



# THE

# CONSULTANTS

# PERSPECTIVE

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PROPERTY/CASUALTY EDITION

## FRACTOGRAPHY AND FAILURE ANALYSIS

by

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### INTRODUCTION

Ever had your palm read? My wife and I did a few years ago just for the fun of it. We were amazed at what the palm reader was able to tell us about ourselves just from the lines on our hands. I had always been a skeptic until that experience.

The science of fractography is something like palm reading in that the fractographer can read the failure surface of a failed component and tell you a great deal about how the failure occurred. Unfortunately, in many cases just reading the failure surface alone doesn't give even the best fractographer all the information necessary to render an opinion as to who or what is responsible for that failure. The article by FORCON consultant, Dr. John Ambrose, explains why and identifies the other type of information that is often necessary in order to make a final determination of responsibility for the failure. Hope you enjoy it.

Bill Ver Eecke

The science of fractography involves the analysis of component fracture surfaces in order to determine the point[s] of origin of the crack or cracks which resulted in the material failure. Using characteristic features such as chevrons, radial/river and beach marks [metals] or mirror, mist, hackle and rib marks [plastics], the fractographer is able to divine origin and progression of fracture to failure. An excellent overview of this subject can be found at <http://www.asminternational.org/bookstore/pfa-parrington.pdf>.

By careful inspection of the origin, it is often possible for the fractographer to associate initiation of the fracture with a single microstructural feature - e.g. nonmetallic inclusion, surface imperfection or stress raiser, shrinkage porosity, etc. From there, it becomes an exercise in associating the origin with the conditions that determined why the origin was located where it was and the relationship between initiation and the process by which propagation occurs.

Analysis of failures in engineered components requires utilization of a number of diagnostic tools in order to be able to

associate the failure with the various factors which caused it to happen. In general, these factors can be divided into two categories - one related to the material from which the component has been constructed, the other related to the functionality of what it is that the component is subjected to during its service life - typically transfer of a mechanical force, electrical current or heat as well as containment of an internal fluid pressure.

A second requirement is that performance constraints - maximum deflection, avoidance of plastic deformation or fracture - must be specified as well. Occurrence of failure cannot be divorced from the operating and service conditions under which the failure occurred.

The majority of engineering plastic components are prepared from granulated thermoplastic polymers [resins] which are melted and either extruded [as tubing] or injected under pressure into a mold [injection molding]. In injection molding, molten resin or melt, flows from the point of injection, or gate, around obstructions with the separated melt fronts meeting or recombining on the other side of the obstruction. Wherever melt fronts recombine, the resultant weld [or knit] lines are locations where the degree of entanglement of polymer molecules have been reduced [Figure 1].

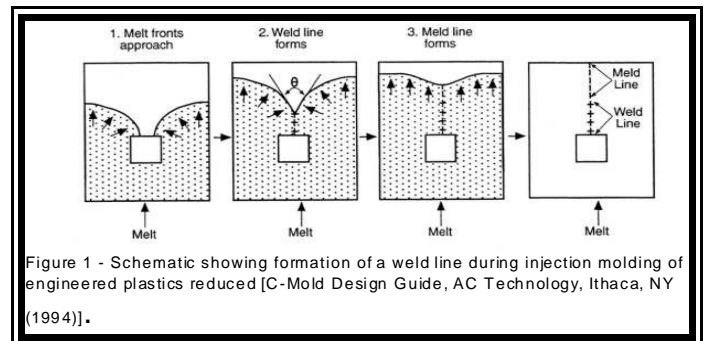


Figure 1 - Schematic showing formation of a weld line during injection molding of engineered plastics reduced [C-Mold Design Guide, AC Technology, Ithaca, NY (1994)].

