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COMPARISON OF VERTICAL DISTANCE AND SLIDING WINDOWS METHOD IN BRASS PLATED TIRE STEEL CORD (BPTSC) DIAMETER MEASUREMENT

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Abstract. *Nowadays, the researchers are still examining the quality of Brass Plated Tire Steel Cord (BPTSC). The waveform is intentionally made to have a pattern as the base of the winding up of the tiring process. Indonesia Bekaert Company has a standard measurement of BPTSC diameter. The measurement process is manually worked by staff. The problem came on the difficulty of quality detection on BPTSC. One of the standard measurements is the diameter of the BPTSC. In this research, three automatic approaches are proposed, namely vertical distance, minimum sliding window, and average sliding window. These methods are supported by image processing to detect the edge of the image cord. All methods were conducted by modifying the pixel distance theory. The result shows that the vertical distance method has an average difference of about 0.0037 mm compared to manual measurement with no misclassified of BPTSC grade. For the sliding window method, the minimum method has a different value of about 0.0026 mm but with one misclassified grade. The best result for diameter distance is coming from the third method that uses an average of sliding window distances of about 0.0023 mm without misclassified.*
Keywords: Brass-plated tire steel cord, Diameter, Pixel distance, sliding window, Image processing

1. **Introduction.** Along with the development of automotive industry technology, today is overgrowing so that competition between the world's automotive manufacturers occurs so tight in creating products that can meet market tastes and be able to influence consumer decisions in making purchases. Major automotive manufacturers in the world who continue to develop their products such as Toyota are the largest car manufacturer in the world ranging from trucks, passenger cars and others. Indonesia Bekaert Company is one of the companies that produce raw materials for wire used to support tires in heavy vehicles and passenger vehicles, which are referred to as Brass Plated Tire Steel Cord (BPTSC). The development of the world tire industry has now reached the innovation in the form of steel fibres. BPTSC production has a change in wave shape in order to get the right precision during the wire winding process, so it requires accuracy in shaping

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the wave size of the BPTSC [1]. The characteristics of BPTSC have waves that function as shafts for wire coils. The need for quality control to maintain the quality of the current wire needs to be improved so that the quality of the tires produced is good, but currently, the Indonesia Bekaert Company still uses manual techniques to measure wire quality, one of which uses a wire diameter indicator [2], and it is difficult for inspection staff to detect the quality of brass plated tire steel cord straps [3]. Manually counting makes quality control impossible in real time, which can cause losses if there is a size bias during production. Wire in output that can reach 1 km in length can be wasted.

Therefore, we need a method that can help the process of quality control in real time. Image processing is a method that can solve these problems. The camera can be mounted in front of the wire directly produced. Thus, early warning can be applied to the production process so that it will reduce the value of losses due to delays in detecting the quality of the brass-plated wire that is Not Good (NG). Thus, this study proposed a method that can calculate one indicator of brass-plated wire quality, namely wire diameter. There are two approaches used, namely vertical distance and sliding window. The second method produces a distance value which is the diameter of the wire. The vertical distance method draws straight lines on the brass-coated bin axis, and then moves on the x-axis to find distances at different points. While the sliding window method does not only run on the x-axis, it uses windows to look for other positions as a distance comparison. They are using statistical calculations average and minimum to find the distance (diameter) with the sliding windows method. In the second part, the proposed method used in this research will be discussed, namely vertical distance and sliding window. Continued in the third part, the evaluation results of the proposed method for discussion will be presented. Finally, the last part gives concluding remarks and future research.

2. **Methods.**

This study conducted trials on 29 samples of brass plated tire steel cord with diameter measurement techniques between pixel distance and sliding windows. To find out the results obtained from the results of measurement techniques, the average results of each sample are calculated by the block diagram representation as shown in Figure 1 which is the model of this research [4,5]. This model is designed based on the company's core business processes.

