Acoustic Technique for Building Envelope Air Permeability Test

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ABSTRACT
Buildings are an enormous consumer of energy, due to air leaks alone buildings waste up to 5% of all energy worldwide. Building envelope airtightness is therefore of paramount importance to minimise energy consumption and to meet cut carbon emissions by 2050, as set out by the Australian Government. Air permeability rate testing is also becoming a requirement for various building rating systems such as WELL and Green Star and must be performed to obtain the relevant credit points. The commonly used current standard measuring technique for air permeability is the blower door test, while thermography and smoke pens are widely used for air leak detection. All these methods have in common, that a difference of either pressure or temperature between inside and outside of the building must be established. Moreover, the blower door test is labour and time intensive. To meet the demand for increased building airtightness and testing, more efficient methods are needed. Following the principle that sound travels the same path as leaking air, acoustic based techniques are proposed. Among those techniques the acoustic imaging shows best potential benefits. This paper provides a short summary of the research published in this area and the plan for further research.

1 INTRODUCTION
The application of acoustic imaging for air permeability test is a relatively new field of research potentially revolutionizing the current testing methods which suffer from inefficiencies and limitations. Acoustic methods based on the sound transmission loss (STL) through gaps, which is usually considerably lower than the STL though the structural elements, were already documented in 1979 (Keast and Pei, 1979) followed in the next decades by other researchers (Card et al., 2009; Iordache and Catalina, 2012; Sonoda and Peterson, 1986; Varshney et al., 2013). The obvious benefits of the acoustic technique are that there is no need for building pressurization, cooling or heating the building, or filling the building with smoke for identifying the air leakages. The acoustic method has been included in the ASTM E1186 – “Standard practices for air leakage site detection in building envelopes and air barrier systems”.

2 ACOUSTIC IMAGING TECHNIQUES
The potential benefits in using acoustic image techniques such as Beamforming (BF) and/ or Nearfield Acoustical Holography (NAH) were described first in a conference paper (Raman et al., 2014) and followed by publications by the same authors who also successfully filed for a patent (Muehleisen and Raman, 2018) and attempted to develop a commercial measuring system (SonicLQ) based on this research.

The most important parameter for acoustic imaging is the spatial resolution of the sound map which is often a function of array design parameter such the number and location (spacing distance) of the microphones and measurement parameters such as the distance to the sound source and its frequency.

Beamforming provides an acoustic image resolution proportional to measurement distance and limited to the Rayleigh limit, which can be poor at low frequencies or small array apertures. (Ginn and Hald, 2005). However, deconvolution methods, such as the DAMAS and CLEAN-SC techniques, can significantly improve the resolution of an array beyond the Rayleigh limit (Hansen, Doolan and Hansen, 2017).

On the other hand the NAH imaging method has a resolution of about half wavelength limited on the high frequencies range by the microphone spacing. However at low frequencies NAH provides better resolution which is never worse than about the measurement distance. SONAH combines the advantages of both methods and can use the same microphone array specially optimized for this method.

3 RESEARCH PLAN

3.1 Acoustic Method for Air Leak Finding (AMALFi)

Air leaks shall remotely be localized by combining the localization of a sound source with the virtual visualization of the sources within an investigation area frame. An acoustic source inside the building generates a specific sound.The sound signal is received by a microphone array outside the building and processed by beamforming, acoustic holography, or similar methods to produce a map of sound intensities. The resulting sound map is superimposed on the image of the investigated area recorded by a video camera.

3.2 Acoustic Method for Air Tightness Examination (AMATE)

Following the steps described above in AMALFi, the functions shall be further extended from pure localisation to real time calculation of the air leakage rate (for each leak), i.e. the leaking air quantity, e.g., in m3/h, shall be displayed at the leak location.

AMALFi has high potential to become a detection tool. It is effective, quick, and easy to use. AMATE has the potential to become a complementary technique to blower door testing, while in cases where the latter constitutes a rather too cumbersome or impractical process, AMATE may even substitute it.

Both, AMALFi and AMATE, are strictly non-intrusive, not labour-intensive, and do not rely on pressure and temperature differences. Both methods can be applied to any building size, reaching from small residential houses to large / complex commercial buildings. Both methods can be used at all stages of construction completion and even at times when the building is in use, which makes both methods suitable for air tightness examination of existing buildings. Hence, both methods can greatly contribute to fulfilling our challenging task to minimise energy consumption, to lower carbon emissions and to improve Indoor Air Quality.

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