Photograph 1: The cracks in the Comet originated at the square windows

Container cranes require structural maintenance

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The first production commercial jetliner in the world, the de Havilland DH 106 Comet, was put into operation in 1952. It was initially a success, but several crashes in 1953 and 1954 resulted in the planes being grounded.

Fatigue failure brought down the Comet

Square windows were a typical feature of airplanes until the Comet and were incorporated into the Comet in spite of testing of fuselage sections under fatigue loading during its development. Only after multiple Comet crashes and an intensive test program of full scale airframes was it determined that due to stress concentrations at the window corners, explosive hull failure would occur between 1,000 to 9,000 cycles of compression and decompression-consistent with the observed failures. In 1958, the Boeing 707 and McDonnell Douglas DC-8 were introduced, with round windows, dominating the industry and introducing the commercial jet age. Although the Comet was modified to have round windows and was reintroduced into service, England had lost the lead in the passenger airliner industry.

Fatigue failure of container cranes

Although a critical fatigue failure in a container crane structure typically kills fewer people than an airplane crash, such failures are as undesirable in the container crane industry as in aviation. Just as England lost the lead in the aircraft industry, persistent operational disruption in a competitive environment can lead to the long-term demise of a container terminal. How is it avoided? The fundamental problem with fatigue design is that a large number of variables influence the number of cycles to failure so that for a given specimen the expected life is an estimate given with a defined reliability. In the case of the Comet, initial testing was insufficient to identify a critical design flaw. Even with extensive testing of components, there is scatter in test results, and always a small probability of failure. In actual use the variability of results is greater because specimens and load histories vary. The aircraft industry led the development of fatigue design and two approaches are used to address this variability: safe-life and damage tolerant.

Design philosophy - safe-life or damage tolerant

The approach in safe-life design is to avoid crack initiation during the design life of the component. If this is achieved, no inspection is required. If a crack should occur, the results could be catastrophic. The safe-life approach lowers allowable fatigue stress ranges to a level where the possibility of failure is suitably remote. Because it results in impractically heavy cranes, the safe-life approach is not suitable for container cranes. The damage tolerant approach is used for the design of container cranes. With the damage tolerant approach some fatigue cracks are expected during the design life of the crane. The cracks, however, must be discovered and repaired before they are large enough to cause failure. Therefore, thorough periodic inspection of the structures is required to detect fatigue cracks before they become critical.

Acceptable chance of failure

Critical container crane components are typically designed with an allowable stress range two standard deviations below the average stress range that results in failure at 2 million cycles of load. The resulting reliability of 97.8% means that in a thousand samples 22 will fail before reaching 2 million cycles of life. If there are 100 critical joints or components on a crane, we can expect 2.2 critical failures during the design life of a crane designed and constructed according to the applicable standards. This probability is unacceptably high. For this reason, inspection is required. In-depth structural inspection of joints will locate cracks and allow them to be repaired, thereby extending the life of the structure. The Liftech criteria for periodic inspection of new cranes are based on a one-in-a-thousand chance of failure in members that can fail without serious consequence and a one-in-one-hundred-thousand chance of failure in members that would cause collapse. Inspection intervals are calculated to meet the criteria. The criteria can be adjusted to suit the level of risk acceptable to the owner. Since, like jet airliners, container cranes have been working since 1958, review of the crane design by an engineer familiar with the history of crane failures can help avoid "infant failures" of cranes, similar to the window design of the Comet, and ensure that state-of-the-art damage tolerant practices are implemented. With an appropriate structural maintenance plan you can balance the risk of failure with the cost of inspection. WPD


Photograph 2: A typical crack in a fracture critical member on a container crane. This crack can be repaired.