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Large structures monitoring using unmanned aerial vehicles

W.K.Chiu[a], W.H. Ong[a*], T. Kuen[b], F.Courtney[b]

[a]*Department of Mechanical & Aersospace Engineering, Monash University, Clayton, Victoria 3168, Australia*
bMelbourne Water, 900 La Trobe Street, Docklands, Victoria 3001, Australia

Abstract

Structural health monitoring offers significant benefits in reducing whole of life costs of infrastructure ownership, and improves the reliability and availability of high value assets. There are significant works towards applying structural health monitoring (SHM) to aircraft, maritime and civil structures. Numerous techniques have been developed to facilitate the monitoring of the structural components and the different classes of defects expected. One of the distinct advantages of SHM is the ability to monitor hard-to-inspect areas of an operating structural component. There is another attractive feature of SHM; incorporating SHM into new design offers a perspective into concept of "safety in design". The integrated sensing system can be used initially to verify the design safety factors used when the structure is first commissioned and subsequently for integrity assessment purposes. In both purposes, the challenge remains with sensor placement, and the durability and reliability of the sensing elements located on the structure. Recent advances in non-contact measurement techniques have overcome some of these limitations. In most of these works, the inspection region is limited due to the constraints associated with the hardware requirement. This paper will discuss the use of displacement measurements using remotely piloted aerial vehicles (RPV) for the condition assessment of a large membrane floating cover that is approximately 170 m x 420 m. It is envisaged that the health monitoring of the membrane can be assisted by the periodic monitoring and assessment of the deformation of the large membrane cover. The collation of the profile of the membrane over time will provide important information for the structural integrity assessment of the floating cover.

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1. Introduction

Large membrane-like covers are used in several environmentally sensitive application contexts, including (i) floating covers for clean water reservoirs, to prevent evaporation and pollution, (ii) landfill covers to stop leakage of hazardous chemicals or harmful matter, (iii) mining applications such as heap leaching, salt evaporation ponds and

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tailings impoundment [1], in addition to being used as floating covers for anaerobic reactors in sewage treatment plants, which is the main focus of this proposal. An unexpected failure of these membranes can have severe detrimental effects on the operation, the environmental and the economic cost. The economic cost is extreme because the cover replacement cost is in the order of 10's of millions (~$50m). In addition, there is also the economic loss associated with the inability to harvest biogas. The cover failure can adversely impact on the operation of the waste treatment plant. It can also result in unpleasant odours being released into surrounding residential areas affecting the air quality. In this respect, early warning of defects, risk or harm to the integrity of the covers is crucial. Whilst the primary aim of these early warning systems can be used to assist with scheduling of repairs or rectification of the situation under the cover, it can also be used to recommend operational changes at the plant to prevent catastrophic failure. In this respect, a robust structural health monitoring methodology will provide timely warnings that are crucial from the point of view of safe continued operation, failure prevention and maintenance management.

Fig. 1. Aerial view of the floating cover at Melbourne Water Western Treatment Plant as seen from Google Earth

The floating covers used in Melbourne Water's Western Treatment Plant (WTP) in Werribee, Victoria, are made from high density polyethylene (HDPE). They are 2 mm thick and typically span an area of 470 m x 170 m, as illustrated in Figure 1. The cover is held down around its perimeter by clamping strips and mechanical fasteners to provide an airtight seal. All sewage inflow is unscreened and passes first through an anaerobic reactor. As the raw sewage undergoes anaerobic digestion, biogases are produced, which are trapped below the floating cover and harvested for electricity generation. Consequently, there is a high premium placed on ensuring that no failures occur in service. The current maintenance practice involves a visual walk-around inspection which is potentially hazardous and time-consuming, but, more importantly, does not provide advance warning of possible failures, or clear indications of distress in the covers. Indeed, a powerful incentive for this proposal is the recent catastrophic failure of a cover sheet at the Melbourne Water treatment plant in December 2014, as shown in Figure 2.

The HDPE material used in the floating cover is extremely durable. The review by Rowe & Sangam [2] show that HDPE geomembranes are very durable and can have expected service life of over 300 years at 20°C, and over 45 years at 40°C [2]. Consequently, well-designed HDPE geomembranes should have long trouble-free lifetimes. However, large covers are fabricated by fusion welding of long strips that are typically 7 m wide. These welded joints are recognised to be the Achilles heel of these large membranes [3], [4], due in part to the pre-processing which involves surface roughening that can induce localised damage. During the operation of the reactor, solidified sewage matter can accumulate on the surface of the reactor to form *scum-bergs* which press against and lift the covers. This deformation has a length scale of around one metre in the vertical direction (uplift) and several metres laterally. Under conditions of wind loading, the scum-bergs can be displaced laterally, which gives rise to mechanical stress on the covers and in particular on the welded joints. Figure 2(a) shows an aerial view of the cover. A close-up view of the torn cover is shown in Figure 2(b). This failure occurred on a day of high wind. The principal maintenance concerns underpinning this proposal are to correctly monitor the stresses associated with these scum-bergs and their lateral movement under high wind conditions, and to assess the likelihood of failure [5].