The above method is divided into two stages. The first phase is taking pictures or often called the preprocessing phase, using computer equipment, digital microscopes, and the addition of LED lights for lighting. The second phase is the phase where the image that has been changed to grey is measured in diameter with two techniques, including pixel distance and sliding windows with three methods of approach. Although the technology can be particularly useful as a measuring tool for BPTSC as part of the measurement accuracy challenge, this technology can also function as part of a practical solution for the challenging digitalization project of the Indonesia Bekaert Company [6]. The features required from this design include: portability, cost-effectiveness, and a user-friendly graphical interface [7].

2.1. **Upper and lower sides.**

Brass plated tire steel cord objects have two sides that form waves, where the first side of brass plated tire steel cord is called the upper point and the second side is called lower. The formation of the top and bottom sides of the brass plated tire steel cord object will continue according to the size of the spindle. Figure 2 shows the form of brass plated tire steel cord in the simulation image, and Figure 3 shows the simulation of brass plated tire steel cord production.

Thirty-three machines operate to roll and spin brass steel tires. Brass steel tire cord accuracy test has stages, 1) Sampling, 2) Samples that have been obtained are then taken to the laboratory and the third stage. The process of measuring the diameter, amplitude, and wavelength is carried out using conventional measuring devices. Each requires a long

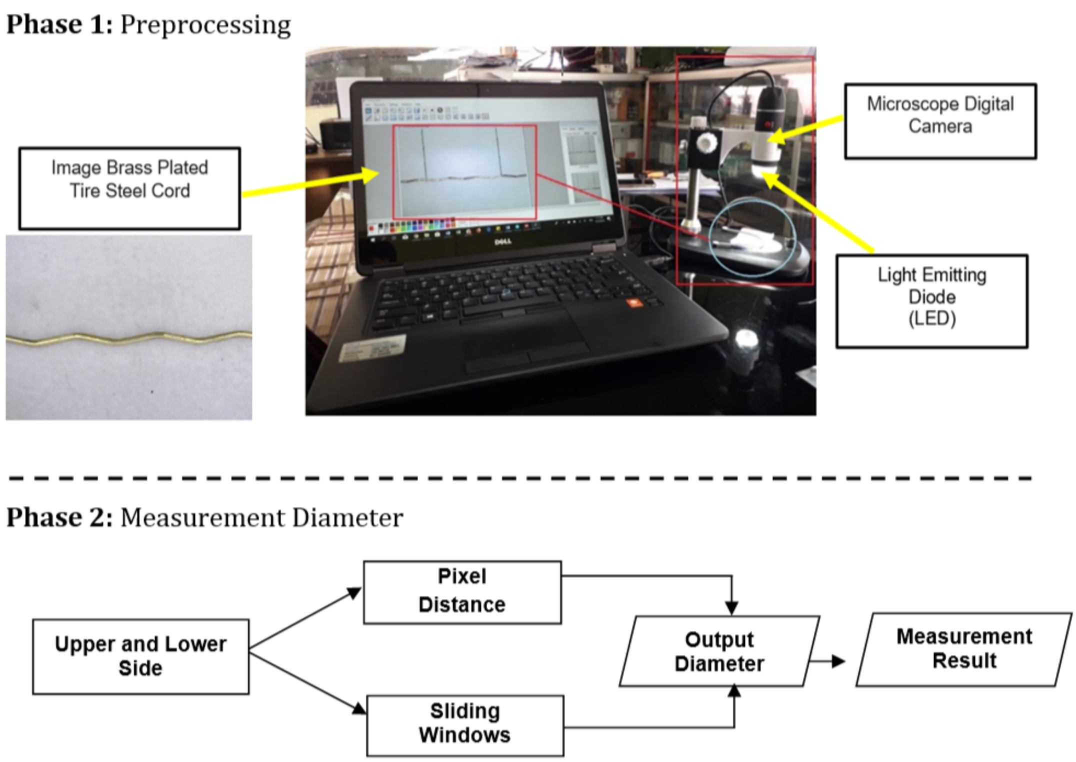

Figure 1. Overview of research proposed method

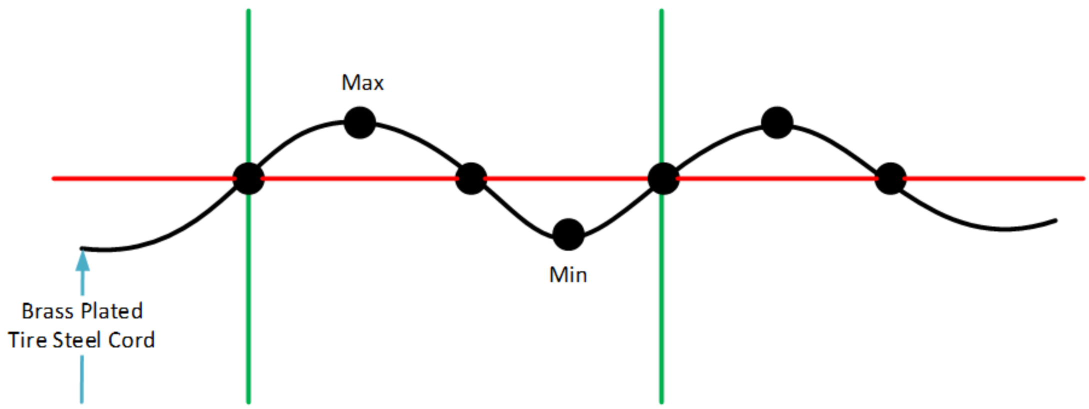

Figure 2. The brass plated tire steel cord in the simulation

time and high accuracy. The risk of errors in this process is very possible if there is such a thing the production process will be repeated by rearranging the machine [7].

2.2. **Pixel distance.** The central problem in image recognition in computer vision is to determine the distance between images and to determine the distance of the image so that it intuitively makes sense [8]. Estimating distance measurements in digital images is useful in various forms of representation and forms a recognition task [9].

Diameter: 1st Method

The first method for finding the BPTSC diameter is the vertical distance. Finding the distance between points on the y axis or called the vertical distance that is taking edge at the lowest point of BPTSC with the top point of BPTSC. Then the value of the two edges is drawn straight so that there is an x value that is always the same, and then on the same line the distance line is drawn from both. Measurement of brass plated tire steel cord is simulated with the formula shown in Figure 4.

