~~Air Conditioning Compressor~~ Air Leak Detection in Air Conditioner Compressors ~~by~~ using Image Processing Techniques ~~for Industrial Applications~~

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Abstract: Ideally, an air conditioner compressor should not have air leakages. However, poor inspection techniques can allow for defects to pass through, which can cause air leakages in compressors. This ~~This~~ paper presents a method to detect air leakage ~~of~~ in an air ~~conditioning~~ conditioner compressor using image processing techniques. ~~Quality of air conditioning compressor should not have air leakage.~~ In order to ~~To test~~ inspect an air ~~conditioning~~ conditioner compressor for air leakage~~leak~~, air is pumped into ~~a~~ the compressor, which is ~~and~~ then submerged into ~~the~~ a water tank. If air bubbles are observed ~~occurs~~ at the surface of the ~~air conditioning~~ compressor, it implies that air leakage exists, and the ~~that leakage~~ compressor must then be returned for maintenance. In this ~~work~~study, a new method to detect air leakage and ~~search~~ identify the leakage point with high accuracy, speed, and reliability~~, fast, and precise processes~~ was proposed. ~~In a preprocessing procedure to detect the air bubbles, threshold and median filter techniques have been used.~~ CConnected-component labelling ~~technique~~ and blob analysis are ~~is~~ used to detect ~~the~~ air bubbles ~~while blob analysis is searching technique to~~ and analy~~s~~ze the group of the air bubbles in sequential images, respectively. The experiments ~~are tested~~ evaluate ~~with~~ the proposed algorithm's ability to determine the leakage point ~~of~~ in an air ~~conditioning~~ conditioner compressor. The location of the leakage point ~~was~~ is presented as a coordinated point. The results demonstrate~~d~~ that the leakage point ~~during~~ observed during the process ~~could~~ can be accurately detected~~.~~; ~~The~~ the estimation point ~~had~~ has an error less than 5% compared to that of the ~~the~~ real leakage point.

1. Introduction

The air conditioner compressor is a major component in air conditioners and refrigerators. Air ~~conditioning~~ conditioner compressor manufacturing has four main subprocesses: (trimming a metal chassis, installing electrical and mechanical components into a compressor, assembling the chassis ~~assembly,~~ and inspecting quality ~~inspection).~~ ~~Air conditioning compressor was a major part in air conditioning and refrigerator manufacturers.~~ During the ~~the~~ compressor manufacturing process, incomplete welds ~~process~~ may cause very small leaks that are difficult to ~~hard~~ identify ~~to be detected by~~ manually~~human~~. Thus, ~~B~~before shipping the air conditioner ~~conditioning~~ compressor, ~~out of the manufacture~~ the assembled compressor ~~will be~~ is inspected to check ~~the air conditioning compressor quality by~~ for air leakage via detection and by searching for leakage points. Manual l~~L~~eakage detection ~~by human causing~~ has a high possibility of error, and therefore, ~~therefore~~ computer vision is implemented to reduce the cost~~s~~ of quality inspection~~s~~ ~~compressors~~ and increase~~s~~ the ~~the~~ accuracy, ~~rapid~~ speed, and reliability of the ~~quality inspection~~ process. ~~A.~~ Rosenfeld and ~~J. L.~~ Pfaltz [1] ~~were~~ proposed a ~~connected~~ connected-component labelling search for the connected pixels of object in a digital image ~~[1].~~ ~~W.~~ Burger and ~~M. J.~~ Burge [2] ~~were~~ proposed a bounding box and centroid calculation of binary regions called blob analysis ~~[2].~~ In ~~this~~ this study~~work~~, ~~the connected~~ connected-component labelling and blob analysis were ~~chosen~~employed for detection; the proposed~~. The~~ inspection method can be applied to other closed tank products ~~that air bubbles~~ where leakage ~~is needed to be reduced~~ detection and measurement ~~dis~~ required.

2. Air conditioner ~~Conditioning C~~compressor ~~I~~inspection ~~T~~test ~~S~~setup

Insert Figure 1 here

~~Insert figure 1 here~~

~~In figure~~Figure~~.~~ 1 presents ~~,~~ a schematic ~~diagram~~ of the ~~air conditioning compressor~~ inspection test setup ~~is presented~~. ~~A~~ The compressor is filled with ~~is~~ compressed air ~~with~~ under a pressure of 5 bars ~~from the air pump~~. ~~And t~~Then, the compressor is submerged into the water in a transparent glass tank, and its position is fixed ~~fix the test compressor~~ at the middle position of the glass tank. Sequential images are ~~taken~~ captured ~~by~~ using a video webcam (OKER HD model 386). A computer with ~~the~~ an image processing algorithm was used to record and shows the inspection result ~~in~~ on a live video.

~~In this paper, we propose a new method to detect leakage and search leakage point is to improve the accuracy, fast and precise inspection process, better than human inspection. If compressed air in a compressor so that leakage~~

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Commented [A4]: I have added some background to ease the reader into the study.

Commented [A5]: I understand that this is the objective of your study.

