Air Leak Detection in Air Conditioner Compressors using Image Processing Techniques

First Author 1, Second Author 2\*, Third Author 3

1 First Department, First University, Address, City, Country Name

2 Second Company Department, Company Address, City, Country Name

3 Third Department, Third University, Address, Country Name

4 Current affiliation: Fourth Department, Fourth University, Address, Country Name

\*[corresponding.author@second.com](mailto:corresponding.author@second.com)

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 paper presents a method to detect air leakage in an air conditioner compressor using image processing techniques. In order to inspect an air conditioner compressor for air leakage, air is pumped into the compressor, which is then submerged into a water tank. If air bubbles are observed at the surface of the compressor, it implies that air leakage exists, and the compressor must then be returned for maintenance. In this study, a new method to detect air leakage and identify the leakage point with high accuracy, speed, and reliability was proposed. Connected-component labelling and blob analysis are used to detect air bubbles and analyse the group of the air bubbles in sequential images, respectively. The experiments evaluate the proposed algorithm’s ability to determine the leakage point in an air conditioner compressor. The location of the leakage point is presented as a coordinated point. The results demonstrate that the leakage point observed during the process can be accurately detected; the estimation point has an error less than 5% compared to that of the real leakage point.

1. Introduction

The air conditioner compressor is a major component in air conditioners and refrigerators. Air conditioner compressor manufacturing has four main subprocesses: trimming a metal chassis, installing electrical and mechanical components into a compressor, assembling the chassis, and inspecting quality. During the compressor manufacturing process, incomplete welds may cause very small leaks that are difficult to identify manually. Thus, before shipping the air conditioner compressor, the assembled compressor is inspected to check for air leakage via detection and by searching for leakage points. Manual leakage detection has a high possibility of error, and therefore, computer vision is implemented to reduce the cost of quality inspections and increase the accuracy, speed, and reliability of the process. Rosenfeld and Pfaltz [1] proposed a connected-component labelling search for the connected pixels of object in a digital image. Burger and Burge [2] proposed a bounding box and centroid calculation of binary regions called blob analysis. In this study, connected-component labelling and blob analysis were employed for detection; the proposed inspection method can be applied to other closed tank products where leakage detection and measurement is required.

1. Air conditioner compressor inspection test setup

*Insert Figure 1 here*

**Fig. 1.** Sample graph with blue (dotted), green (solid) and red (dashed) lines  
**(a)** Subfigure 1, **(b)** Subfigure 2

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

Further, to improve the visibility of air bubbles, a light source was installed above the compressor, and black curtains were used to prevent external light noise [3].

1. ****Image processing algorithm****

The image sequences acquired from the video camera are stored in bitmap files; these files are processed before the initial image processing using connected component labelling and blob analysis to detect leakage and identify the leakage point, respectively.

* 1. Connected-Component Labelling

Connected-component labelling is an image processing technique 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 four-connected or eight-connected [2].

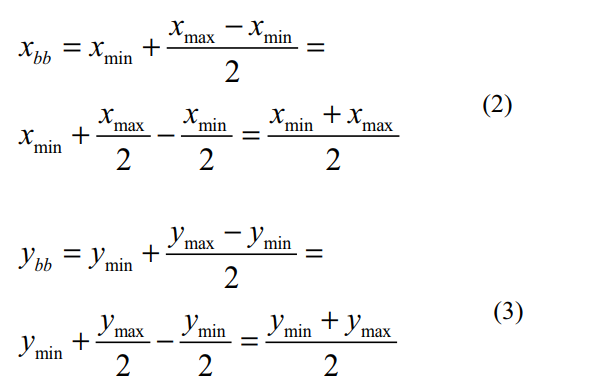
* 1. Blob Analysis Technique

Blob analysis is an image processing technique used to detect and measure blobs in images, as shown in Fig. 2. The centre of mass (or centre of gravity/centroid) of a blob (*xc*, *yc*) is calculated by

(1)

where *N* is the number of pixels in the blob and *xi* and *yi* are the *x* and *y* coordinates of the *N* pixels, respectively.

The bounding box of a blob is the minimum rectangle that contains the blob; 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 xmax–xmin and the height as ymax–ymin. A bounding box can be used as the region of interest. The centre of the bounding box is calculated as



*Insert Figure 2 here*

**Fig. 1.** Sample graph with blue (dotted), green (solid) and red (dashed) lines  
**(a)** Subfigure 1, **(b)** Subfigure 2

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 acquired from a video camera are converted to binary images to separate the interest objects from the background. Binary images are filtered for noise using a median filter.
3. The connected component labelling technique (8-connectivity) is used to detect a group of white pixels that are the air bubbles of interest. We implement the two-pass algorithm that iterates through binary data in an image.
4. Blob analysis is used to detect blobs in the image, and a centroid of blob and value of bounding box are obtained.
5. Compare the *yc* of the blob with the previous frame and add a marker at this blob if *yc* has a value greater than 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*

**Fig. 1.** Sample graph with blue (dotted), green (solid) and red (dashed) lines  
**(a)** Subfigure 1, **(b)** Subfigure 2

1. Experimental result

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

*Insert Figure 4 here*

**Fig. 1.** Sample graph with blue (dotted), green (solid) and red (dashed) lines  
**(a)** Subfigure 1, **(b)** Subfigure 2

Figures 5(a)–5(c) show the red rectangle marker of the leakage point after processing in 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*

**Fig. 1.** Sample graph with blue (dotted), green (solid) and red (dashed) lines  
**(a)** Subfigure 1, **(b)** Subfigure 2

*Insert Figure 5 here*

**Fig. 1.** Sample graph with blue (dotted), green (solid) and red (dashed) lines  
**(a)** Subfigure 1, **(b)** Subfigure 2

1. ****Conclusion****

A new inspection method to detect air leakage and to search for the leakage point in air conditioner compressors with high accuracy, speed, and reliability was proposed. The method can be used to detect air bubbles that escape from an air conditioner compressor. The results demonstrated that the proposed method can identify air leakage in an air conditioner compressor effectively with an accuracy of 95%. The proposed method provides advantages such as cost reduction, reliability, and improvement of the manufacturing process and maintenance of products.

1. 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].

Please note that the IET does not include author biographies in published papers.

1. 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.

Please note that tables, figures and equations should not appear in the middle of the references. If this happens white space will be introduced to avoid items appearing in the references.

* 1. Referencing Style

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.

Please also ensure that you provide as much information as possible to allow the reader to locate the article concerned. This is particularly important for articles appearing in conferences, workshops and books that may not appear in journal databases.

Do not include references for papers that have been submitted and not accepted for publication. Papers that have been accepted for publication are allowed as long as all information is provided.

Please provide all author name(s) and initials, title of the paper, date published, title of the journal or book, volume number, editors (if any), and finally the page range. For books and conferences, the town of publication and publisher (in parentheses) should also be given.

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

* 1. 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

* 1. 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

* 1. 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

* 1. 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

* 1. 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)

* 1. 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

* 1. Thesis

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

* 1. Standard

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

1. 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.