

Remote, Visual Inspection and Digital Analysis for External Corrosion Characterization in Refinery Unit Applications

Slawomir Kus (Slawomir.kus@honeywell.com),
Sridhar Srinivasan (srivasan@gmail.com)

Honeywell Process Solutions,
11201 Greens Crossing Blvd, Suite 700 Houston, TX 77067, USA

ABSTRACT

External corrosion of coated pipelines and equipment is a common problem in refineries and petrochemical plants, especially at locations with elevated humidity e.g. near cooling towers. Usually manifest as damage to the coating layer (spot or uniform), external corrosion will require timely detection and repair in order to ensure sustained reliability in operations. Locations of coating damages are typically revealed by traditional visual inspection. Sometimes, visual inspection is supported by thermographic imaging and may provide additional insights on potential for Corrosion Under Insulation (CUI).

Visual inspection is typically considered to be a low cost and uncomplicated technique. However, it requires significant effort in terms of time and skilled manpower as well as the need for complex infrastructure (scaffolding and / or crane operation are often required), resulting in significant cost of visual characterization.

Recent advances in drone technology offer an attractive and cost-efficient alternative to manual methods and are designed to automate many aspects of visual inspection. Automated drone systems for remote imaging facilitate rapid photographic documentation of relevant unit structures or areas without complex and expensive support infrastructure. When integrated with intelligent data processing systems for rapid analysis and mapping of surfaces with damaged coating, cracked supports, damaged insulation jacketing, drone based visual inspection and data analyses techniques provide a robust and low-cost alternative. This can also be easily combined with thermographic imaging to help identify locations where CUI may be occurring. An important element in remote visual inspection is automated post processing and data analysis utilizing special algorithms for e.g. crack detection in concrete supports or coating damages (size, type, density etc.).

The current paper provides a conceptual framework for automated visual inspection utilizing remote drone systems. It also presents results from a field case study on inspection of multi-level pipe-racks in a refinery environment. Examples of automated image analysis using dedicated algorithms are also given. Potential benefits and challenges of drone-based data acquisition and analyses are also discussed.

Keywords: visual inspection, remote drone system, external corrosion, data analysis

INTRODUCTION

Visual Inspection for External Corrosion – Past, Present & Future

External corrosion of piping systems is typically related to atmospheric corrosion, manifested primarily by coating defects or/and direct surface degradation (rusting) of bare metal surfaces. Available normative documents detailing external corrosion damage assessment are solely based on visual inspection findings.^{1,2} Coating damages on easily accessible, ground level, non-insulated pipelines are relatively easy to locate through simple visual inspection. However, conducting the same inspection on multi-level, long distance pipe racks is a challenging exercise, from both economic and practical aspects. Extensive scaffolding services, crane operation or rope-access can turn a simple visual inspection exercise into a complex logistics nightmare and resources-consuming, expensive operation.

In some cases, it is becoming even more difficult to conduct visual examination when expanding to inspection of more 'critical' types of external corrosion, but typically hidden from inspector's view, such as corrosion under insulation (CUI). This damage mechanism is progressing "undercover" beneath the insulation and, if not addressed in a timely fashion, may result in significant reduction of mechanical integrity.

Simple, visual inspection of insulated pipelines is known to be ineffective in CUI detection (not accounting for situations when insulation is completely or partially stripped). However, it is still considered as a useful approach in identification of areas with potential for CUI. Those are: gaps/damaged cladding, gaps between pipe supports and pipe cladding or water splashing to list a few of concerned areas. Supporting visual assessment by other techniques such as thermal imaging may increase a "hit rate" of CUI areas. It is presumed that abnormal heat signature (hot/cold spots) is likely caused by water/moisture accumulated between insulation fibers, increasing probability of CUI occurrence (Figure 1). However, detection of hot-spots within the insulation thickness provides information / data about possibility – not certainty – of degradation beneath insulation.