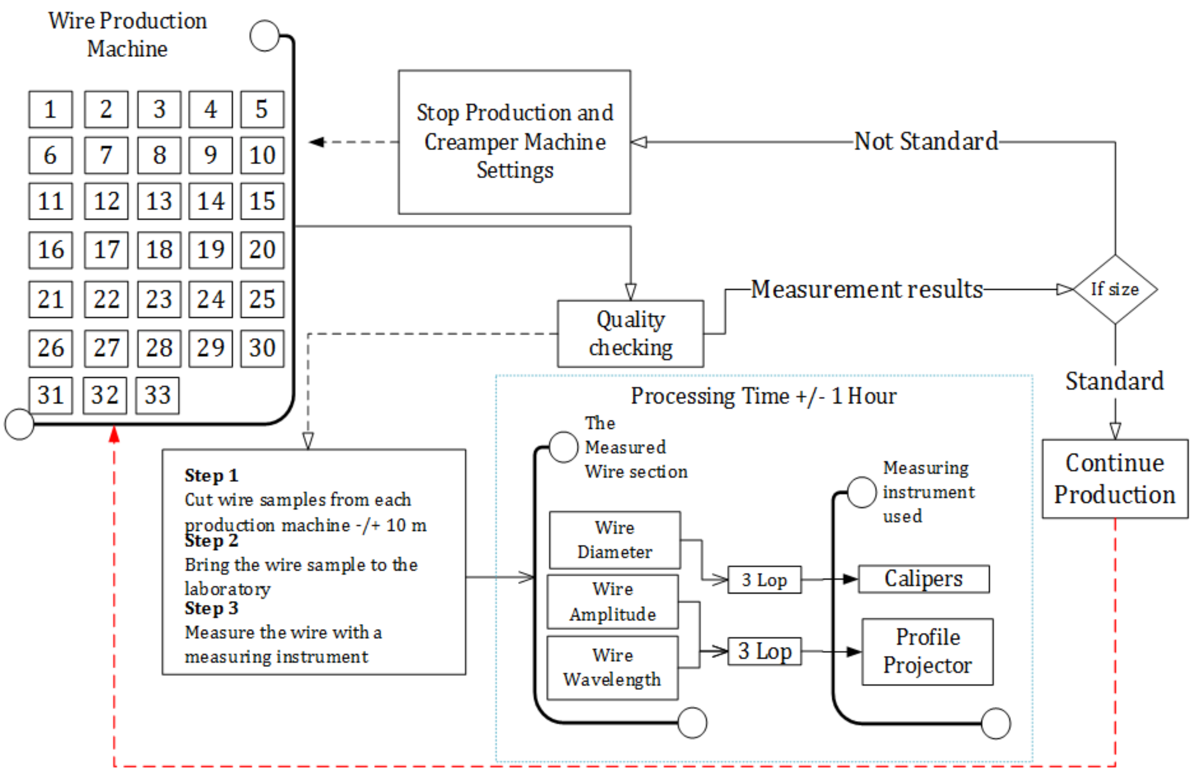

FIGURE 3. Simulation of brass plated tire steel cord production

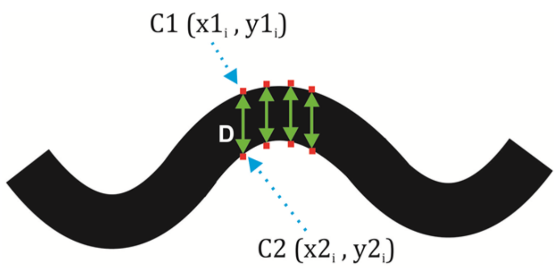

FIGURE 4. Measurement simulation with pixel distance

Algorithm finding diameter by *y-axis* **is**

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input: image I, calibration C
output: distance D
(Note that *follow the surface of* I *to get the top* $(C1(x, y))$ *and bottom* $(C2(x, y))$ *surface*)
for each edge $C1(x, y)$ and $C2(x, y)$ **in** I **do**
if $I(x, y) \leftarrow 1$

$$D_i \leftarrow |x2_i - x1_i| + |y2_i - y1_i|$$

find the distance by getting the **average** of D_i

$$D \leftarrow \frac{\sum_{I=1}^{n} D_i}{n}$$

find the **distance in millimeter** by multiplying distance D with calibration C value

$$D_m \leftarrow D \times C$$

return D_m

The algorithm of diameter measurement techniques using vertical distance, first is variable I is a binary image of BPTSC which is white, second is calibration with variable C is the pairing point that has been measured first, the value obtained from the calibration results is 2 cm which is then compared to the number of pixels on the camera so that when the image is taken at the same position the calibration value is used. In this algorithm the term top is $C1$ while the bottom is called $C2$, then for each BPSC edge measurements were taken and the average value was sought.

2.3. **Sliding windows.** The sliding window requires Ω(N) space considering increasing the order of values, where the oldest items in any window are minimum and must be replaced every time the window moves forward [10].

The sliding window method, a window of specified length, Len, moves over the data, sample by sample, and the statistic is computed over the data in the window [11]. The output for each input sample is the statistic over the window of the current sample and the Len − 1 previous samples [12]. In the first time step, to compute the first Len − 1 outputs when the window does not have enough data yet, the algorithm fills the window with zeros. In the subsequent time steps, to fill the window, the algorithm uses samples from the previous data frame. The moving statistic algorithms have a state and remember the previous data [13].

Diameter: 2nd Method

The second method for finding BPTSC diameters is to use sliding windows with the nearest distance method approach. As in the first method, there are top and bottom BPTSC with the terms $C1$ for top and $C2$ for bottom. The spreading of the points starts from the top position or $C1$ and then the x axis goes from one point to another following a white pixel or pixel which is 1 to search for the diameter value D. Measurement of brass plated steel tire cord is simulated with the formula shown in Figure 5.

