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FORENSIC ENGINEERING AND EXPERT WITNESS SERVICES

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MATERIALS ANALYSIS IN FORENSIC ENGINEERING INVESTIGATIONS

by
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Introduction

Cases involving alleged product malfunction or design defects can take many forms. From simple mechanical failures to complex industrial process accidents, the materials that make up every product often contain subtle clues to the events that led to accident or injury. In many instances that evidence can be used to show what didn't happen, as easily as it can show what did. The use of advanced materials analysis through various techniques can uncover evidence that investigators without materials education might overlook, or simply aren't aware of.

What is Materials Science and Engineering?

The field of Materials Science and Engineering, as a distinct discipline of Engineering, is not very well known, and is not even offered as a major in many engineering institutions. The concepts of manufacturing, materials processing, metallurgy and biomaterials are terms that evoke some recognition among the general population, but few people realize that all of these concepts, and many others fall under the umbrella of Materials Science. Formerly known as just "Metallurgy," Materials Science is the study of the matter used in the realization of any engineering design. In short, it's the study of the "stuff" everything is made of. The metals, plastics, ceramics, biomaterials, semiconductors, liquids and gasses that are used in any engineering process must be defined by known properties, processes and structures. Materials engineers learn the relationships between the structure (atomic scale up to macro scale), processing and properties of the materials used to make every product, from aircraft parts to hip implants. Since many product litigation matters center on the performance and possible failure of materials, Materials Engineers are often best qualified to serve as experts.

Optical and Electron Microscopy A standard optical microscope is often the first place any materials investigation begins. In the event of mechanical failure, the technique of fractography allows a materials engineer to examine the fracture surface of a part, and determine the types of stresses and loads the part experienced prior to failure. It can also help determine the point of origin of the failure, which may provide more clues to why the part failed in the first place. Optical microscopy is usually the first method applied, because it is inexpensive and typically nondestructive. However, the gold standard for fractography is performed in the Scanning Electron Microscope (SEM). As you can see in Figure 1, the SEM allows experts to examine materials at magnifications far greater than optical microscopy will permit. The scale marker bar at the top left of the figure indicates a distance of 200 micrometers (or 10-6 meters), far beyond the image quality of traditional optical microscopy. Dimples in this photo indicate that the metal failed in a ductile shear, which helps prove that the aluminum pin used to hold two components together wasn't sufficiently strong enough for the design load. The added level of detail provided by electron microscopy can refine the fractographic analysis and provide much greater insight into the failure mode of materials.

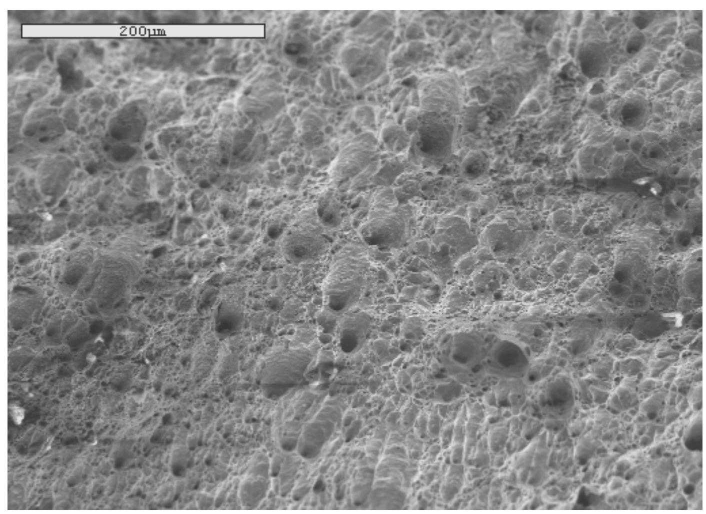

Figure 1 SEM fractograph of a failed aluminum pin. Note the scale marker bar indicates the size of 200 micrometers (roughly 1000X depending on the size of the photo at publication)

EDS and X-ray Analysis Possibly one of the most useful tools in the realm of forensic materials analysis is Energy Dispersive Spectroscopy, or EDS. This technique is performed in the SEM, and can be coupled with fractography and other visual analyses to create a very clear picture of the chemistry and chemical identity of different materials. The electron beam used the in the SEM creates X-rays when it strikes a material. These x-rays can be collected, and used to determine what elements are present in the material. The results of this technique can be used in many different types of forensic matters. EDS can help determine if a material is the correct composition, if the material corroded due to exposure with certain elements, how the material reacted in the course of a fire or explosion, or whether the product is even the manufacturer it is alleged to be.

