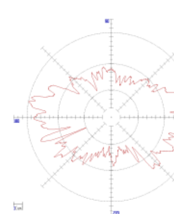
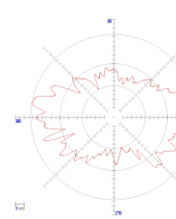
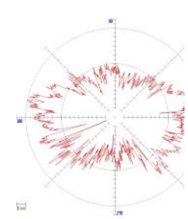
**(continued on the next page)**

**(TABLE 2: continued)**

| Specimen no | | Method | | | | | |
|---|---|---|---|---|---|---|---|
| | | **2CR-50** | **2CR-75** | **2CRPC-50** | **2CRPC-75** | **Gaussian** | **No filter** |
| *6* | LSC | 13.7 | 15.1 | 13.8 | 15.3 | 12.5 | 21.6 |
| | |  |  |  |  |  |  |
| | MZC | 11.4 | 12.5 | 11.6 | 12.5 | 12.1 | 18.5 |
| | MIC | 16.8 | 18.2 | 16.8 | 18.2 | 16.6 | 25.4 |
| | MCC | 12.3 | 13.1 | 12.2 | 12.9 | 11.5 | 24.4 |
| *7* | LSC | 11.6 | 13.6 | 11.6 | 13.8 | 11.4 | 20.2 |
| | |  |  |  |  |  |  |
| | MZC | 10.7 | 12.7 | 10.6 | 12.6 | 10.4 | 19.7 |
| | MIC | 11.2 | 12.9 | 11 | 12.7 | 11.3 | 20.1 |
| | MCC | 11.6 | 13.5 | 11.7 | 13.6 | 11.2 | 20.3 |
| *8* | LSC | 17 | 19 | 17.1 | 19.3 | 19.4 | 26.1 |
| | |  |  |  |  |  |  |
| | MZC | 18.4 | 20.1 | 18.3 | 20.3 | 18.3 | 27.2 |
| | MIC | 18.5 | 20.1 | 18.5 | 20.6 | 18.4 | 27.6 |
| | MCC | 21.4 | 20.2 | 19.7 | 22 | 20.8 | 30.4 |
| *9* | LSC | 11.2 | 11.9 | 11.1 | 11.9 | 11.1 | 18.2 |
| | |  |  |  |  |  |  |
| | MZC | 10.4 | 11.3 | 10.4 | 11.4 | 10.4 | 17.2 |
| | MIC | 12.7 | 13.5 | 12.6 | 13.5 | 12.7 | 19.4 |
| | MCC | 13.8 | 13.2 | 13.3 | 12.5 | 12.5 μ | 22.2 μ |
| *10* | LSC | 12.9 | 13.7 | 12.7 | 14.1 | 12.8 | 19.6 |
| | |  |  |  |  |  |  |
| | MZC | 11.7 | 12.5 | 11.6 | 13 | 11.7 | 18.1 |
| | MIC | 12.1 | 12.5 | 12 | 13.1 | 11.9 | 19 |
| | MCC | 14.2 | 15.9 | 14.4 | 16.1 | 14.1 | 20.4 |