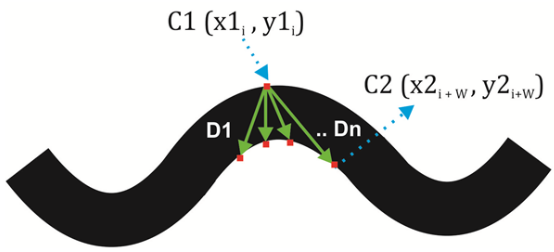

FIGURE 5. Measurement simulation with minimum sliding windows

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Algorithm finding diameter by nearest distance **is**

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input: image I, calibration C, window sliding w
output: D as distance
(Note that *follow the surface of* I *to get the top* $(C1(x,y))$ *and bottom* $(C2(x,y))$ *surface*)
define $w \leftarrow \{-3,-2,-1,0,1,2,3\}$
for each edge $C1(x,y)$ and $C2(x,y)$ **in** I **do**
  for each $C2(x_{i+w},y)$ **in** I **do**
    if $I(x,y) \leftarrow 1$

$$D_j \leftarrow \sum_{s=w}^{w} \left(|x2_{j+w} - x1_j| + |y2_{j+w} - y1_j|\right)$$

$$D_i \leftarrow \min_j D_j$$

find the distance by getting the **average** of D_i

$$D \leftarrow \frac{\sum_{I=1}^{n} D_i}{n}$$

find the **distance in millimeter** by multiplying distance D with calibration C value

$$D_m \leftarrow D \times C$$

return D_m

Diameter: 3rd Method

The third method for finding BPTSC diameters is to use sliding windows with the mean distance method approach. As in the first method, there are top and bottom BPTSC with the terms $C1$ for top and $C2$ for bottom. The spread of points starts from the top point or $C1$, and then the x axis goes from one location to another following a white pixel or pixel value of 1 to find the amount of diameter D. The results of the measurement look up the average cost. The measurement of brass plated tire steel cord is simulated with the formula shown in Figure 6.

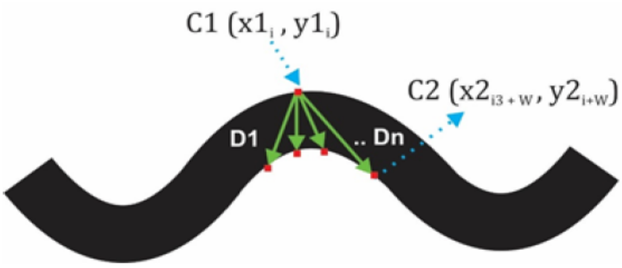

Figure 6. Measurement simulation with average sliding windows

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Algorithm finding diameter by mean distance **is**

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input: image I, calibration C, window sliding w
output: D as distance
(Note that *follow the surface of I to get the top* ($C1(x, y)$) *and bottom* ($C2(x, y)$) *surface*)
define $w \leftarrow \{-3, -2, -1, 0, 1, 2, 3\}$
for each edge $C1(x, y)$ and $C2(x, y)$ **in** I **do**
for each $C2(x_{i+w}, y)$ **in** I **do**
if $I(x, y) \leftarrow 1$

$$D_j \leftarrow \sum_{s=w}^{w} \left(|x2_{j+w} - x1_j| + |y2_{j+w} - y1_j|\right)$$

$$D_i \leftarrow \frac{1}{m} \sum_{j=1}^{m} D_j$$

find the distance by getting the **average** of D_i

$$D \leftarrow \frac{\sum_{I=1}^{n} D_i}{n}$$

find the **distance in millimetre** by multiplying distance D with calibration C value

$$D_m \leftarrow D \times C$$

return D_m

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3. **Result and Discussion.** We explain the process of measuring the diameter of the brass tire cord using industry standards with image processing techniques and MATLAB. Each result obtained from the measurement uses the three proposed approaches. BPTSC was tested by comparing standard production tables from Indonesia Bekaert Company. Table 1 shows the standard reference value of the company, Table 2 is a sample with the results of the diameter that has been measured using conventional techniques, and Table 3 shows measurements with digital image techniques.