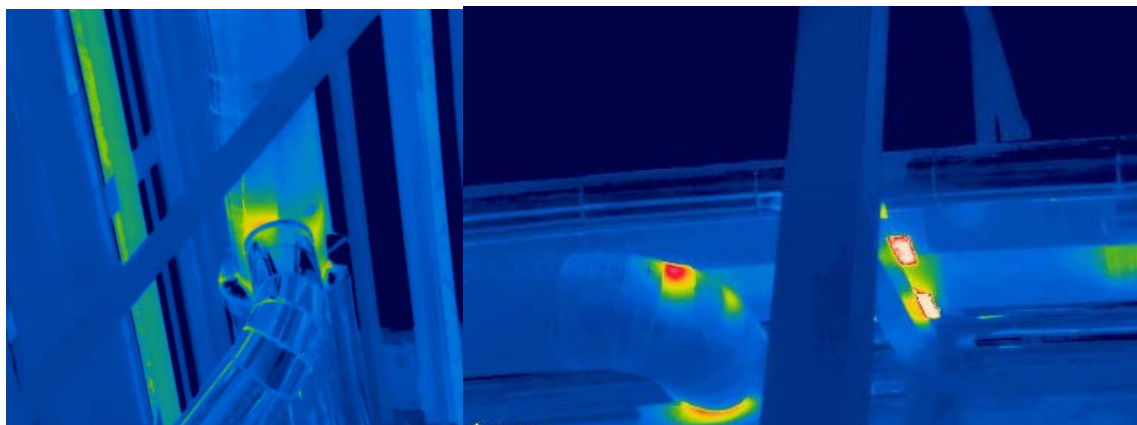


Figure 1 Example of thermographic images of piping systems.

Effectiveness of visual and/or thermal inspection will greatly depend on distance from which inspection is conducted. The most effective, visual examination, wherein the inspector is physically located proximate to the inspected area, is rarely utilized due to high cost of concomitant infrastructure requirements (scaffolding, crane). Unconventional systems including inspection using rope-access, which some practitioners claim as an effective approach in assessing CUI, seems barely practical or economically infeasible (lack of skilled personnel, safety requirements, timing).³

Recent progress in development of small, Unmanned Aerial Vehicles (UAV), has caused new applications for different types of remote services including visual inspection of industrial installations. Currently, UAV inspections are utilized mainly in characterizing / assessing electrical transmission

systems for support crack detection, flare tips for general corrosion and cracks or off-shore structures with difficult-to-access areas near splash zones.⁴⁻⁷ Short inspection time, low manpower requirements and concomitant lower costs, with greater automation and data analyses make UAV inspection a very attractive option in a very complex and challenging set of critical infrastructure applications in refineries or petrochemical plants. Specific safety requirements regarding use of electronic equipment in refining environment (explosion zones), may seriously limit applicability of UAV inspection. Lack of refinery-specific normative guidelines governing usage of remotely controlled aerial vehicles alongside overtly conservative approaches of HSE personnel may complicate inspections through UAV.

UAV Inspection in Refinery – Safety Considerations

Safe refinery operations is of paramount importance and hence governs all activities within a refinery's boundary, including utilization of safe inspection technologies. Presence of flammable liquids and gases with low ignition temperature and wide range between lower and upper explosive limits makes usage of electrically driven devices highly risky. Any type of electrical equipment operated in potentially explosive environments must follow rigorously safety standards and provide various levels of protection, such as intrinsically safe (power limited) design, explosion proof enclosures or non-sparking design to list some of the most popular safety measures when operating electrical equipment in the presence of flammable/explosive hydrocarbons (vapor or liquid). UAV inspection, and hence involvement of remotely-operated, electrical-equipment (drone) rises safety concerns on high level as multiple scenarios may compromise safety barriers existing in process units. Some of these concerns are briefly evaluated below.

1. Ignition of hydrocarbon vapors by UAV's engines

At the time of paper preparation, there was no commercially available, fully intrinsically-safe commercially available drone system. Typical UAV equipment comprises uncovered, electrical engines, energy accumulator (battery) and analytical instruments (cameras, analyzers etc.). It is therefore a possible, but low probability, scenario for ignition of hydrocarbon vapors that can be released undetected, when UAV will be passing near-by. Design of fully-intrinsically safe UAV may be challenging due to number of rotating elements and open electrical circuits. Hence, the most reliable mitigation method to prevent potential ignition of hydrocarbon vapors is a properly established flight plan.

The flight-plan should address this by maintaining a specific, minimum distance between UAV and critical structures (pipes, vents, column etc.). As there are no specific normative rules regulating minimum safe distance between UAV and refinery structures, such distance limits should be determined on a case-by-case basis, stemming from site-relevant risk assessment and extant boundaries for explosion zones.

2. Impact-ignition of hydrocarbons and pipe rupture due to impact

Another potentially problematic scenario is when the UAV suffers complete loss of power supply. Such an event, however highly unlikely as flammable hydrocarbons are in contained systems, cannot be completely ruled out because free-falling objects (c.a. 10kg) from the height of about 20m will possess a kinetic energy of above 1.9kJ while ignition energy for e.g. gasoline is in the range of millijoules.

Additional problem is a potential pipe rupture due to impact of free-falling UAV. Theoretically, object of 10kg that is free-falling from c.a. 20m may generate +200kN impact force. Proper analysis of this scenario is however more complex as several elements should be considered including: deflection of insulation layer, surface of contact, deflection of UAV structure and its elasticity (frame is usually made of carbon-fiber type polymers), impact angle etc. and is beyond of the scope of this paper.

Applying certain safety measures like low battery alarm, carefully designed flight plan (not extremely high altitude), experienced UAV pilot and using a low-weight UAV's may help to reduce potential risk of