**(continued on the next page)**

**(TABLE 2: continued)**

| Specimen no | | Method | | | | | |
|---|---|---|---|---|---|---|---|
| | | **2CR-50** | **2CR-75** | **2CRPC-50** | **2CRPC-75** | **Gaussian** | **No filter** |
| *11* | LSC | 10.7 | 11.2 | 10.1 | 11 | 10.3 | 14.9 |
| | |  |  |  |  |  |  |
| | MZC | 9.3 | 9.9 | 8.9 | 9.7 | 9.1 | 14.7 |
| | MIC | 12.2 | 12.7 | 11.7 | 12.4 | 11.8 | 12.6 |
| | MCC | 9.6 | 10.2 | 9.2 | 10.1 | 9.4 | 12.5 |
| *12* | LSC | 16.8 | 18.9 | 15.6 | 18.2 | 16 | 22.8 |
| | |  |  |  |  |  |  |
| | MZC | 16.1 | 18.4 | 15.2 | 17.7 | 15.5 | 22.4 |
| | MIC | 16.6 | 19.3 | 15.9 | 18.2 | 16.3 | 23 |
| | MCC | 15.1 | 17.4 | 14.8 | 16.9 | 14.9 | 22.3 |
| *13* | LSC | 4.8 | 5.1 | 4.7 | 5 | 4.7 | 7.4 |
| | |  |  |  |  |  |  |
| | MZC | 4.4 | 4.7 | 4.4 | 4.8 | 4.4 | 7.2 |
| | MIC | 4.9 | 4.9 | 4.8 | 5.1 | 4.9 | 7 |
| | MCC | 4.7 | 5.1 | 4.7 | 5.1 | 4.6 | 7 |
| *14* | LSC | 10.9 | 12.4 | 11 | 13.5 | 11.1 | 22.8 |
| | |  |  |  |  |  |  |
| | MZC | 10.6 | 12.4 | 11 | 13 | 7.7 | 22.7 |
| | MIC | 8.2 | 9.1 | 8.5 | 10.1 | 8.7 | 18.1 |
| | MCC | 8.4 | 9 | 7.9 | 9.6 | 5.8 | 17.2 |
| *15* | LSC | 5.7 | 6.3 | 5.8 | 6.4 | 5.8 | 10 |
| | |  |  |  |  |  |  |
| | MZC | 5.4 | 6.1 | 5.5 | 6.2 | 5.4 | 10 |
| | MIC | 5.8 | 6.4 | 6 | 6.4 | 6 | 10 |
| | MCC | 5.8 | 6.2 | 6 | 6.3 | 5.9 | 9.8 |