Case Study: Rubber Recycling Factory Explosion

A rubber recycling facility processed used tires to produce rubber dust, a filler additive in asphalt and concrete and other various industrial applications. The facility employed wet grinding of the rubber, followed by water removal, and drying in a flash dryer. The flash dryer is essentially a cyclone of hot air used to dry the product while propelling it through into the conveyor system for silo storage and/or loading into bags. On an almost daily basis, the facility would experience "backfires" in flash dryer, which was a term used to describe small dust explosions which occurred when the dried product would accidentally ignite. The backfires were the result of operating the flash dryer at a temperature above the ignition temperature of the rubber dust. By running the dryer at an excessively high temperature, more product could be pushed through the dryer, thus increasing production capacity. The risk associated with this practice was the likelihood that if the rubber dried completely before leaving the dryer, the heat of the drier would ignite the rubber. The plant operated continually under this model until one day, the backfires resulted in the escape of burning embers, resulting in a plant wide dust explosion.

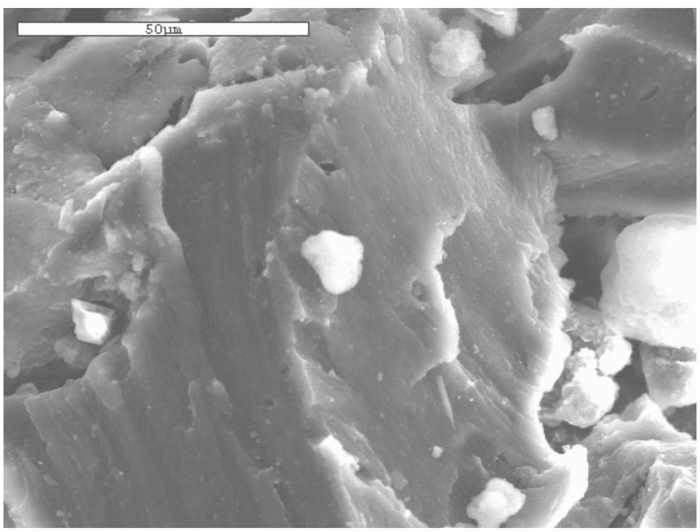

Figure 2 SEM micrograph of rubber dust samples removed from the factory. Note: the small white particle in the center of the photograph is a piece of the silica powder used as an anti-clumping agent.

Since rubber dust can clump together, the process engineers at the plant employed a product called amorphous colloidal silica powder, to keep the rubber dust from clumping together and clogging up the conveyor system. In this matter, the manufacturer alleged to have supplied the silica powder represented the "deepest pocket." Among the many issues of cause and origin, explosion analysis and process faults, one primary issue became the identity of the manufacturer of the silica powder, as there was evidence that another brand of silica powder had been used for the year preceding the big explosion. In short, it became critical to determine what brand of silica powder was being used. Through the course of discovery, it was learned that one producer of the silica powder used sodium chloride in their solution, while the other used sodium sulfate. While these two processes produced silica powder for the same industrial purpose, the process differences resulted in minute chemical traces that would allow one to be distinguished from the other. EDS analysis was employed to verify that one brand of silica powder contained trace amounts sulfur, while the other brand, the one produced by the defendant in the case, contained chlorine.

Rubber dust and explosion debris was collected from hundreds of locations throughout the plant during the initial OSHA investigation. The dust samples were marked and stored in unlined metal cans, which helped the course of the forensic investigation immensely. By examining the dust from these various locations, the colloidal silica could be easily distinguished from the rubber dust, as seen in figure 2. Random samples of rubber dust were taken from locations all over the plant, and hundreds of EDS scans were performed on the silica particles found on the dust particles. Not one piece of silica observed in this process contained chlorine. Figure 3 shows one of the hundreds of EDS spectra that exhibited direct evidence of sulfur in the silica powders, and no evidence of chlorine.

