HOTSEAT

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Metallurgical and heat treat forensics play an important part in determining how and why parts fail.

AUTOMOBILES AND AIRPLANES HAVE BEEN in the news recently — GM cars for ignition recall issues and airplanes because of crashes due to weather, missiles, and undetermined reasons. No matter the case, metallurgical and heat treat forensics play an important role in determining what and how things happen.

Cars and airplanes contain steel, cast and wrought aluminum, copper, titanium, and composites, among other complex alloys of these same materials. It's critical that the aftermath of any incident be preserved exactly as found so experts can piece together the clues that will always be present to help explain what occurred.

Let's consider, for example, an ordinary steel clothes hanger in these three scenarios:

1. Flex it back and forth repeatedly and the flex point will get warm (even hot) and get progressively harder to bend before it breaks. This is called work hardening, where the metal can actually become brittle where initially it could be bent easily.

2. If the hanger is flexed more slowly over a time, instead of work hardening, the hanger will break from fatigue. It will break even when the force required to bend the hanger is well under the forced required to cause work hardening.

3. However, if the hanger were to be used to lift something heavy beyond its strength limit, instead of a chain, it will begin to neck down, at some point reaching its yield strength, stretch, and then break. Now duplicate the three tests at -70°F (-57°C), the temperature at an altitude of 35,000 feet and the fracture surfaces of the hanger would be different to the experienced observer in an SEM (scanning electron microscope). It doesn't matter how large or small the hanger is, the failure mode would be observable.

I don't know why the failure mechanism caused the ignition switch failures. But certainly a very small piece of metal or plastic moved from its intended position, either from vibration or excessive force from too much weight on the key fob, as mentioned in news stories. But since the failures didn't occur very soon after the cars were first placed in service, the failure mode was likely related to fatigue of some component.

The classic failure mode related to airplanes is fatigue, either in the fuselage around rivets or on wing surfaces when subjected to strong winds — especially up and down drafts. The force created when landing is also an issue specifically for commuter flights, as the airplane takes off and lands many times over a month. Obviously, designers take an airplane's intended purpose into consideration.

Heat treat furnaces, like any complex machine, will, at times, suffer the same fate. Components fail. But every engineer must know the intended purpose and anticipate how the system will be used and how likely the user will follow the maintenance protocol. No matter if it's for a household blender, furnace, automobile or airplane. Airplanes (for obvious reasons) must be subjected to rigorous scheduled maintenance in order to catch potential failures before they can happen.

Where heat treat furnaces are concerned, very high temperatures and explosive atmospheres are the critical parameters we must contend with and the heat resisting alloys we use in their construction. Just as car and airplane manufacturers have to retain records from their supply chain, furnace providers do as well, to ensure that the systems comply with industrial risk insurers and our own quality system. Record retention is intrinsic with today's technology and off-site backup tape security.

Components can fail from fatigue, as described above; workmanship, like misassembly causing unintended wear; or improper heat treatment. This is what investigators face when they reconstruct the situation to find the root cause. One of the biggest puzzles to overcome in any failure investigation is heat and the length of time between the failure event and evidence discovery. Heat can alter the microstructure of metal and oxidation from exposure or both.

So what occurred first? Did heat contribute to the failure by weakening a component or did heat alter the material after the fact? Sometimes this can be determined by comparing the fracture surface morphology to the quantity and type of oxidation on the part and knowing the intended heat treatment process. The time required to achieve the intended microstructure and the time the part actually received from records kept by the original heat treater and hopefully a sample taken from the same processed lot. The metal in question is also an issue; aluminum melts at 1000°F to 1100°F, but steel's microstructure changes above 1333°F.

Another puzzle investigators must consider is mechanical deformation. Did the metal or component change shape as a result of the failure, or, in the case of an automobile or airplane, an impact with another object?

Heat treaters are not immune from component failures, but rarely do they cause catastrophic damage. When they involve a car, airplane, or furnace they are likely the result of improper human intervention somewhere along the human/machine interface process.

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