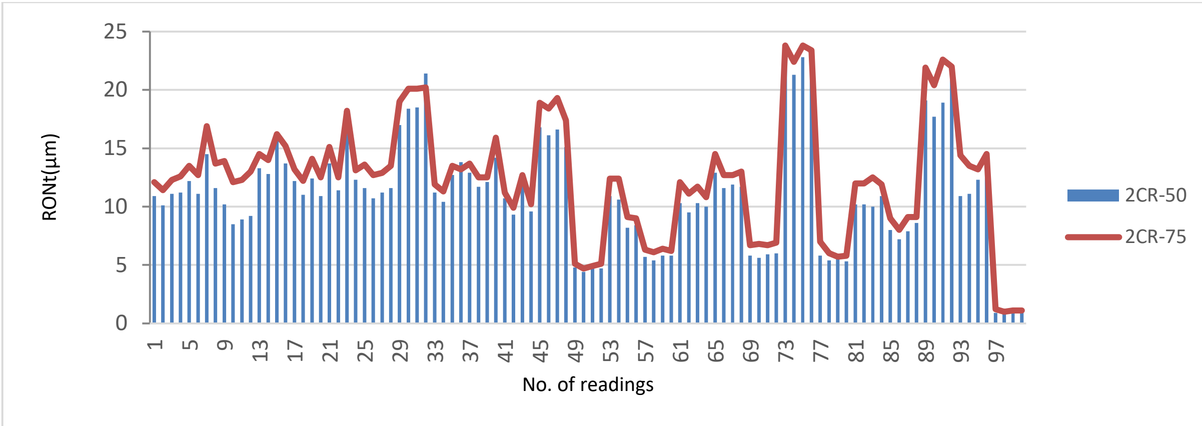



Fig. 10. Comparison between values of RONt using 2CR-50 and 2CR-75 filters

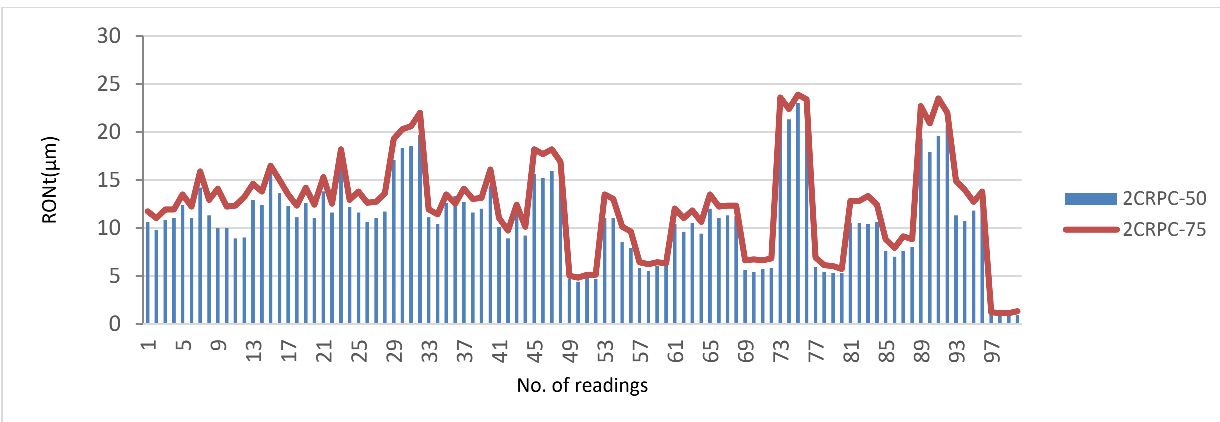



Fig. 11. Comparison between values of RONt using 2CRPC-50 and 2CRPC-75 filters

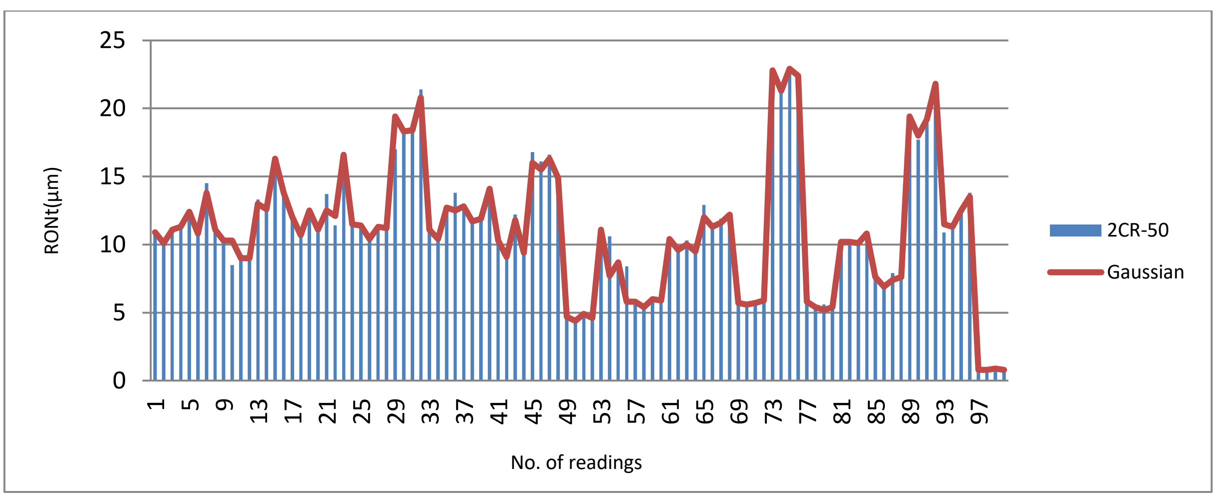



Fig. 12. Comparison between values of RONt using 2CR-50 and Gaussian filters