In the table to improve accuracy, checking is 3 times the measurement. The specification is the standard brass plated steel tire cord that meets the criteria. It is explained about the wire section tested with minimum specifications, aiming at the target achieved and the maximum limit value defect or NG (Not Good). Overall, the current process is explained in Figure 2.

Table 1. Standard measurement value BPTSC

No	Item test	Result (mm)			Specification (mm)		
		1	2	3	Min	Aim	Max
1	Diameter	0.240	0.238	0.240	0.230	0.240	0.250
2	Wave amount	0.397	0.402	0.391	0.330	0.400	0.470
3	Wavelength	3.522	3.531	3.516	3.420	3.600	3.780

Table 2. Brass steel tire cord dataset using manual measurements by expert

No	Dataset	Diameter measurement
1	Image Brass Plated Tire Steel Cord 1	0.238
2	Image Brass Plated Tire Steel Cord 2	0.238
3	Image Brass Plated Tire Steel Cord 3	0.238
4	Image Brass Plated Tire Steel Cord 4	0.238
5	Image Brass Plated Tire Steel Cord 5	0.238
6	Image Brass Plated Tire Steel Cord 6	0.238
7	Image Brass Plated Tire Steel Cord 7	0.238
8	Image Brass Plated Tire Steel Cord 8	0.238
9	Image Brass Plated Tire Steel Cord 9	0.238
10	Image Brass Plated Tire Steel Cord 10	0.238
11	Image Brass Plated Tire Steel Cord 11	0.238
12	Image Brass Plated Tire Steel Cord 12	0.238
13	Image Brass Plated Tire Steel Cord 13	0.238
14	Image Brass Plated Tire Steel Cord 14	0.238
15	Image Brass Plated Tire Steel Cord 15	0.238
16	Image Brass Plated Tire Steel Cord 16	0.238
17	Image Brass Plated Tire Steel Cord 17	0.238
18	Image Brass Plated Tire Steel Cord 18	0.238
19	Image Brass Plated Tire Steel Cord 19	0.238
20	Image Brass Plated Tire Steel Cord 20	0.238
21	Image Brass Plated Tire Steel Cord 21	0.238
22	Image Brass Plated Tire Steel Cord 22	0.238
23	Image Brass Plated Tire Steel Cord 23	0.238
24	Image Brass Plated Tire Steel Cord 24	0.238
25	Image Brass Plated Tire Steel Cord 25	0.238
26	Image Brass Plated Tire Steel Cord 26	0.238
27	Image Brass Plated Tire Steel Cord 27	0.238
28	Image Brass Plated Tire Steel Cord 28	0.239
29	Image Brass Plated Tire Steel Cord 29	0.238
	Average	0.238

In Table 2, the BPTSC diameter measurements that have been carried out using manual techniques produce an average measurement value of 0.238 mm, where the results of these measurements are obtained from experts at Indonesia Bekaert Company.

In Table 3 the result of diameter measurement is got using manual techniques, then we conduct trials using image processing measurement techniques using the vertical distance and sliding windows method which uses the nearest distance and mean distance measurement approach.

Brass plated tire steel cord diameter measurements, can be presented in graphical form which can be seen in Figure 7.

