

MECHANICAL ENGINEERING ASPECTS OF DAMAGE TO BUILDINGS, EQUIPMENT AND MACHINERY

Fatigue – Real Tolerance – Reverse Engineering

Mechanical engineers put mechanical energy to useful work and they convert other forms of energy into mechanical energy.

In buildings, the mechanical engineer uses HVAC (heating, ventilating, and air conditioning) and other mechanical systems to create the desired environment, be it office space or an ice rink. In other situations, mechanical engineers are called upon to move people in cars, elevators, etc. In manufacturing plants, the mechanical engineer uses machinery to assist or replace human beings. In process and energy plants, the mechanical engineer puts mechanical energy to work often using rotating and fired equipment. At DGPA, we do a lot of mechanical engineering analysis and investigation into damage and injury. We'd like to share a few interesting insights:

CAUSE—The hazard of *fatigue* is common in machinery and equipment. Relatively slight misalignments or non-symmetrical loading of rotating shafts can cause fatigue failure. Blades, tubing, and other components can resonate to cause undesired gas flow fluctuations.

How can you tell whether damage is the result of fatigue? The fracture surfaces of an overloaded steel component typically have a grainy structure. When fatigue occurs, there will be an apparent smoothness in a portion of the fracture surface before the grainy structure begins. For example, when the initiating crack is examined under a microscope, the fracture surfaces appear to be the result of waves lapping on a beach (beachmarks—transgranular cracking).

Loads that are applied and removed thousands of times (cycles) can lead to failure below simple overload levels. *Fatigue* must be considered during structural design of a building when a structure will be subjected to 20,000 cycles or more. Normally, buildings

are not subject to enough cycles of loading for fatigue to be a problem. However, fatigue can be a problem in buildings with heavy runway girders or heavy, vibrating or moving machinery.

COST—What actually needs to be repaired can drive project costs. Often, the key question is: What are the *real tolerances*? In rotating equipment, the alignment tolerances are usually very tight (in mils—thousandths of an inch) because bending of a rotating shaft can cause fatigue.

In air ducts and gas flues in fired equipment and HVAC systems, there can be a high tolerance for misalignment. Racked ductwork, bowed furnaces may be just as functional and reliable as they were prior to the damage. Usually, the change in cross-section does not significantly change the amount of energy required to move the gases or air.

DOWNTIME—Downtime penalties can swing the balance of repair vs. replace, making significantly damaged equipment and machinery economically repairable. It becomes a matter of repair costs vs. replacement cost plus the impact on the schedule. Long procurement lead times for new equipment and machinery can put the machinery and equipment replacement on the critical path. In these cases, repair is often an option.

It often makes sense to repair machinery that appears to be significantly damaged even without downtime considerations because of how the equipment is priced and because the more expensive components are often very durable.

What if the original design and manufacturing drawings are not available? Quite often, the parts can be measured precisely enough to machine replacements. Spare part information often contains what type of material needs to be used. In other words, it is often quite possible to *reverse engineer* the machinery and equipment design.

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