Fig. 13. Comparison between values of RONt using 2CRPC-50 and Gaussian filters

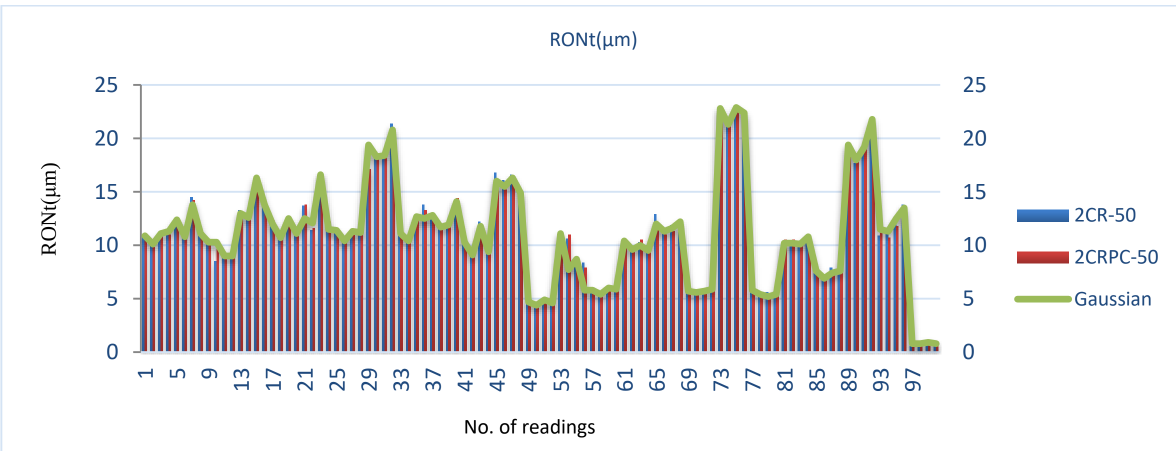



Fig. 14. Comparison between values of RONt using 2CR50, 2CRPC-50 and Gaussian

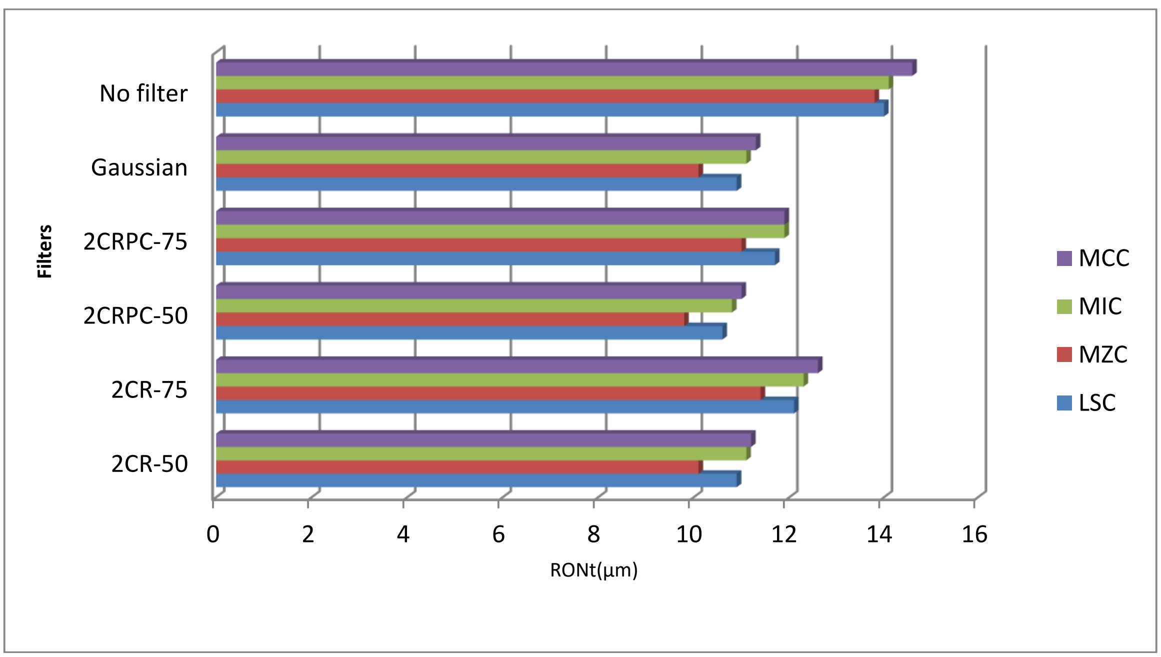



Fig.15. Comparison among filters used with LSC, MZC, MIC and MCC methods for specimen no (1).