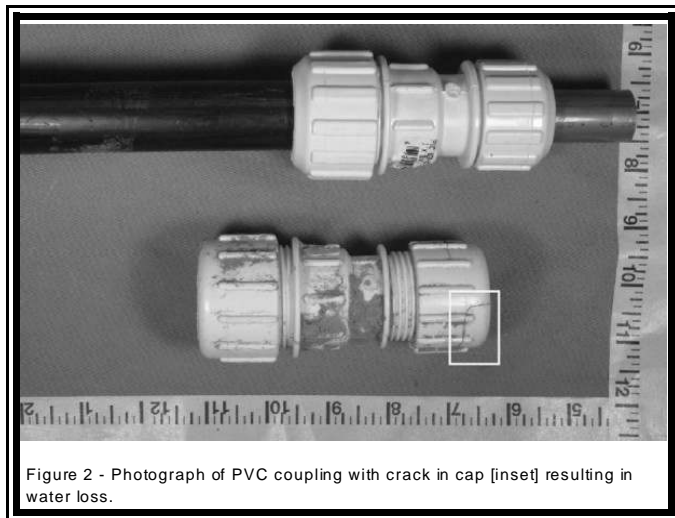
As a result, material strength is reduced; sometimes, depending upon viscosity and temperature of the melt, the reduction can be significant. The issue is not whether weld lines can be eliminated - they cannot. It then becomes the responsibility of the manufacturer to design his fabrication process such that weld lines are located at regions where the component is not stressed in service, at least not to levels where mechanical failure could occur.

Which brings us back to the problem of being unable to disassociate material properties, manufacturing methodology and service function from each other. Failure can result from either application of stress above the nominal strength of the material or

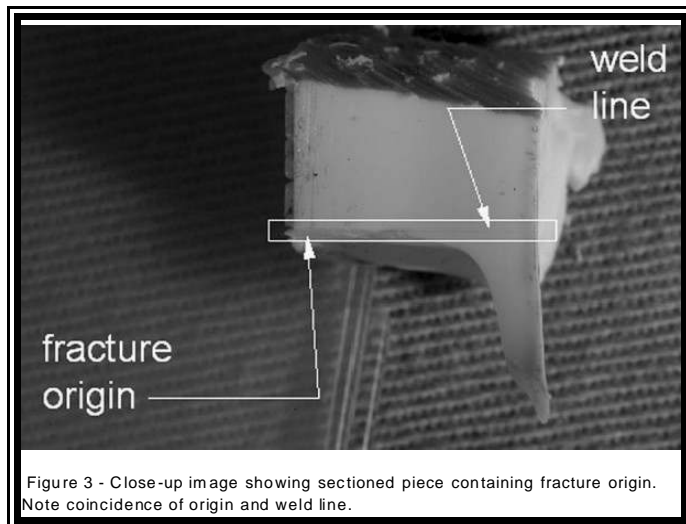
by application of a nominal service stress to a component possessing insufficient strength to endure it. It is for this reason that identification of origin and determination of fracture path does not necessarily resolve the issue of causation.

### Failure of a PVC Coupling

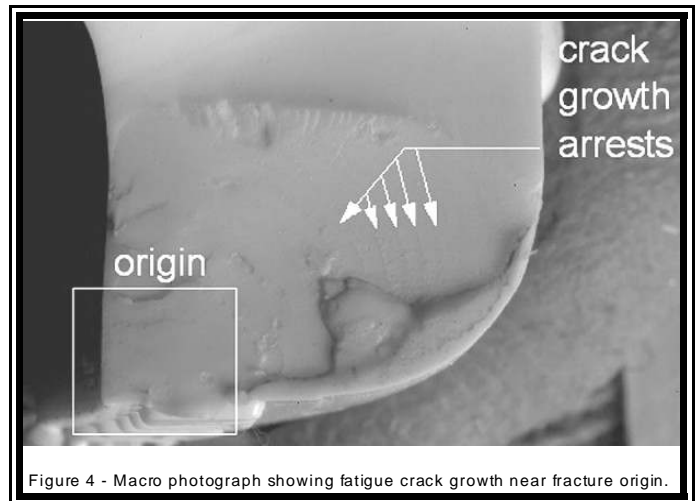
A recent case study involving failure of a plastic coupling joining sections of copper and polyethylene tubing is an excellent illustration of this situation [Figure 2]. The coupling was installed by a subcontractor and failed in about nine months, causing water damage to a residence. Following visual inspection, the origin of the fracture was located at the edge of the opening through which tubing passed.



Following notification of the manufacturer, the coupling was sectioned and the fracture origin found to coincide with a weld line [Figure 3]. The crack was found to have propagated over a period of time by a fatigue crack growth process [Figure 4].