Commented [A6]: Note that this term is generally referred to as "Air conditioner compressor"

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Recommendation: Please briefly mention how you found the real leakage point.

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Air leakage detection, Connected-component labelling, Blob analysis, Leakage point identification, Compressor inspection.

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~~was occurred. Air bubbles escaped from leakage point and float over to surface the water due to air pressure within a compressor.~~

~~In~~ Further, to improve the visibility of air bubbles, ~~a compressor inspection test setup, the~~ a light source was installed above the compressor, and black curtains were used ~~to so that air bubbles obviously are seen in white color. prevent external light noise~~ ~~All curtain scenes are black to prevent external light noise~~ [3], ~~as shown Fig. 1~~.

~~Insert figure 1 here~~

~~In figure. 1, a schematic diagram of the air conditioning compressor inspection test setup is presented. A compressor is compressed air with under pressure of 5 bars from the air pump. And then submerge into the water transparent glass tank and fix the test compressor at middle position of the glass tank. Sequential images are taken by a video webcam (OKER HD model 386). A computer with the image processing algorithm was used to record and shows the inspection result in live video.~~

3. Image ~~P~~processing ~~A~~algorithm

The ~~i~~Image sequences acquired from ~~a~~ the video camera ~~is~~ are stored in bitmap files ~~;~~, these files are ~~and they were~~ processed before the initial image processing ~~to detect leakage by~~ using connected component labelling ~~technique~~ and ~~search leakage point by~~ blob analysis to detect leakage and identify the leakage point, respectively ~~technique~~.

3.1. ~~3.1~~ Connected ~~-~~Component Labelling ~~Technique~~

~~Connected~~ Connected-component labelling is an image processing technique ~~used to~~ that is used to detect a connected region in binary digital images [4,5]. Connectivity is determined by the medium; image graphs, for example, can be 4four-connected or ~~8~~eight-connected [2].

~~3.1.~~3.2. ~~3.2~~ Blob Analysis Technique

Blob analysis is an image processing technique used to detect and measure blobs in images, ~~as and make selected measurements of those blobs~~ shown in Fig. 2. The c~~C~~entere of mass (or centere of gravity ~~or~~ /centroid) of a blob (x_c, y_c) ~~is~~ is calculated ~~as~~ by

$$x_c = \frac{1}{N}\sum_{i-1}^{N} x_i,$$

$$y_c = \frac{1}{N}\sum_{i-1}^{N} y_i$$

~~(1) N N 1 1~~
~~$xc = \sum xi$, $yc = \sum yi$~~
~~$i=1\ N\ i=1$ (1) N~~

where N is the number of pixels in the ~~BLOB~~ blob and x_i and y_i are the x and y coordinates of the N pixels, respectively.

The b~~B~~ounding box of a blob is the minimum rectangle ~~which~~ that contains the blob~~;~~. ~~It~~ it is defined by going through all pixels for a blob and finding the four pixels with the minimum x-value, maximum x-value, minimum y-value, and maximum y-value, respectively. From these values, the width of the bounding box is given as x_{max}—x_{min} and the height as y_{max}—y_{min}. A bounding box can be used as the region of interest. The c~~C~~entere of the bounding box is calculated as

$$x_{bb} = x_{\min} + \frac{x_{\max} - x_{\min}}{2} = x_{\min} + \frac{x_{\max}}{2} - \frac{x_{\min}}{2} = \frac{x_{\min} + x_{\max}}{2} \quad (2)$$

$$y_{bb} = y_{\min} + \frac{y_{\max} - y_{\min}}{2} = y_{\min} + \frac{y_{\max}}{2} - \frac{y_{\min}}{2} = \frac{y_{\min} + y_{\max}}{2} \quad (3)$$

Insert Figure 2 here

~~**Insert Figure 2 here**~~

~~Generally~~In general, the proposed algorithm can be summarized as follows:

1. Initialize the threshold for white pixel detection and number of initial frames.
2. Colour images ~~are~~ acquired from a video camera are converted to binary images to separate the ~~interest~~ interest objects from ~~a~~ the background. Binary images are filtered ~~a~~ for noise ~~by~~ using a median filter.
3. ~~Use~~ The connected component labelling technique (8-connectivity) is used to detect a group of white pixels ~~which~~ that ~~is~~ are the air bubbles of interest~~,~~. ~~we~~ We implement the two-pass algorithm that iterates through binary data in an image.
4. ~~Use~~ Bblob analysis ~~technique~~ is used to detect blobs in ~~an~~ the image, and ~~we will get~~ a centroid of blob and value of bounding box are obtained.
5. Compare the y_c of ~~a~~ the blob with the previous frame and add a ~~make a~~ marker at this blob if y_c has a value greater than ~~a~~ the previous frame. Display the result.
6. Check for the end frame.

The above procedure can also be described by the flowchart shown in Fig. 3.

Insert Figure 3 here

~~**Insert Figure 3**~~

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Recommendation: Please talk about the method you used for this conversion.