TABLE 3
ONE-WAY ANOVA: FILTERS VERSUS METHODS

One-way ANOVA: 2CR-50 versus Methods

**Analysis of Variance**

| Source | DF | Seq SS | Contribution | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|---|---|
| Methods | 3 | 15.09 | 1.11% | 15.09 | 5.030 | 0.33 | 0.805 |
| Error | 88 | 1347.72 | 98.89% | 1347.72 | 15.315 | | |
| Total | 91 | 1362.81 | 100.00% | | | | |

One-way ANOVA: 2CR-75 versus Methods

**Analysis of Variance**

| Source | DF | Seq SS | Contribution | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|---|---|
| Methods | 3 | 12.39 | 0.77% | 12.39 | 4.130 | 0.23 | 0.877 |
| Error | 88 | 1600.24 | 99.23% | 1600.24 | 18.185 | | |
| Total | 91 | 1612.63 | 100.00% | | | | |

One-way ANOVA: 2CRPC-50 versus Methods

**Analysis of Variance**

| Source | DF | Seq SS | Contribution | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|---|---|
| Methods | 3 | 12.02 | 0.92% | 12.02 | 4.006 | 0.27 | 0.846 |
| Error | 88 | 1297.93 | 99.08% | 1297.93 | 14.749 | | |
| Total | 91 | 1309.95 | 100.00% | | | | |

One-way ANOVA: 2CRPC-75 versus Methods

**Analysis of Variance**

| Source | DF | Seq SS | Contribution | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|---|---|
| Methods | 3 | 13.78 | 0.83% | 13.78 | 4.592 | 0.25 | 0.864 |
| Error | 88 | 1644.26 | 99.17% | 1644.26 | 18.685 | | |
| Total | 91 | 1658.03 | 100.00% | | | | |

One-way ANOVA: Gaussian versus Methods

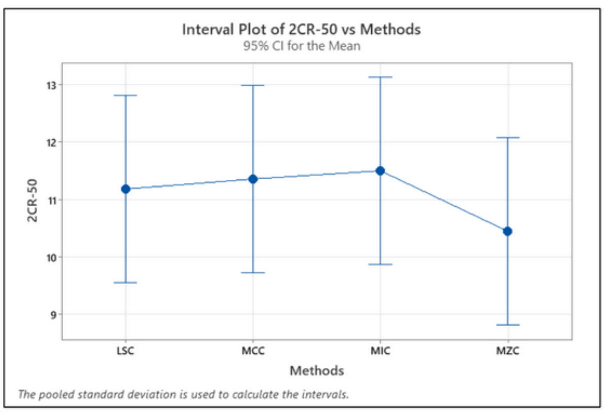
**Analysis of Variance**

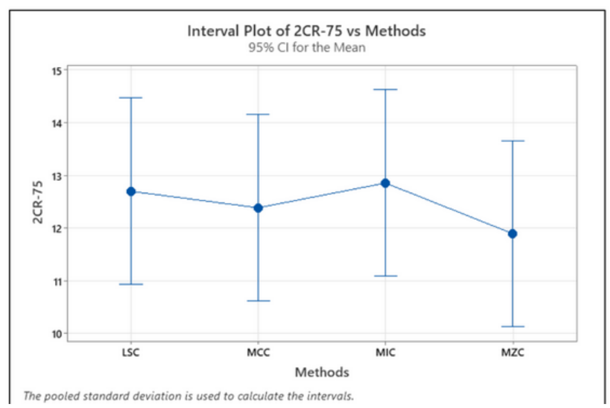
| Source | DF | Seq SS | Contribution | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|---|---|
| Methods | 3 | 14.82 | 1.05% | 14.82 | 4.939 | 0.31 | 0.820 |
| Error | 87 | 1398.89 | 98.95% | 1398.89 | 16.079 | | |
| Total | 90 | 1413.71 | 100.00% | | | | |