Table 3. Brass steel tire cord dataset using image processing

Image	Vertical distance			Minimum sliding window			Average sliding window		
	Distance (mm)	Check*	Diff** (mm)	Distance (mm)	Check	Diff (mm)	Distance (mm)	Check	Diff (mm)
1	0.2446	TRUE	0.0066	0.2406	TRUE	0.0026	0.2407	TRUE	0.0027
2	0.2397	TRUE	0.0017	0.2355	TRUE	0.0025	0.2348	TRUE	0.0032
3	0.2449	TRUE	0.0069	0.2410	TRUE	0.0030	0.2407	TRUE	0.0027
4	0.2437	TRUE	0.0057	0.2404	TRUE	0.0024	0.2403	TRUE	0.0023
5	0.2479	TRUE	0.0099	0.2451	TRUE	0.0071	0.2460	TRUE	0.0080
6	0.2441	TRUE	0.0061	0.2402	TRUE	0.0022	0.2378	TRUE	0.0002
7	0.2430	TRUE	0.0050	0.2388	TRUE	0.0008	0.2391	TRUE	0.0011
8	0.2441	TRUE	0.0061	0.2406	TRUE	0.0026	0.2392	TRUE	0.0012
9	0.2417	TRUE	0.0037	0.2370	TRUE	0.0010	0.2372	TRUE	0.0008
10	0.2399	TRUE	0.0019	0.2367	TRUE	0.0013	0.2379	TRUE	0.0001
11	0.2448	TRUE	0.0068	0.2420	TRUE	0.0040	0.2390	TRUE	0.0010
12	0.2409	TRUE	0.0029	0.2376	TRUE	0.0004	0.2381	TRUE	0.0001
13	0.2343	TRUE	0.0037	0.2307	TRUE	0.0073	0.2318	TRUE	0.0062
14	0.2378	TRUE	0.0002	0.2342	TRUE	0.0038	0.2364	TRUE	0.0016
15	0.2334	TRUE	0.0046	0.2298	FALSE	0.0082	0.2318	TRUE	0.0062
16	0.2372	TRUE	0.0008	0.2337	TRUE	0.0043	0.2346	TRUE	0.0034
17	0.2416	TRUE	0.0036	0.2379	TRUE	0.0001	0.2380	TRUE	0.0000
18	0.2446	TRUE	0.0066	0.2409	TRUE	0.0029	0.2410	TRUE	0.0030
19	0.2360	TRUE	0.0020	0.2326	TRUE	0.0054	0.2300	TRUE	0.0080
20	0.2426	TRUE	0.0046	0.2386	TRUE	0.0006	0.2385	TRUE	0.0005
21	0.2403	TRUE	0.0023	0.2366	TRUE	0.0014	0.2373	TRUE	0.0007
22	0.2396	TRUE	0.0016	0.2374	TRUE	0.0006	0.2384	TRUE	0.0004
23	0.2384	TRUE	0.0004	0.2363	TRUE	0.0017	0.2376	TRUE	0.0004
24	0.2417	TRUE	0.0037	0.2395	TRUE	0.0015	0.2411	TRUE	0.0031
25	0.2413	TRUE	0.0033	0.2387	TRUE	0.0007	0.2396	TRUE	0.0016
26	0.2392	TRUE	0.0012	0.2363	TRUE	0.0017	0.2372	TRUE	0.0008
27	0.2408	TRUE	0.0028	0.2376	TRUE	0.0004	0.2336	TRUE	0.0044
28	0.2402	TRUE	0.0012	0.2374	TRUE	0.0016	0.2376	TRUE	0.0014
29	0.2383	TRUE	0.0003	0.2353	TRUE	0.0027	0.2360	TRUE	0.0020
	Average		0.0037	Average		0.0026	Average		0.0023

Note: * The value is the comparison of image processing result with standard measurement value (0.23-0.250 mm).
** The difference of image processing result with manual measurement result (data ground truth).

After measuring using the image processing technique with the vertical distance method and the two sliding windows method approaches, the next in Table 3 obtained the average value difference with manual measurements where the vertical distance method got a value of 0.0037 mm, sliding windows with the nearest distance or minimum sliding windows approach to obtain a difference value of 0.0026 mm. In contrast, the results of measurements using average distance receive an average value of 0.0023 mm.