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4. Experimental Rresult

Figure 3 shows ~~a~~ the colour image captured from the ~~a~~ video camera and ~~a~~ the pre-processed image. The experiments were performed using ~~a computer programming compatible~~ a ~~with~~ laptop with CPU Intel(R) core (TM) 2 Duo P7350. The original image size ~~is~~ was 800 × 600 pixels.

Insert Figure 4 here

~~**Insert Figure 4**~~

Figures 5(a)–5(c) shows the red rectangle marker of the leakage point after processing in ~~difference~~ different frames in image sequences to detect the first point to search by the connected component labelling technique and blob analysis technique, respectively.

Insert Figure 5 here

~~**Insert Figure 5**~~

5. Conclusion

A new inspection method to detect air leakage ~~area~~ and to search for the leakage point in air conditioner compressors with high accuracy, ~~fast~~speed, and ~~reliabl~~reliability~~e inspection process~~ was proposed. The method can be used to detect air bubbles that escape from an air conditioner ~~conditioning~~ compressor. ~~A simple image processing algorithm consists of connected component labeling technique and blob analysis technique.~~ The results demonstrated that the proposed method can identify ~~the~~ air leakage in an air conditioner~~conditioning~~ compressor effectively ~~within~~ with an accuracy of 95%. The proposed method provides ~~benefits~~ advantages ~~for industrial application~~ such as cost reduction, reliability, and improvement of the manufacturing process and ~~and value treatment~~ maintenance of products.

6. Acknowledgments

Acknowledgements should be placed after the conclusion and before the references section. This is where reference to any grant numbers or supporting bodies should be included. The funding information should also be entered into the first submission step on Manuscript Central which collects Fundref information [4].

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7. References

An average research paper should reference between 20 and 30 works, the bulk of which should be recently published (i.e. within the last five years) leading-edge articles in the field, preferably from top journals or conferences. You should compare your own findings to this recent research and demonstrate how your work improves on it in order to demonstrate that your work shows a significant advance over the state of the art – a pre-requisite for publication in IET Research Journals.

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You should number your references sequentially throughout the text, and each reference should be individually numbered and enclosed in square brackets (e.g. [1]).

Please ensure that all references in the Reference list are cited in the text and vice versa. Failure to do so may cause delays in the production of your article.

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If the number of authors on a reference is greater than three please list the first three authors followed by *et al.* The reference list should be uninterrupted by figures, tables or equations.

Example References

7.2. Websites

[1] 'Author Guide - IET Research Journals', http://digital-library.theiet.org/journals/author-guide, accessed 27 November 2014

[2] 'Research journal length policy', http://digital-library.theiet.org/files/research_journals_length_policy.pdf, accessed 27 November 2014

Commented [A34]: The results are poorly presented. See my comments below.

Commented [A35]: I suggest that you draw a clear comparison between the manual methods, the methods for image detection, and your method on parameters such as speed, feasibility, reliability, and accuracy.

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Commented [A40]: Focus area: There are other methods that have better accuracy but other limitations. The paper does not discuss these.
Recommendation: Please consider conducting more thorough literature research and providing comparisons with these methods.

7.3. Patent

[3] ‘ORCID: Connecting research and researchers’, http://orcid.org/, accessed 3 December 2014

[4] ‘Fundref’, http://www.crossref.org/fundref/, accessed 4 December 2014

7.4. Journal articles

[5] Smith, T., Jones, M.: 'The title of the paper', IET Syst. Biol., 2007, 1, (2), pp. 1–7

[6] Borwn, L., Thomas, H., James, C., et al.:'The title of the paper, IET Communications, 2012, 6, (5), pp 125-138

7.5. Conference Paper

[7] Jones, L., Brown, D.: 'The title of the conference paper'. Proc. Int. Conf. Systems Biology, Stockholm, Sweden, May 2006, pp. 1–7

7.6. Book, book chapter and manual

[8] Hodges, A., Smith, N.: 'The title of the book chapter', in Brown, S. (Ed.): 'Handbook of Systems Biology' (IEE Press, 2004, 1st edn.), pp. 1–7

[9] Harrison, E.A., and Abbott, C.: 'The title of the book' (XYZ Press, 2005, 2nd edn. 2006)

7.7. Report

[10] IET., 'Report Title' (Publisher, 2013), pp. 1-5

[11] Brown, F.: 'The title of the patent (if available)'. British Patent 123456, July 2004

[12] Smith, D., Hodges, J.: British Patent Application 98765, 1925

7.8. Thesis

[13] Abbott, N.L.: 'The title of the thesis'. PhD thesis, XYZ University, 2005

7.9. Standard

[14] BS1234: 'The title of the standard', 2006

8. Appendices

Additional material, e.g. mathematical derivations, tables and figures larger than half a page that may interrupt the flow of your paper's argument should form a separate Appendix section (see Table 2). Do not, however, use appendices to lengthen your article unnecessarily as this section is included in the word count. If the material can be found in another work, cite this work rather than reproduce it. The appendix section should be in double column format, and come after the references.

Table 2 Example of large table

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