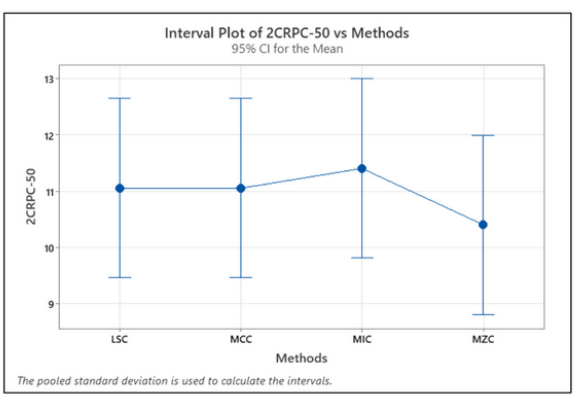
One-way ANOVA: No filter versus Methods

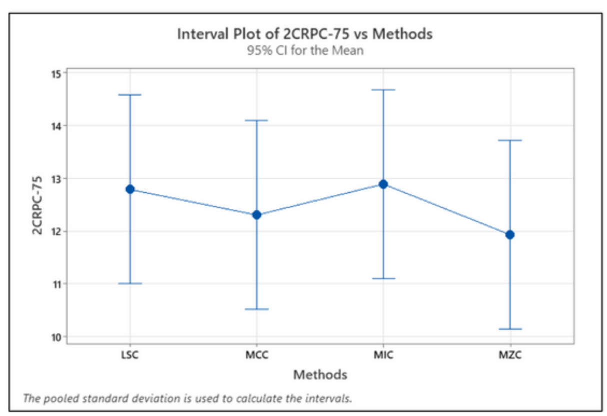
**Analysis of Variance**

| Source | DF | Seq SS | Contribution | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|---|---|
| Methods | 3 | 9.52 | 0.28% | 9.52 | 3.174 | 0.08 | 0.970 |
| Error | 87 | 3399.80 | 99.72% | 3399.80 | 39.078 | | |
| Total | 90 | 3409.33 | 100.00% | | | | |