4. Conclusions.

Two methods, that is, vertical distance and sliding windows are used in measuring BPTSC diameters using digital images, so both methods are considered as differentiators in determining the best diameter measurement method. Image processing techniques using the vertical distance method and the two sliding window approaches,

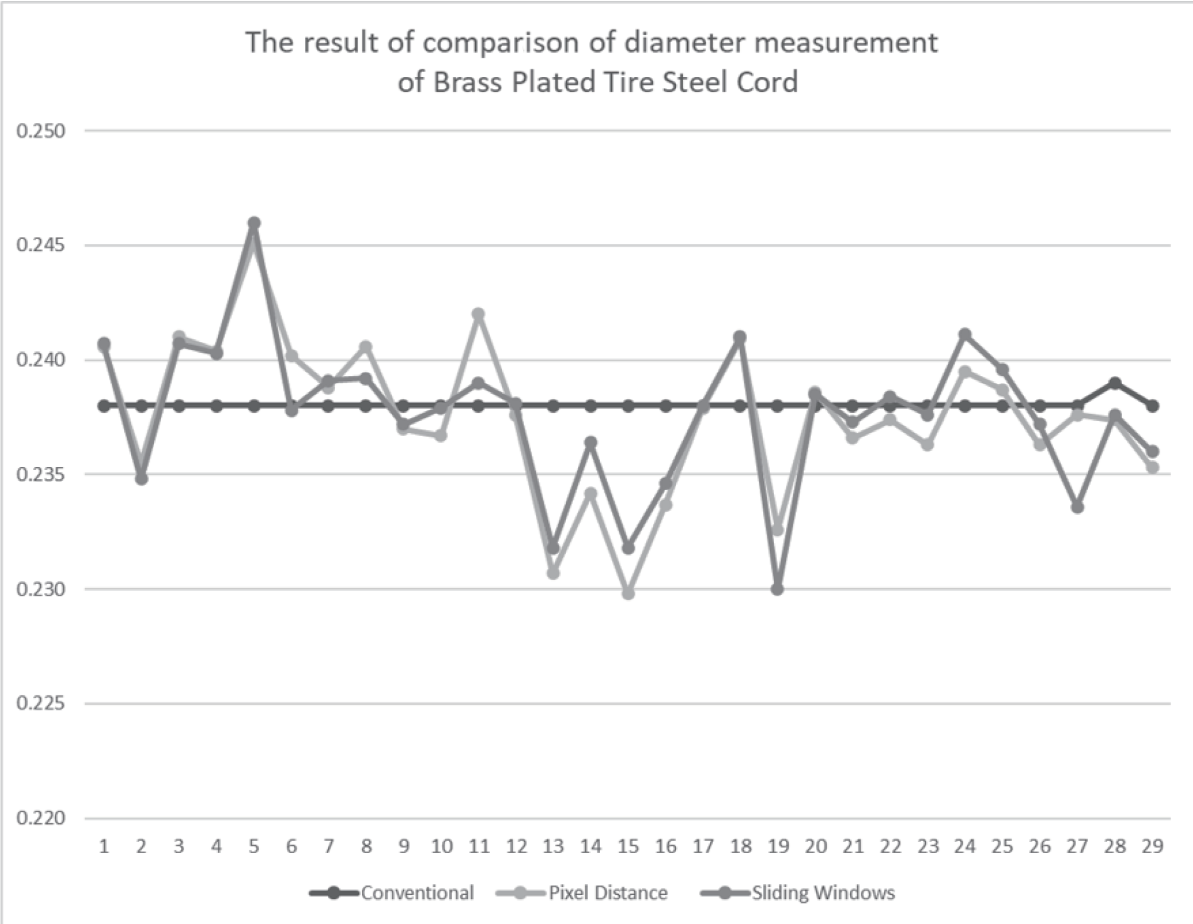

Figure 7. The results of comparison of diameter measurements of brass plated tire steel cord

then in Table 3 we get the difference in average values with manual measurements where the vertical distance method gets a value of 0.0037 mm, the sliding window with the closest distance to the distance or the minimum sliding window approach to get the different value of 0.0026 mm. Conversely, the results of measurements using average distance receive an average value of 0.0023 mm. The accuracy of the two methods in measuring BPTSC diameter is considered quite good. Still, the best method in this comparison is the sliding window with the average distance method approach. For the future, this research will continue by applying this method in real time using video settings in the industry.

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