The fact that the failure is associated with a material defect [the weld line] does not, by itself, establish causation as being the result of a manufacturing defect. The radial crack extending around



the circumference of the coupling cap [Figure 2] provided the outlet for the water causing the damage. The crack propagation path followed the hoop stress introduced into the root of the threaded cap during the assembly of the coupling. However, this crack was preceded by the crack which initiated at the hole in the top of the cap, a location which would not normally be under tensile stress - unless the tubing were bent to the degree that sufficient stress were introduced into this region to result in initiation of the fatigue crack leading to final failure. Unless this region were also coincident with the location of the weld line, there can be no causal relationship between the "manufacturing" defect and the failure of the component.

The point of all this is that the failed component by itself is often enough for the failure analyst to provide an opinion regarding causation, but not necessarily responsibility. Unless the failed component is placed in the context of the system in which it has functioned, an analysis of all contributions to the failure cannot be made. Ideally, the analyst should be able to inspect the failure venue, photograph and obtain the various measurements necessary, then to physically remove the affected component. If for whatever reason, this is not possible, it is important for the physical evidence to be photographed and for the photographs to be made in such a way that relevant orientation and position be evident from the photographs, both before and after the component has been removed. A digital camera, some kind of measuring tape [I like the sticky-backed stuff shown in Figure 2] and a sketch/note pad are the key tools for the individual designated to do the initial inspection. In the case of plumbing component failures, direction of water flow, whether hot or cold and proximity to the water main are important. A means for collection of water samples and a measurement of water pressure are also necessary.

The bottom line is this - the more information in the hands of the experienced analyst, the more substantiated his opinions will be. Substantiated opinions lead to conclusions which are less likely to be disputed or contradicted.

### ABOUT THE AUTHOR

FORCON consultant Dr. John Ambrose obtained his B.S. in Chemistry from Washington & Lee University and his Ph.D. from the University of Maryland.

His work experience includes being a research chemist for Newport News Shipbuilding and Dry Dock Company, a research scientist in the Corrosion and Electrodeposition section of the National Bureau of

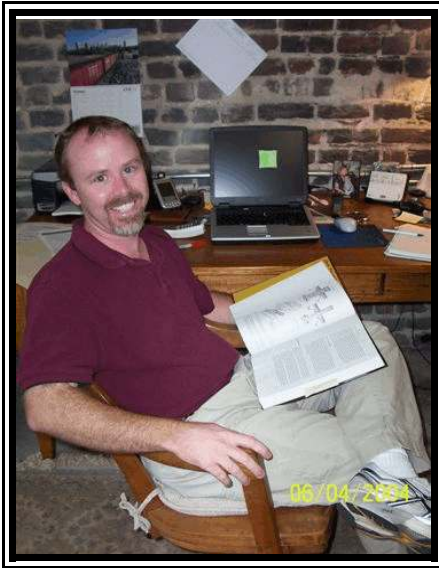
Standards, and an Associate Professor of Materials Science and Engineering at the University of Florida. He has extensive experience in the application of materials selection criteria for failure prevention or control in systems design, and in the forensic analysis of all types of materials failures.

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#### Dano Holland, P.E.

Dano Holland is the new Lead Structural Engineer for the Richmond, Virginia office.



Dano holds a degree in Civil Engineering from Clemson University. He has practiced engineering and served as a project manager in the industrial, commercial and residential construction industries. He is a registered Professional Engineer in Virginia.

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- Construction document review and evaluation

Dano's full resume is available on our website at [www.forcon.com/VAmap.htm](http://www.forcon.com/VAmap.htm) or by calling 800-390-0980.

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### FORCON News

- Mike Pinion, PE of the Richmond office received his CFEI designation from the National Association of Fire Investigators (NAFI).
- John Leffler, PE, CFEI of the Atlanta office received his CVFI designation from NAFI. John also became an ASE Certified Automobile Technician and completed courses in Auto Theft and Arson Investigation as well as in Investigative Locksmithing. John is now licensed as a Professional Engineer in Alabama as well as Georgia.
- FORCON now offers 3D photorealistic computer renderings and forensic animations. Contact John Leffler at the Atlanta office for details, at [jleffler@forcon.com](mailto:jleffler@forcon.com) or 770/390-0980.

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