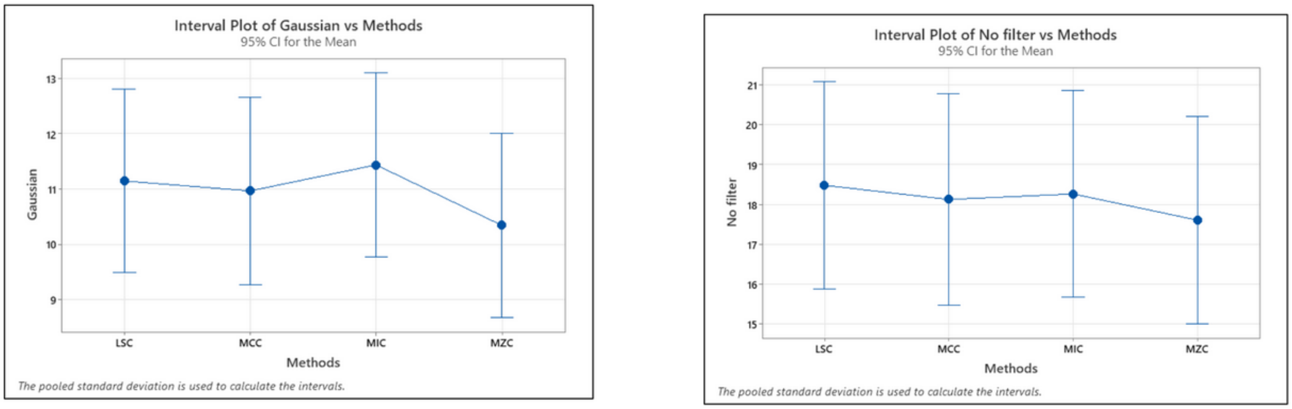



Figure 16. One-way ANOVA: Filters versus Methods

## V. RESULTS AND DISCUSSION

The experimental data revealed that the type of filter employed has a significant impact on the values of roundness error. In case of no filters, the measured value of the roundness error increases significantly, as shown Table 2 and Figure 15. Theoretical and experimental values of RONt using 2CR50, 2CRPC50 filters are less than 2CR75 and 2CRPC75 filters respectively, as shown in Table 2 and Figures 7, 10,11 and 15. From Figures 15 and Tables 2 values of RONt using Gaussian filter is less than 2CR75 and 2CRPC75 filters. The RONt values utilizing 2CR50 and 2CRPC50 filters are lower than the Gaussian filter when the ratio $\frac{\lambda}{\lambda c}$ is less than 1, whereas RONt values using Gaussian are less than 2CR50, 2CRPC50 filters when the ratio $\frac{\lambda}{\lambda c}$ is more than 1, as shown in Table 2 and Figure 8. From ANNOVA analysis the method used in RONt evaluation does not affect the relationship between the above-mentioned filters, but rather affects their values Figure 16 and Table 3.

## VI. CONCLUSION

Through the practical and theoretical study of filters, the following can be concluded:

1- The use of filters affects, to a large and varying degree the final values of the roundness error according to the type of filter used.
2- The RONt error value obtained from using the 2CR50 filter is lower than that obtained from using 2CR75 filter regardless of the method used in estimating the RONt values.
3- The RONt error value obtained from using the 2CRPC50 filter is lower than that obtained from using 2CRPC75 regardless of the method used in estimating RONt values.
4- The relationship between Gaussian, 2CR50 and 2CRPC 50 filters depends on the following ratio$\frac{\lambda}{\lambda c}$.
5- The method used in RONt evaluation (LSC, MZC, MCC and MIC) does not affect the relationship between the filters, but rather affects their values.

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"There are no potential conflicts of interest concerning the research, authorship or publication of his article".

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***Title Arabic:***

**المرشحات المستخدمة لتقييم خطأ الاستدارة: دراسة مقارنة عملية**

***Arabic Abstract:***

**تعتبر المرشحات (الفلاتر) خطوة ضرورية في قياس الاستدارة حيث يؤثر نوع المرشح على قيمة خطأ الاستدارة. هناك العديد من الدراسات التي تشرح الفروق بين المرشحات نظريًا وقليل منها درس الاختلافات عمليًا. لذلك تهدف هذه الدراسة إلى تقديم مقارنة عملية بين المرشحات التالية**

**2CR50 , 2CR75، 2CRPC50، 2CRPC75، Gaussian, no filter عملية القياس لعدد ٢٥ عينة تمت باستخدام جهاز (RA-120 ROUNTEST ) مع الطرق المرجعية التالية (LSC, MZC,MCC,MIC) و أظهرت الدراسة أن المرشحات لها تأثير واضح على قيم خطأ الاستدارة (RONt) وأن المرشحات 2CRPC50 و 2CR50 و Gaussian تعطي أدنى قيم لـ (RONt) مقارنة بالآخرين وأن العلاقة بينهما تعتمد على العلاقة بين الطول الموجي λ والقطع في الطول λc أيضًا من تحليل ANOVA ، لا تؤثر الطرق LSC و MZCو MIC و MCC المستخدمة في تقييم RONt على العلاقة بين المرشحات المذكورة أعلاه ، بل تؤثر على قيمها.**