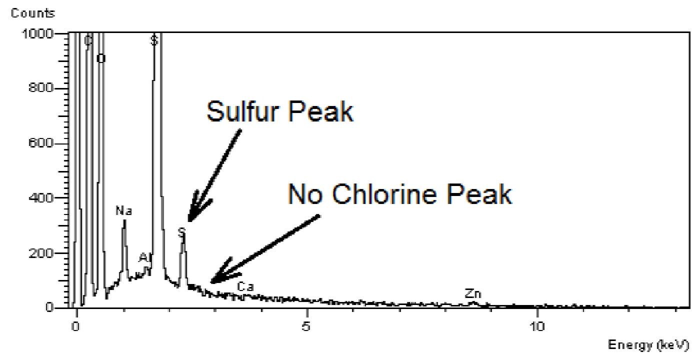

Figure 3. EDS Spectrum obtained from silica particles in a randomly selected rubber dust sample removed from the exploded factory. The absence of a chlorine peak indicates a different product supplier than the one named in the lawsuit.

The conclusion drawn from the statistically valid sampling methods, combined with the sheer number of silica particles analyzed was that the silica powder being used by the rubber factory at the time of the explosion was not the product produced by the defendant. This scientific finding was supported by inventory records of the plant, showing that the other brand of silica powder had been continually delivered for almost one year prior to the explosion, with no deliveries made by the defendant. The drive to keep the defendant in the case stemmed from the fact that the other silica supplier was a foreign corporation, and had gone bankrupt. The judge excused the defendant from the case in a pretrial motion.

Conclusions

Forensic engineering experts are being held to an increasing level of scrutiny with respect to their qualification to testify. As long as the more specialized branches of engineering study remain unknown to the attorneys, the details and facts that can be elicited by advanced investigation techniques may never be brought to light. Facts that can make or break a product liability case, or industrial explosion investigation may simply be ignored by investigators who are unaware of the potential of materials analysis to tell the story of what happened. It is incumbent upon the attorneys managing these cases to become aware of the variety and breadth of expertise within engineering and the sciences. Finally, it's the responsibility of the engineers and scientists to remain current in their fields, utilizing accepted science and sound methodology to reach valid conclusions and to assist in the legal process.

ABOUT THE AUTHOR

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Dr. Eason combines experience from academia, industry, and consulting to address a variety of engineering and forensic subjects. His broad based materials engineering education allows him to examine product defect and safety issues of metals, plastics, glass, and ceramics, including corrosion, fatigue, overload, and material selection. Paul has also actively participated in risk assessment for project management and failure modes and effects analysis in process and product design. As a forensic consultant, he has combined his knowledge of materials behavior with traditional techniques of fire investigation to tackle complex cause and origin issues and product liability concerns. Paul is also a nationally certified fire and explosion investigator and a licensed professional engineer in the state of Florida. He is versed in multiple forms of materials analysis, teaches undergraduate courses in materials engineering and mechanical design, and has worked on projects involving product design and manufacturing, product defects, failure analysis, corrosion, fire and explosion origin and cause, and industrial accidents.

His full resume is available at www.forcon.com under the Tampa office.

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FORCON News!

Forcon expands in the Philadelphia area

We are proud to announce that Tony Schneider joined our Philadelphia area office as Regional Marketing Director. With Tony's assistance Forcon has been expanding the services available out of that office and now has the capability to provide the full range of engineering and architectural services needed for most property, liability, or workers comp claim investigations. Visit our website to view the full CVs of our Philadelphia and Pittsburgh area teams. Tony can be reached at 215-640-0273 or tschneider@forcon.com.

Forcon opens new office in Annapolis, Maryland

Walt and Heather Laird are pleased to announce the opening of our Annapolis office. Current staffing allows us to provide civil, marine, materials, mechanical and structural engineering expertise out of that location. Visit our website to view the full CVs of our Maryland team. Contact Heather Laird at 804.230.4820 or e-mail her hlaird@forcon.com for additional information.

Forcon adds structural engineering capability in Charleston, South Carolina

We are pleased to announce that Russell T. Mease, PE has joined Forcon's Atlanta office as a structural engineering consultant operating out of Charleston, South Carolina. His experience includes structural design, exterior cladding and components, roofing, concrete construction, building weatherproofing and crawlspace integrity. His full CV is available on our website under Atlanta, Georgia. Russell can be contacted through our Atlanta Office.

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In-house educational and C.E. approved seminars are available to insurance / self-insured / TPA claims, defense law firms and conference / meetings as part of their agenda. For additional information, please contact Bob Dwyre radwyre@forcon.com.

The list of approved C.E. seminars includes a one hour course on Subrogating Wind Damage based on the article in this newsletter.

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