Quantitative Post-Processing Module of Online Automatic Image Inspection for Inner Bubble Defects in a Tire

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Abstract. In tire manufacture processing, there are six main procedures including mixing, extruding, calendaring, cutting, building, and inspection. The ripened rubber is wrapping on the steel cord, ply, and different materials in the calendaring processing. When the manufacture processing is completed, the specifications of the tire including profile, dimension, intensity and defect inspection etc. must be verified. The processing of defect inspection is aimed to ensure whether there have been defected inside the tire, to avoid the influence of the durability and safety. Currently, the determinations of defect and its dimension of the tire are detected by defect inspection machine. And the results of the defect inspections can be determined only by the operators, according to self-experience. For this reason, the determination of the tire defect is not a kind of absolute inspection based on the same standard. Therefore, in this investigation, the defect inspection machine and the defect inspection program are combined for the automatic tire defect detection.

To verify the Accuracy and the comparison experiments with defect inspection machine have also been carried out. According to the experiment results, the accuracy rate of the proposed measurement system is about 85 % (samples are more than 5000 images) and the maximum deviation between this system and reference system is 5 mm.

Introduction

Tires belong to one of the most important expendables in car industry. Thus, the quality of tires influence driving safety. It is indispensable that how tire manufacturing industry assures stable qualified products and remains high production capacity at the same time. Tire’s quality and quantity are affected by operator’s experiences and manufacturing technology. As a result, introducing automatic inspection technology into tire manufacturing processes is able to improve both tires’ quality and quantity.

After manufacturing processes have been completed, the specifications of the tire profile, defect, and balance etc. must be inspected. The tire profile can be detected by laser displacement sensor or machine vision. The steel cord dimension and arrangement can be inspected by x-ray machine. Nevertheless, defects inside the tires, which cannot inspected by x-ray machine. Therefore, they must be inspected by technology of laser interferometry, such as speckle interferometry, digital holography and etc.

Principle of Measurement

Define the Parameters of Bubble

In this investigation, the bubble dimension and position are inspected by the self-developed detection module. The bubble has three types, including type 1, type 2, and type 3. The length and width of bubble are horizontal and vertical-directed. (Table 1)
Table 1. Inspection type.

| Type   | Shape   | Dimension |
|--------|---------|-----------|
| Type 1 | ![Image](image1) | ![Image](image2) |
| Type 2 | ![Image](image3) | ![Image](image4) |
| Type 3 | ![Image](image5) | ![Image](image6) |

**Inspect Manners of Bubble**

The inspection items contain tread images and sidewall images on tire, the defects on tread image were calculated by standard deviation of gray value. To reduce the measurement times and the inaccuracy rate of sidewall image, the following steps have to be done: Firstly, define the inspection range by interference of sidewall profile. Secondly, exclude interference from images by low gray value. Finally, determine defects on inspection range by standard deviation of gray value. When standard value was larger than thresholds, the position of bubble would be expressed in rectangle.

![Image](image7) ![Image](image8)

**Define the Inspection Range**

Inspection images contain one tread and two sidewalls. Inspection range is full inspection on tread images while the sidewall images include Conveyor and sidewall. Hence, the experiment has to determine the inspection range by least square fitting of circles.
Measure the Bubble

The bubble’s position is marked by rectangle and its size is calculated through the maximum Vertical and horizontal rectangle number. Then, multiply by resolution is bubble’s length and width.

\[ V = R_y \times w \times e \] (1)
\[ H = R_x \times h \times e \] (2)

\( V \) is defect’s length. \( H \) is defect’s width. \( R_y \) is vertical rectangle number. \( R_x \) is horizontal rectangle number. \( h \) is horizontal pixel. \( w \) is vertical pixel. \( e \) is resolution.

Measurement System

The system contains the measurement machine, sensor, and inspection software. Two cameras, a conveyor, Illumination module and computer are included in inspection machine. Tires will be transported to measurement machine by conveyor. After that, images will be taken by cameras. The main function of sensor signal is starting inspection software.

![System of measurement diagram]

Figure 3. System of measurement.

Accuracy and Measurement Result

To verify the Accuracy with defect inspection machine have also been carried out. According to the experiment results, the accuracy rate of the measurement system is about 85 % (samples are more than 5000 images).

In order to verify the measurement function (length and width) of self-developed module, this research compared the measurement results of the length and width of bubbles between the Measurement machine and self-developed module. Measurement machine inspected a tire 10 times and produced different image results. The results refer to figure 4 and figure 5. Measuring errors refer to figure 6 and figure 7.

Based on analysis of accuracy rate, the main reason is that inspection range is not suitable for every type of sidewalls. Therefore, the interference was misjudged as bubble.

![Measurement result graph]

Figure 4. Measurement result.
Conclusions

This study aims to enhance the performances of the automatic defect inspection system. The results of this investigation can be summarized as listed below:

1. The inspection module system was structured by machine vision. The measurement parameter contains defect’s position and dimension.
2. With aid of this developed processing module, the same measurement standard can be realized and the inspection error can be significantly minimized.
3. Based on the experiment results, the accuracy rate of the proposed measuring module system is about 85 % and the maximum deviation between this system and reference system is 5 mm on the same samples.
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